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Effects of type of packaging material on physicochemical and sensory characteristics of deep-fat-fried banana chips

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Abstract: A storage study of deep-fat-fried banana chips was carried out for 8 weeks at ambient temperature (27 °C), using four types of packaging material: laminated aluminium foil (LAF), oriented polypropylene (OPP), polypropylene (PP) and low-density polyethylene (LDPE). The physicochemical and sensory characteristics of the stored banana chips were analysed at weeks 0, 2, 4, 6 and 8. The quality parameters determined were moisture content, water activity (a_w), thiobarbituric acid-reactive substances (TBARS), texture (breaking force), colour and sensory attributes. The moisture content, a_w, TBARS and breaking force values of all samples increased during storage. The colour also changed during storage, showing higher *L* and lower *a* and *b* values. Samples packed in LAF had the lowest moisture content, a_w, TBARS and breaking force values. The most notable sensory change that occurred during storage was a decrease in crispness. Samples packed in LAF had higher scores than the other three samples, whilst LDPE gave the lowest scores for crispness as well as product colour. There were no significant differences ($P > 0.05$) in rancid odour among samples packed in OPP, PP and LDPE. However, there were significant differences ($P < 0.05$) between samples packed in LAF and the other three samples, with LAF giving the lowest rancid odour.

Keywords: deep-fat frying; banana chips; refined, bleached and deodorised palm olein; oleoresin rosemary; packaging material; sensory evaluation

INTRODUCTION

Deep-fat frying is one of the oldest methods for creating unique flavour and texture in processed foods.[1] It is faster and more efficient than drying in an oven or boiling in water.[2] However, immersion frying involves chemical and physical changes in foods, including starch gelatinisation, protein denaturation, water vaporisation and crust formation. Various factors such as the rate of heating, oil penetration into the food, oil–food interactions and oil degradation affect the texture and final product quality.[1]

Nowadays, consumers tend to look for natural snack foods and are keenly aware of what kind of food they are eating.[3] In this regard, banana chips prepared by deep-fat frying could become a popular snack food.[4] Green *Abu* bananas fried in refined, bleached and deodorised palm olein have been found to show good quality.[5,6]

The main causes of spoilage in this kind of snack food are moisture absorption, fat rancidity, breakage during handling, and environmental factors such as oxygen, temperature, light and relative humidity. Shelf-life tests must be related to critical deterioration factors (chemical, physical and sensory); in this respect, the problem of moisture absorption is more serious than that of oxygen exposure. To ensure repeated sales, deep-fat-fried banana chips have to be shelf-stable and crisp when they are consumed.[8] In the processing and storage of banana chips, proper packaging is important to preserve the quality.[9] The essential function of a packaging material is to protect against water absorption, rancidity, loss of odour and entry of foreign odours, thereby extending the shelf-life of the product.[8]

The objective of this study was to determine the effects of type of packaging material and time of storage on the physicochemical and sensory characteristics of deep-fat-fried banana chips.

MATERIALS AND METHODS

Materials

Mature but unripe bananas. *Musa acuminata* × *balbisiana* cv Bliggoe (*Pisang Abu*), were obtained from a local market.[10] Refined, bleached and deodorised (RBD) palm olein was obtained from a local refinery (Ngo Chew Hong Oils and Fats SB, Selangor, Malaysia). Oleoresin rosemary (Herbalox® Brand,

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Characteristic	Packaging material			
	LAF	*OPP*	*PP*	*LDPE*
General clarity	Opaque	Highly transparent	Fairly transparent	Translucent
Thickness (mm)	0.01	0.05	0.09	0.10
Number of layers	4	1	1	1
Melting point (°C)				
First layer	167.1	167.5	161.6	110.6
Second layer	106.6			
Third layer	>400			
Fourth layer	167.1			
Water vapour transmission rate at 38°C and 90% RH ($g\,m^{-2}\,day^{-1}$)	0.48	6.61	7.67	8.77

Values are mean of three determinations.

Table 1. Characteristics of packaging films used for deep-fat-fried banana chips

Type O, Kalsec, Kalamazoo, MI, USA) was a gift from Gulf Chemical, Selangor, Malaysia. Laminated aluminium foil (LAF) was obtained from Wellgo (Bangkok, Thailand). Oriented polypropylene (OPP), polypropylene (PP) and low-density polyethylene (LDPE) were obtained from Chareangkit Plastic Industry (Bangkok, Thailand). Table 1 summarises the characteristics of the packaging materials used and Fig 1 shows their DSC melting curves. All chemicals and solvents used were of analytical grade unless otherwise specified.

Experimental design

Abu bananas were prepared according to Ammawath *et al.*[5] Whole green bananas were peeled and 200 g batches were soaked in 1 l of 20 g kg^{-1} sodium chloride solution for 30 min. They were then lightly blotted dry with tissue paper and sliced to a thickness of 2 mm using a mechanical slicer, before being weighed into 150 g batches for frying. RBD palm olein (4.5 kg) was used as the frying medium, supplemented with oleoresin rosemary (1 g) in accordance with Che Man *et al.*[6] The temperature was raised to 180 ± 5°C in 20 min and the batches of raw bananas were fried for 3 min. The fried banana chips were allowed to cool and were then packed (100 g each) in the four different packaging materials (LAF, OPP, PP and LDPE) using an ARSH-300 Impulse Sealer (Arrow Brand, Perniagaan Timbang Dan Sukat Ban Hing SB, Selangor, Malaysia). Frying experiments were conducted in two replicates each time. The storage study was conducted at ambient temperature (27°C) for 8 weeks; all analyses were carried out at weeks 0, 2, 4, 6 and 8.

Analysis of packaging films

Thickness was determined using an external micrometer (model M 110-25, Mitutoyo, Kanagawa, Japan).[11] The water vapour transmission rate was determined using moisture-pervious cups (model 188, Toyoseiki, Tokyo, Japan).[12] Melting points of the packaging materials were determined using a DSC-7 differential scanning calorimeter (Perkin Elmer Corp, Norwalk, CT, USA).[13]

Physicochemical analysis of chips

Moisture content was determined according to AOAC methods.[14] Thiobarbituric acid-reactive substance (TBARS) values were determined according to Ke *et al.*[15] Water activity (a_w) was determined using a water activity analyser (Wert-Messer, Kulmbach, Germany). Colour was determined using an Ultra Scan SN 7877 colorimeter (Hunter Lab, Reston, VA, USA). The breaking force of fried chips was determined using a TA-XT2i texture analyser (Stable Micro Systems, Godalming, UK).

Sensory evaluation of chips

Sensory evaluation was carried out by 12 trained panellists. A brief account of the training of the panellists is given in the Appendix, together with details of the scoring system.

The fried chips packed in the four different packaging materials were evaluated at weeks 0, 2, 4, 6 and 8 in a single testing session with two replications. Sensory profiling was carried out using FIZZ software,[16] where sample coding, form creation, data collection, calculation of equations, statistical analysis and printing-out of data are done by means of an integrated computer-assisted system. A quantitative

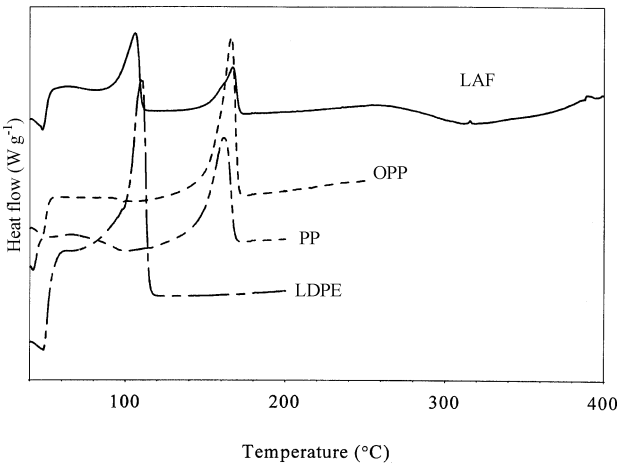

Figure 1. DSC melting curves of packaging materials.

Table 2. Changes in chemical characteristics of deep-fat-fried banana chips packed in different packaging materials during storage

Chemical characteristic	Week	Packaging material			
		LAF	OPP	PP	LDPE
Moisture (g kg^{-1})	0	$27.80 \pm 0.37^{E,a}$	$28.02 \pm 0.17^{E,a}$	$28.01 \pm 0.50^{E,a}$	$28.42 \pm 0.03^{E,a}$
	2	$29.18 \pm 0.42^{D,a}$	$30.62 \pm 0.44^{D,b}$	$30.98 \pm 0.58^{D,b}$	$33.47 \pm 0.38^{D,c}$
	4	$30.10 \pm 0.55^{C,a}$	$32.99 \pm 0.24^{C,b}$	$33.50 \pm 0.82^{C,b}$	$37.18 \pm 0.42^{C,c}$
	6	$33.17 \pm 0.48^{B,a}$	$38.24 \pm 0.72^{B,b}$	$38.40 \pm 0.79^{B,b}$	$42.84 \pm 0.17^{B,c}$
	8	$38.32 \pm 0.55^{A,a}$	$48.19 \pm 0.14^{A,b}$	$48.54 \pm 0.55^{A,b}$	$59.40 \pm 0.38^{A,c}$
Water activity	0	<0.4	<0.4	<0.4	<0.4
	2	<0.4	0.40–0.41	0.40–0.41	0.41–0.42
	4	0.40–0.41	0.41–0.42	0.41–0.42	0.43–0.44
	6	0.41–0.42	0.43–0.44	0.43–0.44	0.44–0.45
	8	0.44–0.45	0.45–0.46	0.45–0.47	0.49–0.51
Thiobarbituric acid-reactive substances (μmol kg^{-1})	0	$11.48 \pm 0.19^{E,a}$	$11.34 \pm 0.44^{E,a}$	$11.84 \pm 0.17^{E,a}$	$11.70 \pm 0.75^{E,a}$
	2	$14.37 \pm 0.74^{D,a}$	$14.95 \pm 0.32^{D,a}$	$15.02 \pm 0.35^{D,a}$	$15.31 \pm 0.33^{D,a}$
	4	$17.04 \pm 0.33^{C,a}$	$17.68 \pm 0.22^{C,a}$	$17.88 \pm 0.39^{C,a}$	$18.05 \pm 0.83^{C,a}$
	6	$19.95 \pm 0.43^{B,c}$	$22.93 \pm 1.02^{B,b}$	$23.59 \pm 1.26^{B,a,b}$	$24.48 \pm 0.19^{B,a}$
	8	$21.74 \pm 0.38^{A,c}$	$27.05 \pm 0.83^{A,b}$	$27.59 \pm 1.26^{A,b}$	$30.84 \pm 1.06^{A,a}$

Values are mean ± standard deviation of three analyses.
[A–E] Means within a column with different letters are significantly different ($P < 0.05$).
[a–c] Means within a row with different letters are significantly different ($P < 0.05$).

descriptive analysis (QDA) technique was used to assess the quality of the fried chips. The sensory attribute descriptors were product colour, rancid odour and crispness, using a scale of 0–10 cm, where 0 indicates negative attributes and 10 indicates positive attributes.[17]

Statistical analysis

Data were analysed using the ANOVA procedure of the SAS software package.[18] Significant differences ($P < 0.05$) between means were further determined by Duncan's multiple-range test.[18]

RESULTS AND DISCUSSION

Physicochemical characteristics

Moisture content

Data on the changes in moisture content of the stored chips are presented in Table 2. The changes in moisture content of all samples during the 8-week storage period were significant ($P < 0.05$). Samples packed in LAF recorded the lowest increase in moisture content. The highest increase was exhibited by samples packed in LDPE. Similar observations were made on durian fruit leather by Irwandi *et al.*[19] These differences might be due to the differences in moisture vapour permeability of the packaging films, as seen in Table 1. The water vapour transmission rates (at 38 °C and 90% RH) of LAF, OPP, PP and LDPE were 0.48, 6.61, 7.67 and 8.77 g m^{-2} day^{-1} respectively. At week 8 the moisture content of samples packed in LDPE reached 59.4 g kg^{-1}, while the values for samples packed in LAF, OPP and PP were 38.3, 48.2 and 48.5 g kg^{-1} respectively.

Water activity (a_w)

The a_w values of deep-fat-fried banana chips packed in the various plastic materials during 8 weeks of storage are given in Table 2. At week 0 the a_w values of all samples were lower than 0.4. Similar observations were made on deep-fat-fried banana chips by Ammawath *et al.*[5] After 8 weeks of storage the a_w values of samples packed in LAF, OPP, PP and LDPE were 0.44–0.45, 0.45–0.46, 0.45–0.47 and 0.49–0.51 respectively. Foods with a_w lower than 0.6 are essentially free from microbial growth.[19] The water activity and water content have a profound influence on the textural properties of foods.[20] Katz and Labuza[21] examined the relationship between a_w and crispness in a study on popcorn and found that higher a_w was associated with lower crispness.

Thiobarbituric acid-reactive substances (TBARS)

The 2-thiobarbituric acid reaction has been widely used as an objective measure of oxidative deterioration in oils.[15] Our results for TBARS values are shown in Table 2. The TBARS values of all samples increased significantly ($P < 0.05$) during storage, with LDPE giving the highest increase. At week 8 the increments in TBARS value of chips packed in the different types of packaging material were in the order LAF < OPP = PP < LDPE.

Texture

The most desirable textural characteristic of fried foods is crispness. It is a highly valued and universally liked characteristic that signifies freshness and high quality.[22] The breaking force value of samples increased with increasing moisture content. This corresponded to a decrease in crispness score.[23] The breaking force values of banana chips packed in the different types of packaging material at various times during the storage period are shown in Table 3. The initial values for samples packed in LAF, OPP, PP and

Table 3. Changes in physical characteristics of deep-fat-fried banana chips packed in different packaging materials during storage

Physical characteristic	Week	Packaging material			
		LAF	OPP	PP	LDPE
Breaking force (N)	0	$2.76 \pm 0.40^{C,a}$	$2.79 \pm 0.53^{D,a}$	$2.88 \pm 0.63^{D,a}$	$2.87 \pm 0.56^{D,a}$
	2	$2.88 \pm 0.34^{B,C,a}$	$3.04 \pm 0.43^{C,D,a}$	$3.13 \pm 0.46^{C,D,a}$	$3.22 \pm 0.44^{C,D,a}$
	4	$3.05 \pm 0.57^{B,C,a}$	$3.34 \pm 0.63^{B,C,a,b}$	$3.39 \pm 0.58^{C,a,b}$	$3.71 \pm 0.70^{B,C,b}$
	6	$3.31 \pm 0.60^{B,a}$	$3.79 \pm 0.64^{B,a}$	$3.96 \pm 0.52^{B,a,b}$	$4.21 \pm 0.70^{B,b}$
	8	$3.96 \pm 0.48^{A,a}$	$4.53 \pm 0.55^{A,b}$	$4.54 \pm 0.49^{A,b}$	$5.11 \pm 0.83^{A,c}$
Colour (*L*)	0	$55.11 \pm 1.60^{C,a}$	$55.05 \pm 2.35^{C,a}$	$55.01 \pm 1.44^{D,a}$	$55.75 \pm 2.02^{C,a}$
	2	$57.49 \pm 1.99^{B,a}$	$57.55 \pm 3.36^{B,a}$	$57.83 \pm 2.67^{C,a}$	$58.01 \pm 1.26^{B,a}$
	4	$58.74 \pm 2.79^{A,B,b}$	$59.98 \pm 3.31^{A,b}$	$59.67 \pm 1.41^{B,b}$	$62.75 \pm 2.24^{A,a}$
	6	$59.14 \pm 3.14^{A,B,b}$	$60.36 \pm 1.86^{A,b}$	$60.07 \pm 1.79^{B,b}$	$62.90 \pm 2.38^{A,a}$
	8	$60.17 \pm 1.00^{A,c}$	$62.29 \pm 1.49^{A,b}$	$62.15 \pm 1.44^{A,b}$	$64.02 \pm 2.38^{A,a}$
Colour (*a*)	0	$6.52 \pm 1.33^{A,a}$	$6.55 \pm 1.05^{A,a}$	$6.34 \pm 0.81^{A,a}$	$6.26 \pm 1.04^{A,a}$
	2	$6.38 \pm 1.48^{A,a}$	$6.27 \pm 0.84^{A,a}$	$6.03 \pm 1.32^{B,a}$	$5.88 \pm 1.07^{A,a}$
	4	$6.00 \pm 0.65^{A,a}$	$5.90 \pm 0.58^{A,B,a}$	$5.88 \pm 0.74^{B,a}$	$5.60 \pm 1.16^{A,B,a}$
	6	$5.66 \pm 0.85^{A,a}$	$5.42 \pm 0.95^{B,a}$	$5.46 \pm 0.78^{C,a}$	$5.30 \pm 1.23^{A,B,a}$
	8	$5.49 \pm 0.73^{A,a}$	$5.30 \pm 0.57^{B,a}$	$5.33 \pm 0.43^{D,a}$	$4.77 \pm 0.61^{B,b}$
Colour (*b*)	0	$21.20 \pm 1.64^{A,a}$	$21.24 \pm 1.09^{A,a}$	$21.22 \pm 0.87^{A,a}$	$21.30 \pm 1.06^{A,a}$
	2	$21.14 \pm 1.03^{A,a}$	$21.15 \pm 1.11^{A,a}$	$21.19 \pm 1.30^{A,B,a}$	$21.07 \pm 1.52^{A,a}$
	4	$20.95 \pm 1.75^{A,a}$	$20.94 \pm 0.64^{A,a}$	$20.86 \pm 1.97^{A,B,a}$	$20.75 \pm 1.26^{A,a}$
	6	$20.91 \pm 1.36^{A,a}$	$20.77 \pm 1.19^{A,a}$	$20.72 \pm 1.11^{B,a}$	$20.41 \pm 0.94^{A,a}$
	8	$20.80 \pm 2.28^{A,a}$	$20.69 \pm 1.45^{A,a}$	$20.60 \pm 1.20^{B,a}$	$20.31 \pm 1.34^{A,a}$

Values are mean ± standard deviation of three analyses.
[A–D] Means within a column with different letters are significantly different ($P < 0.05$).
[a–c] Means within a row with different letters are significantly different ($P < 0.05$).

LDPE were 2.76, 2.79, 2.88 and 2.87 N respectively and all values increased significantly ($P < 0.05$) during storage. At week 8 the breaking force values of samples packed in LAF, OPP, PP and LDPE were 3.96, 4.53, 4.54 and 5.11 N respectively, with the value for samples packed in LAF being significantly different ($P < 0.05$) from those of the other samples. Samples packed in OPP and PP did not differ significantly ($P > 0.05$), but there were significant differences ($P < 0.05$) between them and samples packed in LAF and LDPE.

Colour

The lightness (*L*), redness (*a*) and yellowness (*b*) of fried banana chips packed in the different types of packaging material after various periods of storage are shown in Table 3. The *L* values of all samples increased significantly ($P < 0.05$) during storage for 8

Table 4. Sensory descriptive profiles of deep-fat-fried banana chips packed in different packaging materials during storage

Attribute descriptor	Week	Packaging material			
		LAF	OPP	PP	LDPE
Crispness	0	$9.75 \pm 0.72^{A,a}$	$9.75 \pm 0.59^{A,a}$	$9.75 \pm 0.49^{A,a}$	$9.73 \pm 0.65^{A,a}$
	2	$9.39 \pm 0.70^{A,B,a}$	$9.03 \pm 0.72^{A,B,a,b}$	$8.99 \pm 0.93^{A,B,a,b}$	$8.67 \pm 0.61^{B,b}$
	4	$9.11 \pm 1.30^{A,B,a}$	$8.33 \pm 1.29^{B,C,a,b}$	$8.17 \pm 1.28^{B,C,a,b}$	$7.60 \pm 1.06^{C,b}$
	6	$8.49 \pm 1.20^{B,a}$	$7.32 \pm 2.08^{C,a,b}$	$7.18 \pm 1.61^{C,a,b}$	$6.40 \pm 1.80^{D,b}$
	8	$6.96 \pm 1.35^{C,a}$	$5.71 \pm 1.45^{D,b}$	$5.65 \pm 1.43^{D,b}$	$4.16 \pm 1.30^{E,c}$
Product colour	0	$9.71 \pm 0.71^{A,a}$	$9.69 \pm 0.78^{A,a}$	$9.73 \pm 0.50^{A,a}$	$9.69 \pm 0.78^{A,a}$
	2	$9.62 \pm 0.44^{A,a}$	$9.59 \pm 0.48^{A,a}$	$9.52 \pm 0.66^{A,a}$	$9.34 \pm 0.69^{A,B,a}$
	4	$9.42 \pm 0.48^{A,B,a}$	$9.35 \pm 0.75^{A,a}$	$9.34 \pm 0.76^{A,B,a}$	$8.86 \pm 0.87^{B,C,a}$
	6	$9.33 \pm 0.40^{A,B,a}$	$9.29 \pm 0.43^{A,B,a}$	$9.23 \pm 0.90^{A,B,a}$	$8.34 \pm 0.74^{C,D,b}$
	8	$9.00 \pm 0.80^{B,a}$	$8.82 \pm 0.53^{B,a}$	$8.78 \pm 0.68^{B,a}$	$8.08 \pm 0.65^{D,b}$
Rancid odour	0	$9.75 \pm 0.40^{A,a}$	$9.75 \pm 0.26^{A,a}$	$9.79 \pm 0.23^{A,a}$	$9.77 \pm 0.27^{A,a}$
	2	$9.67 \pm 0.40^{A,a}$	$9.66 \pm 0.38^{A,B,a}$	$9.65 \pm 0.48^{A,B,a}$	$9.62 \pm 0.65^{A,B,a}$
	4	$9.64 \pm 0.43^{A,a}$	$9.63 \pm 0.41^{A,B,a}$	$9.58 \pm 0.40^{A,B,a}$	$9.41 \pm 0.34^{B,C,a}$
	6	$9.57 \pm 0.41^{A,a}$	$9.46 \pm 0.32^{B,C,a}$	$9.39 \pm 0.26^{B,C,a,b}$	$9.14 \pm 0.19^{D,C,b}$
	8	$9.54 \pm 0.48^{A,a}$	$9.22 \pm 0.22^{C,b}$	$9.17 \pm 0.22^{C,b}$	$8.97 \pm 0.20^{D,b}$

Values are mean ± standard deviation of scores of 12 trained panel lists (see Tables 5–7).
[A–E] Means within a column with different letters are significantly different ($P < 0.05$).
[a–c] Means within a row with different letters are significantly different ($P < 0.05$).

weeks. The greatest increase was for chips packed in LDPE, followed by those packed in PP, OPP and LAF. Conversely, the *a* and *b* values decreased significantly ($P < 0.05$) for samples packed in OPP, PP and LDPE, while those of samples packed in LAF did not change significantly ($P > 0.05$). The results indicate that the samples developed off-colours during storage, especially those packed in LDPE. These changes are due to the high degree of unsaturation of the carotenoids, which makes them susceptible to oxidation, resulting in a decrease in yellowness and a loss of colour during storage.[24,25]

Sensory characteristics

The sensory characteristics of the fried banana chips at various times during the storage period are presented in Table 4. Fig 2 shows a cobweb configuration of the sensory characteristics. The most notable differences during storage occurred in crispness. The crispness scores of all samples decreased significantly ($P < 0.05$) during storage. At week 8, samples packed in LAF recorded a significantly high score ($P < 0.05$), while LDPE gave the lowest score ($P < 0.05$), and the decrements in crispness of chips packed in the different types of packaging material were in the order LAF < OPP = PP < LDPE. The order of sensory scores for crispness was similar to that of breaking force values. The product colour (yellowish) scores of all samples decrease significantly ($P < 0.05$) during the storage period. At week 8 there were no significant differences ($P > 0.05$) among samples packed in LAF, OPP and PP, while there were significant differences ($P < 0.05$) between samples packed in LDPE and the other three samples, with samples packed in LDPE recording the lowest product colour score. These results were similar to those determined using the colorimeter. In the case of the rancid odour descriptor, at week 8 there were significant differences ($P < 0.05$) between samples packed in LAF and the other three samples. LAF gave the highest score, while there were no significant

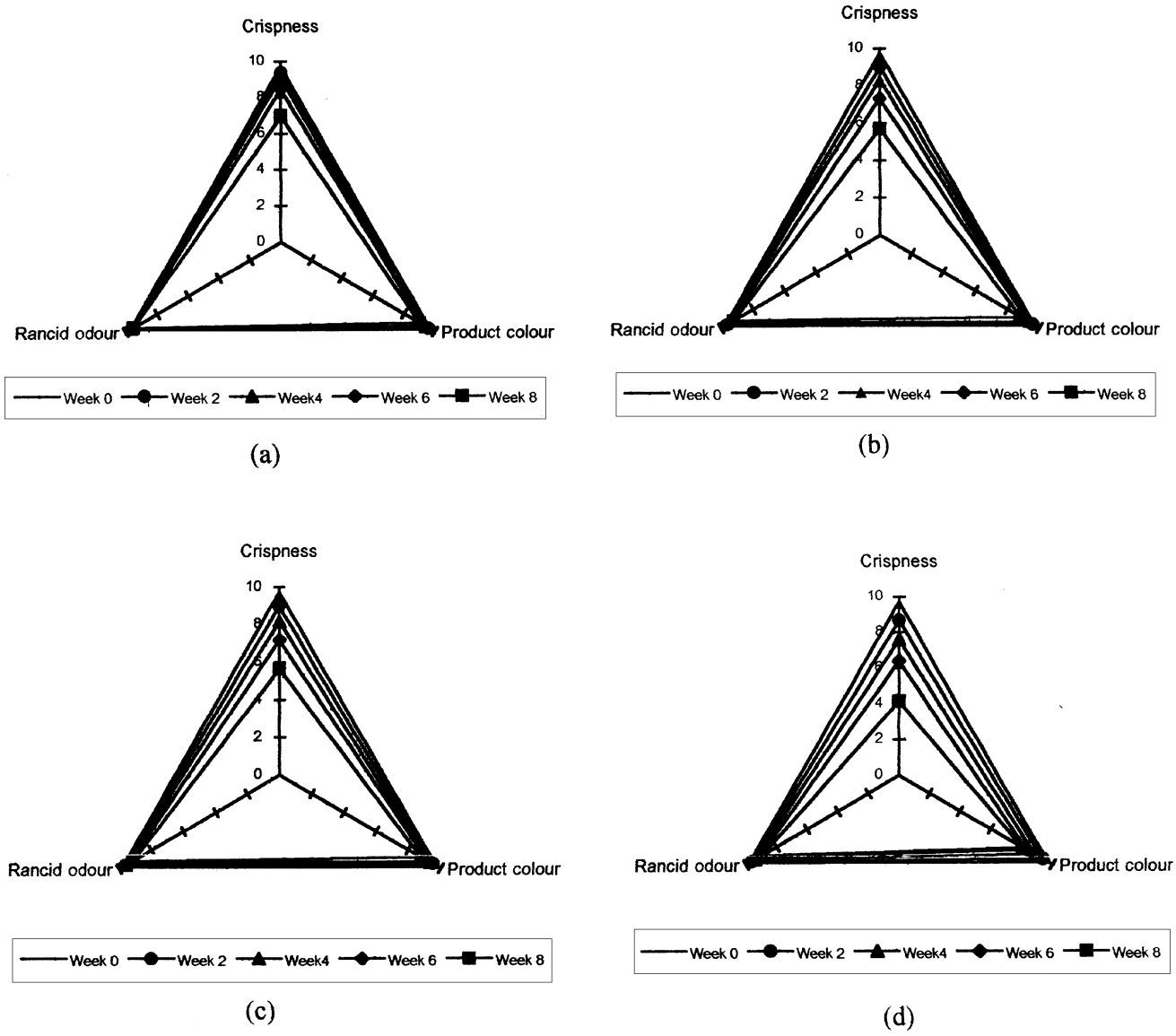

Figure 2. Sensory descriptive profiles of deep-fat-fried banana chips packed in different packaging materials: (a) LAF; (b) OPP; (c) PP; (d) LDPE.

Table 5. Varying degrees of rancidity

Scale	Description	TBARS (μmol kg^{-1})
10–8	Bland	10–20
8–6	Suspicion of off-odour	20–30
6–4	Noticeable but very slight off-odour	30–40
4–2	Distinct off-odour	40–50
2–0	Markedly disagreeable off-odour, very rancid	>50

Table 7. Varying degrees of crispness

Scale	Description	Breaking force (N)
10–8	Extremely crispy	2.0–3.5
8–6	Very crispy	3.5–4.0
6–4	Crispy	4.0–4.5
4–2	Slightly crispy	4.5–5.0
2–0	Not crispy	>5.0

differences ($P < 0.05$) among samples packed in OPP, PP and LDPE. However, the TBARS values showed significant differences ($P < 0.05$) between samples packed in OPP and PP and those packed in LDPE, with LDPE giving a higher degree of oxidation. The lack of correlation between rancid odour scores and TBARS values may be due to the slightly oxidised and strong flavour of fried banana chips preventing the panel from accurately assessing the varying degrees of oxidation. This lack of correlation has been noted previously by Che Man and Tan[26] and Chu *et al.*[27] They reported that when sensory panel data were compared with chemical measurements of oxidation, it was observed that the panel failed to detect the presence of rancid notes even though TBARS values indicated an increase in oxidation. From the comparison of all sensory attribute descriptors, the most noticeable alteration during storage concerned crispness.

CONCLUSION

Among the four types of packaging material used for packing deep-fat-fried banana chips, LAF resulted in the smallest changes in moisture content, a_w and TBARS values during storage. Sensory evaluation of the chips by a trained panel indicated that, after 8 weeks of storage, LAF gave the highest scores for crispness and rancid odour, but no significant differences in product colour compared with OPP and PP, while LDPE gave the lowest scores for all characteristics. The most notable differences between descriptors in the sensory profile during storage were related to crispness.

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APPENDIX

A panel of 12 persons was selected from a group of 20 postgraduate students. Three training sessions were conducted using deep-fat-fried bananas with varying degrees of rancidity, colour and crispness as controls. The controls were also prepared and presented to remind the panellists at every sensory session. The varying degrees of rancidity of the chips were determined through TBARS values, colour by a colorimeter and crispness by a texture analyser. The 0–10 cm scale was anchored according to the predetermined TBARS, colour and crispness values as shown in Tables 5–7.

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Table 6. Varying degrees of colour

Scale	Description	Colour		
		L	a	b
10–8	Bland	55–60	5.5–6.0	20–21
8–6	Suspicion of off-colour	60–65	5.0–5.5	19–20
6–4	Noticeable but very slight off-colour	65–70	4.5–5.0	18–19
4–2	Distinct off-colour	70–75	4.0–4.5	17–18
2–0	Markedly disagreeable off-colour	>75	<4.0	<17

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