Physico-chemical changes during storage of dehydrated plantain slices packaged in two polymeric film pouches

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SUMMARY

The changes in some physico-chemical properties of dehydrated plantain slices packaged in polyethylene and polypropylene pouches and stored, at 37 °C and 75 per cent RH, for 6 months were studied. Moisture gain, non-enzymatic browning, colour changes, puncture force, *p*H, ascorbic acid and total acidity were measured. The rates of moisture gain and decrease in puncture force were significantly faster ($P < 0.01$) in the plantain slices packaged in polyethylene than in polypropylene pouches. Correlation between the rates of decrease in brightness and the extent of non-enzymatic browning in the plantain slices, was better when packaged in polypropylene than in polyethylene pouches. The *p*H, total acidity and ascorbic acid content remained almost unchanged. The study indicated that the adverse changes in physico-chemical properties of the dehydrated plantain slices were less in polypropylene than in polyethylene.

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RÉSUMÉ

JOHNSON, P-N. T.: *Les changements physico-chimiques pendant la conservation des tranches de plantain déshydratée, emballée en deux cellophanes polyméres.* Des changements en quelques propriétés physico-chimiques des tranches de plantain déhydratées emballées dans les cellophanes polyéthylène et polypropylène conservées à 37°C et 75 pour cent RH, pour 6 mois étaient étudiées. Le gain d'humidité, la brunissement non-enzymatique, les changements de couleur, la force de percement, le *p*H, acide ascorbique et l'acidité totale étaient mesués. Les proportions de gain d' humidité et la diminution en force de percement étaient considérablement plus rapide ($P < 0.01$) dans les tranches de plantain emballées en cellophanes polyéthylène qu'en cellophane polypropylène. La corrélation entre les proportions de diminution en brillant et l'étendue du brunissement non-enzymatique dans les tranches de plantain étaient meilleurs lorsqu' emballées en cellophane polypropylène qu'en cellophane polyéthyène. Le *p*H, l' acidité totale et le contenu d'acide ascorbique restaient presque inchangés. L étude indiquait que les changements défavourables en propriétés physico-chimiques des tranches de plantain déhydratée étaient moins en polypropylène qu'en polyéthyléne.

Introduction

In the recent past, most reported studies on plantain (*Musa*, AAB) have been on its post-harvest handling and storage. Work on the production of plantain into preserved products has rather been on a very limited scale. Some traditional plantain products are mainly dried products, either in the form of chips or flour. Most of these plantain products have stability problems of discoloration, due to browning, flavour deterioration, and hygroscopicity (Marriott & Lancaster, 1983). Pre-treatment is one method extensively used in food processing to minimize some of the adverse quality defects in air-dried food products (Okos *et al.*, 1992). Johnson (1996) showed that the reconstitutability of air-dried plantain can be improved significantly if pre-treated by moist-infusion. Labuza (1984) has pointed out that dehydrated foods, if not adequately protected, have a high tendency to absorb moisture and deteriorate. Taoukis, El Meskine & Labuza (1988) also explained that chemical inhibitors of non-enzymatic browning are effective so long as the dehydrated food is stored at low moisture content, low temperature, and low humidity. To extend the shelf-life of foods which readily absorb moisture, the use of packaging to reduce or perhaps eliminate the transfer of moisture into the foods has been suggested by several workers (Okos *et al*., 1992).

This study was, therefore, carried out to investigate some of the physical and chemical changes that may occur during the storage of dehydrated plantain slices packaged in two common polymeric film materials.

Materials and methods

Dehydrated plantain samples

Freshly peeled plantain samples (var. French Horn) at the ripening stage 3 (Medlicott, 1992), cut into 2 mm disc, were immediately infused in 40 °B sucrose solution for 16 h, at 4 °C (Jayaraman, 1988). The 40 °B sucrose solution also contained 4 g kg^{-1} potassium sorbate and 2 g kg^{-1} of potassium metabisulphite as a preservative and also to inhibit non-enzymatic browning. The slices were then finally air-dried to about 3.6 per cent d.s. Thirty slices of the dried samples were aseptically packed, with the help of sterilized forceps, into rectangular pouches of polyethylene (low density) and polypropylene (metallized and opaque), each about 148 mm × 125 mm, and immediately sealed. The unpackaged samples, as control, were kept in uncovered plastic cups. A laboratory humidity chamber (LEEC Humidity Chamber model SF3), set a 37 °C and 75 % RH (obtained by placing a tray containing saturated solution of NaCl inside the chamber), was used for storage.

Analytical procedures

Moisture gain of the packaged plantain slices. This involved methods as explained by Labuza (1984). The weight changes (to the accuracy of ± 0.1 mg) of the packaged plantain slices, at 2-week intervals, were monitored. The methods of Davies, Karel & Procter (1960) and Tubert & Iglesias (1985) were used to determine the film permeability rates of the packaging materials. Finally, the saturated salts method (Speiss & Wolf, 1987) was used to construct the moisture adsorption isotherm of the dehydrated plantain, at 37 °C, for the a_w range 0.1 to 0.9.

Puncture force. The Steven's Texture Analyzer was used to measure the puncture force of 20 plantain slices from three different packets of each treatment, at 2-week intervals. Three well-spaced penetrations were made half-way between the midsection and the edge of each plantain slice by the cylindrical probe 4 mm in diameter and 20 mm long with flat end (TA40), and travelling at a speed of 3 mm/min to a distance of 3 mm. The puncture forces recorded at the three points were averaged and recorded as a measure of the firmness of the plantain slice at the time of measurement.

Colour measurement, non-enzymatic browning, and other chemical analyses. The CIELAB colour parameters, L*, a*, and b* values (MacDougall, 1988) for 20 dehydrated plantain slices from each treatment were continuously monitored, at 2-week intervals, by a Hunter Lab Colorquest spectrophotometer (Beckman DU-2). Because of illumination and colour variations on the fruit surface, the colour of each slice was measured at three points and the average taken. Non-enzymatic browning (Abdelhaq & Labuza, 1987), at 2-week intervals, and ascorbic acid (Joslyn, 1970), at monthly intervals, were also determined spectrophoto-metrically. Once a month, the total acidity was also measured as malic acid (AOAC, 1984).

Statistical analysis. Analysis of variances and means among the plantain slices stored in the two packaging materials as well as the un-packaged slices were calculated. Duncan's multiple range test was used to determine significant differences (P<0.01).

Results and discussion

The following mass transfer equation and the moisture adsorption isotherm of the dehydrated plantain (Fig. 1) (Labuza, 1984) were used to generate the moisture gain curves (Fig. 2).

$$\ln \tau = \ln\left[\frac{m_e - m_i}{m_e - m}\right] = K\frac{A}{W_s}\frac{P_o}{b}t$$

where τ = the unaccomplished moisture ratio; m_e = the equilibrium moisture content at the prevailing temperature and humidity in the storage chamber; m_i = initial moisture content of the dehydrated

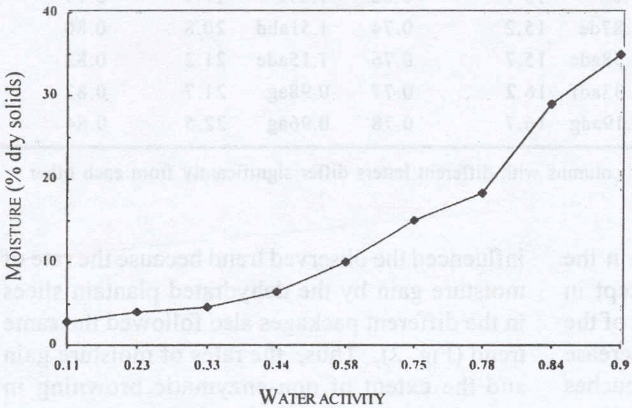

Fig.1. Moisture adsorption isotherm of dehydrated plantain samples (pre-treated by moist-infusion using 40 °B sucrose) at 37 °C.

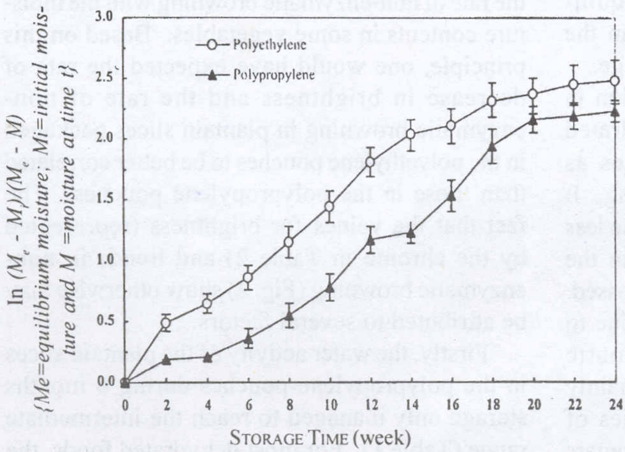

Fig. 2. Moisture gain by dehydrated plantain slices stored in polyethylene and polypropylene pouches at 37 °C and 75 % RH.

plantain slices; m = moisture content at any time, t, during the storage period (all in kg H_2O kg^{-1} d.s); K = film permeability and was estimated as 0.072 and 0.141, all in g H_2O/day m^2 mm Hg, for polypropylene and polyethylene, respectively; A = total surface area of the package was 3.42×10^{-2} m^2; W_s, the weight of dry solids = 28.5×10^{-3} kg; P_o = vapour pressure of pure water at 37 °C was calculated as 36.27 mm Hg; and b = isotherm slope. The isotherm slope, estimated to be 0.285 kg H_2O kg^{-1} d.s. per a_w unit, was determined from Fig. 1 (Labuza, 1984) at a critical moisture content of 15.6 per cent d.s. This moisture was found to correspond to the stage when the unpackaged plantain slices, used as control in the study, began to turn brown.

In Fig. 2, the slower rate of moisture gain by the plantain slices in polypropylene compared to those in the polyethylene pouches can be attributed to the better moisture-barrier properties of polypropylene. At 90 % RH, the water vapour permeabilities, at 37 °C, for polypropylene and polyethylene are 5 and 20 g. mil/m^2. 24 h, respectively (Saravacos, 1995). The levelling off of the rate of moisture gain from the 16th week of storage is due to a gradual decrease in the driving potential for the moisture transfer, which is the difference between the water activities of the combined air and plantain slices inside the packages and immediate surrounding air outside the packages.

The relatively slow rate of moisture gain by the dehydrated plantain slices stored in polypropylene pouches as compared to those in polyethylene seems to have influenced the trends in texture (Table 1). This observation agrees with the explanation of Bourne (1987) that the a_w has a major effect on the texture of a food during storage. Table 1 also indicates that by the end

TABLE 1

Puncture Force, Moisture Content and Estimated a_w for Dehydrated Plantain Slices Stored in Two Packaging Materials at 37 °C and 75 % RH

Storage time (week)	Polypropylene Puncture force (kgf)	Polypropylene Moisture content (% d.s)	Polypropylene Estimated a_w	Polyethylene Puncture force (kgf)	Polyethylene Moisture content (% d.s)	Polyethylene Estimated a_w	No packaging Puncture force (kgf)	No packaging Moisture content (% d.s)	No packaging Estimated a_w
0 (initial)	3.98a	3.61	0.21	3.98a	3.61	0.21	3.98a	3.61	0.21
2	3.81b	4.89	0.28	3.62ab	6.23	0.43	2.98c	8.82	0.58
4	3.64ab	6.12	0.42	3.41bc	10.8	0.56	2.05d	16.8	0.75
8	3.53abc	7.18	0.51	3.08	13.1	0.62	1.87f	17.9	0.79
12	3.34abd	11.1	0.58	2.87de	15.2	0.74	1.51abd	20.8	0.80
16	3.27abe	13.5	0.62	2.58adc	15.7	0.76	1.15ade	21.2	0.82
20	3.14g	14.7	0.69	2.33adf	16.2	0.77	0.98ag	21.7	0.82
24	3.11g	14.5	0.71	2.19adg	16.7	0.78	0.96ag	22.5	0.84

Mean values (for the puncture force) in rows or columns with different letters differ significantly from each other ($P<0.01$).

of the 6 months of storage, the decrease in the firmness of dehydrated plantain slices kept in polypropylene was only about 22 per cent of the original compared with the 45 per cent decrease for plantain slices stored in polyethylene pouches and 75 per cent for the unpackaged plantain slices. The estimated water activities were obtained from Fig. 1. Table 1 further indicates that the a_w of the unpackaged dehydrated plantain slices equilibrated with the humidity conditions within the storage compartment after 4 weeks of storage.

Table 2 gives the trend for the reduction in brightness and yellowness of the dehydrated plantain slices in the different packages as polypropylene <polyethylene<no-packaging. It was observed that the plantain slices became less yellow, more red, and slightly darker than the freshly dehydrated slices as storage progressed. The change in colour is most probably due to non-enzymatic browning. Non-enzymatic browning in dehydrated foods is caused mainly by the Maillard reaction, which is a series of condensation reactions involving reducing sugars and amino group (O'Brien & Morrisey, 1989). The moisture level of the food most probably influenced the observed trend because the rate of moisture gain by the dehydrated plantain slices in the different packages also followed the same trend (Fig. 2). Thus, the rates of moisture gain and the extent of non-enzymatic browning in plantain are directly correlated.

Legault *et al.* (1947) and Mizrahi, Labuza & Karel (1970) have established models correlating the rate of non-enzymatic browning with the moisture contents in some vegetables. Based on this principle, one would have expected the rate of decrease in brightness and the rate of non-enzymatic browning in plantain slices packaged in the polyethylene pouches to be better correlated than those in the polypropylene pouches. The fact that the values for brightness (represented by the chroma in Table 2) and trends in non-enzymatic browning (Fig. 3) show otherwise may be attributed to several factors.

Firstly, the water activity of the plantain slices in the polypropylene pouches during 6 months storage only managed to reach the intermediate range (Table 1). For most dehydrated foods, the rate of non-enzymatic browning is at its maximum around $a_w = 0.65$ (Labuza, 1984). The relatively

TABLE 2

Colour Parameters a, b*, Chroma and Hue Angles for Dehydrated Plantain Slices Stored in Two Packaging Materials at 37 °C and 75 % RH*

Storage time	Polypropylene				Polyethylene				No packaging			
(week)	a*	b*	Chroma	Hue angle	a*	b*	Chroma	Hue angle	a*	b*	Chroma	Hue angle
0 (initial)	4.51 (0.5)	24.8 (1.5)	25.3	79.7	4.51 (0.5)	24.8 (1.5)	25.3	79.7	4.51 (0.5)	24.8 (1.5)	25.3	79.7
2	4.81 (0.4)	24.9 (2.5)	25.2	79.1	4.89 (0.3)	22.7 (1.5)	23.2	77.8	5.21 (0.5)	22.2 (2.1)	22.8	76.8
4	4.85 (0.2)	24.2 (2.3)	24.7	78.8	4.98 (1.1)	21.3 (1.8)	21.9	76.8	5.86 (0.8)	20.2 (2.2)	20.9	73.8
8	5.21 (0.2)	23.2 (3.1)	23.8	77.5	5.01 (0.7)	20.9 (1.6)	21.5	76.5	6.46 (1.1)	18.7 (2.6)	19.7	70.9
12	6.47 (0.5)	22.7 (2.9)	23.6	74.1	5.83 (0.3)	18.9 (1.8)	19.7	72.8	7.45 (1.2)	16.5 (2.2)	18.1	65.6
16	6.85 (0.2)	22.2 (2.3)	23.2	72.9	6.26 (0.8)	16.1 (1.3)	17.3	68.8	8.12 (1.1)	12.5 (2.4)	14.9	57.0
20	7.14 (0.3)	22.1 (2.3)	23.2	72.1	6.52 (0.3)	15.7 (1.4)	16.9	67.4	8.48 (1.3)	9.5 (1.9)	12.7	48.3
24	7.22 (0.2)	21.9 (1.1)	23.1	71.8	6.93 (0.5)	15.5 (1.4)	16.9	65.9	8.94 (1.3)	8.9 (1.5)	12.6	44.9

Chroma = $(a^{*2} + b^{*2})$ and Hue angle = $\tan^{-1} b^*/a^*$ (MacDougall, 1988). Values in bracket ( ) are the standard deviations. Chroma = Brightness and Hue angles = Yellowness of the dehydrated plantain slices.

high amounts of moisture absorbed by the plantain slices stored in the polyethylene as compared to those in the polypropylene pouches may have caused a dilution effect reducing the extent of browning (Labuza, 1984), and perhaps minimizing the decrease in brightness.

Secondly, the decrease in brightness is probably not directly related to the development of non-enzymatic browning in the plantain slices, but rather to some other biochemical reactions. Brightness and browning are two important quality indices which will influence the acceptability of dehydrated plantain products. This observation suggests that polypropylene is a better packaging material than polyethylene for increasing the shelf-life of dehydrated plantain slices, at normal ambient tropical conditions, within the first 4 months of storage. Because whilst dehydrated plantain slices stored in polyethylene will absorb moisture easily, those stored in polypropylene may be unacceptable because of non-enzymatic browning after 4 months.

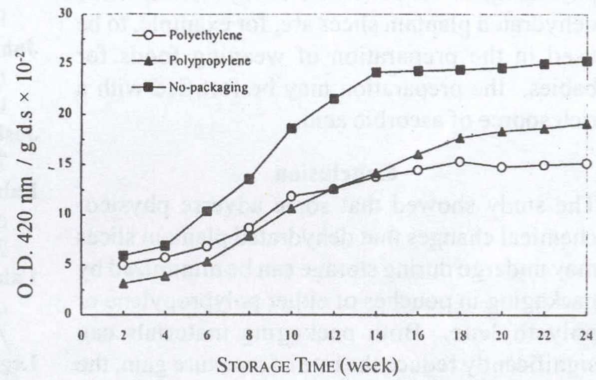

Fig. 3. Non-enzymatic browning in dehydrated plantain slices stored in polyethylene and polypropylene pouches at 37 °C and 75 per cent RH.

The total acidity and *p*H of the dehydrated plantain slices from the three treatments remained almost constant at 3.2 and 5.3 mEq, respectively. This means that no fermentation or rancidity occurred during the storage. The microbial status of the plantain slices did not also change. This indicates that the potassium sorbate at the concentration used during the pre-treatment was adequate for preserving the plantain slices.

The ascorbic acid content of the fresh plantain reduced from an initial value of 260 μg/g dry weight basis of the plantain to 95 μg/g just after dehydration. This is because most of the thermolabile ascorbic acid leached out during the pre-treatment by moist-infusion. It was noted that the type of packaging did not significantly ($P>0.01$) affect the content of the remaining ascorbic acid during storage. It is not clear why this happened, because the increase in a_w during storage should have further reduced the ascorbic acid content. Labuza (1972) has suggested that elevated a_w may act to lower the activation energy for ascorbic acid destruction. Perhaps the short duration for storage did not allow significant decreases in ascorbic acid content to be detected. However, the potential for further reduction is worrying, because the recommended daily allowances of ascorbic acid for humans range from 1·5 to 60 mg, depending on age, sex, and physiological status (Pyke, 1979). Thus, if the dehydrated plantain slices are, for example, to be used in the preparation of weaning foods for babies, the preparation may be fortified with a rich source of ascorbic acid.

Conclusion

The study showed that some adverse physico-chemical changes that dehydrated plantain slices may undergo during storage can be minimized by packaging in pouches of either polypropylene or polyethylene. Both packaging materials can significantly reduce the rate of moisture gain, the decrease in firmness, the tendency to become blackish red, and the extent of non-enzymatic browning. They therefore enhance the overall acceptability of dehydrated plantain. Polypropylene packaging material, which has a lower film permeability, reduces the changes in these properties much better than polyethylene of the same thickness and dimensions.

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