

## Nutritional Composition and Lipid Oxidation Stability of Beef Patties Packed with Biodegradable and Non-Biodegradable Materials

(Kestabilan Komposisi Makanan dan Pengoksidaan Lemak Burger Daging yang Dibungkus dengan Bahan Mudah Urai dan Tidak Mudah Urai Secara Biologi)

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### ABSTRACT

*Long term environmental problems of non-biodegradable plastic, the need to conserve finite fossil fuels and the impact of globalization of food supply are some of the driving forces in looking towards biodegradable plastics as an alternative to the existing petrochemical-based polymers for food packaging application. The stability of nutritional composition, lipid oxidation, physical traits of beef patties packed with different types of plastics and the surface morphology of plastics after 3 months of frozen storage (-18 were studied. Beef patties were packed with either non-biodegradable high density polyethylene (PE), hydro-biodegradable low density polyethylene/thermoplastic sago starch plastic (PES), hydro-biodegradable polylactic acid plastic (PLA) or oxo-biodegradable plastic (OXO)). There were no differences in most of the nutrients analyzed and lipid oxidation values of beef patties packed with either biodegradable or non-biodegradable plastics after storage. There were significant ( $p$  decreased in fat for cooked patties and moisture for both raw and cooked patties. Lipid oxidation indices of beef patties increased after storage but they were not significant ( $p$  Beef patties packed with biodegradable packaging materials were able to retain moisture without jeopardizing the diameter reduction during storage. In summary, the application of biodegradable plastics for packing beef patties was considered acceptable and can be suggested as an alternative packaging item to replace conventional polyethylene plastic packaging.*

*Keywords: Beef patty; biodegradable; lipid oxidation; nutritional composition; packaging*

### ABSTRAK

*Masalah berpanjangan akibat penggunaan plastik tidak terbiodegradasi, keperluan untuk memelihara bahan api fosil yang terhad serta impak daripada globalisasi bekalan makanan merupakan antara pendorong utama dalam menggantikan plastik petrokimia yang sedia ada dengan plastik terbiodegradasi dalam sektor pembungkusan makanan. Kestabilan komposisi pemakanan, pengoksidaan lemak, sifat fizikal burger daging yang dibungkus dengan plastik yang berlainan serta morfologi permukaan plastik selepas 3 bulan penyimpanan beku (-18 telah dikaji. Burger daging dibungkus sama ada dengan polietilena jenis ketumpatan tinggi yang tidak terbiodegradasi (PE), plastik hidro-terbiodegradasi polietilena jenis ketumpatan rendah/termoplastik kanji sago (PES), plastik hidro-terbiodegradasi asid polilaktik (BPLA) atau plastik oxo-terbiodegradasi (OXO)). Tidak ada perbezaan yang ketara dalam corak perubahan dalam kebanyakan nutrien yang dianalisis dan nilai pengoksidaan lemak burger daging yang dibungkus dengan plastik tidak terbiodegradasi atau plastik terbiodegradasi selepas tempoh penyimpanan. Terdapat penurunan yang ketara ( $p < 0.05$  untuk lemak dalam burger masak dan kelembapan untuk kedua-dua burger mentah dan masak. Nilai pengoksidaan lemak burger meningkat selepas tempoh penyimpanan tetapi ia tidak ketara ( $p > 0.05$  Burger daging yang dibungkus dengan plastik terbiodegradasi mampu mengekalkan kelembapan tanpa memudaratkan pengurangan diameter semasa penyimpanan. Kesimpulannya, aplikasi pembungkusan plastik terbiodegradasi untuk burger daging dapat diterima dan boleh dicadangkan sebagai pembungkus alternatif bagi menggantikan pembungkusan plastik polietilena konvensional.*

*Kata kunci: Biodegradasi; burger daging; komposisi pemakanan; pembungkusan; pengoksidaan lemak*

### INTRODUCTION

Food packaging is the largest growing sector within the plastic packaging market (Comstock et al. 2004). The environmental impact of persistent plastic waste is raising general global concern (Mitrus et al. 2009). Satisfactory landfill sites are limited and incineration may cause toxic air pollution (Mitrus et al. 2009). Furthermore, conventional plastics manufactured from fossil fuels consume a lot of non-renewable and finite resources. With

rising petroleum costs, the reliance on petroleum products in the production of plastic packaging materials needed to be reconsidered (Cutter 2006). Moreover, food packaging has been impacted by globalization of the food supply, consumers are demanding that food packaging materials be more natural, disposable, potentially biodegradable as well as recyclable (Lopez-Rubio et al. 2004). It is important to find durable plastic substitutes and cost-effective ways to manufacture packaging materials.

Bio-based polymers, also known as biodegradable polymers can be obtained from renewable resources or non-renewable petroleum sources (Comstock et al. 2004). Biopolymers are generally characterized by a relatively high permeability to oxygen and water vapor; thus their utilization in food packaging is of interest mainly for foodstuffs such as meat, having few gas and vapor barrier requirement, with a shelf life limited to a few days of storage (Avella et al. 2005). Due to the natural origin of bio-based polymers, many of the bio-based packaging materials are considered safe for food packaging purposes (Holm 2010).

Starch has potential applications in the market dominated by petroleum-based materials, because it is abundant, renewable, safe and economic (Fang et al. 2005). Polylactic acid (PLA) is a biodegradable thermoplastic that can be produced synthetically or from renewable resources or other biomass by bacterial fermentation used to produce lactic acid (Holm et al. 2006; Jin & Zhang 2008). PLA is of current interest not only because of the demand to replace many petroleum-based polymers but also because of their potentially useful physical and mechanical characteristics (Jin & Zhang 2008). Oxo-biodegradable plastics are the products from a modification of conventional plastics (Ojeda et al. 2009). They are considered as a more economical alternative as they are based on pro-oxidant additives added to polyethylenes, polypropylene, polystyrene or other polymers. Oxo-biodegradable plastic is ideal to be used for frozen food packaging, as it can be kept for extended periods at low temperature and will then quickly degrade when it becomes a waste product at normal temperatures.

Bio-based packaging materials have been shown to prevent moisture loss, drip, reduce lipid oxidation and improve flavor attributes, as well as enhancing the handling properties, color retention and microbial stability of foods (Cutter 2006). Even so, the lack of food bio-based packaging materials on the market is apparent. In Malaysia, the application of degradable packaging plastic in wrapping processed food products is not yet practiced (Wan Rosli & Solihah 2012). The purpose of this study was to investigate the effect of different packaging materials on nutrients stability of beef patties and susceptibility of beef patties to lipid oxidation after three months of frozen storage.

## MATERIALS AND METHODS

### PLASTICS SAMPLES

Conventional high density polyethylene, oxo-biodegradable plastics and polylactic acid plastics were sponsored by three different plastic companies. Low density polyethylene/thermoplastic sago starch plastics invented by Universiti Sains Malaysia (School of Material Sciences, Engineering Campus) were used for this proposed study. Then, the plastics were resized into rectangular shape of 12 × 30 cm by using a plastic sealer machine.

### PROCESSING OF BEEF PATTIES

Beef patties were prepared according to the formulation and processes established by Wan Rosli et al. (2011). The finished patties were packed with biodegradable packaging plastics of polyethylene/thermostable Sago (PES), polylactic acid (PLA) and oxo-biodegradable (OXO) packaging plastics. The non-biodegradable packaging used as control in the present study was polyethylene (PE) packaging plastics. The technique of packaging when packing patties used in the present study was hygienic manual packaging conditions where the operator who wearing mask and glove manually pack the frozen patties in the packaging containers. This technique is considered traditional and not involving either vacuum pack or MAP techniques.

### PROXIMATE COMPOSITION

Proximate composition analyses were conducted using AOAC (1996) for moisture, ash and protein by nitrogen conversion factor of 6.25 according to Kjeldahl method. Calorific value of beef patties was determined using bomb calorimetry method by referring to the operating instructions of C 2000 basic IKA- calorimeter. Meanwhile, the procedure for the lipid extraction was based on modified Kinsella method (Kinsella et al. 1977).

### COOKING YIELD

Cooking yield of beef patties was determined by calculating weight differences of patties before and after cooking, as follows (El-Magoli et al. 1996):

$$\text{Cooking yield (\%)} = \frac{(\text{cooked weight} \times 100)}{\text{Raw weight}}$$

### MOISTURE RETENTION

The moisture retention values represent the amount of moisture retained in the cooked product per 100 g of raw sample. Moisture retention was calculated according to formula by Yi et al. (2012):

$$\text{Moisture retention (\%)} = \frac{\left( \frac{\text{cooked weight} \times \text{percent moisture in cooked patties}}{\text{raw weight} \times \text{percent moisture in raw beef patties}} \right) \times 100}$$

### DIAMETER REDUCTION

Change in beef patties' diameter was determined using the following equation:

$$\text{Diameter reduction (\%)} = \frac{\frac{\text{raw beef patties diameter-cooked beef patties diameter}}{\text{raw beef patties diameter}} \times 100}$$

### PEROXIDE VALUE MEASUREMENT

Exactly 2-5 g fat extracted from beef patty was dissolved in 30 mL of chloroform-glacial acetic acid (3:2) blended

solution by continuous shaking using a magnetic stirrer. Then saturated solution of KI (0.5 mL) was added. The mixture was shaken by hand for 30 s. After the addition of 30 mL distilled water, the mixture was titrated against sodium thiosulphate (0.1 N) until deep purplish color disappeared by using starch solution (1%) as an indicator. A parallel blank titration was done. The amount of iodine present was determined by using a standard sodium thiosulfate solution as the titrant and a starch indicator and thus it reflects the amount of peroxide present in lipid (Rogers & Emil 2005).

#### THIOBARBITURATE ACID REACTIVE SUBSTANCES MEASUREMENT

Thiobarbiturate acid reactive substance assay was performed according to Trindade et al. (2010) with some modification. Sample was ground by using a waring blender (Waring brand, 8010S model) prior analysis. The sample (5 g) was homogenized in 10 mL extracting solution (7.5 g/100 mL trichloroacetic acid) by using Ultraturax homogenizer for approximately 2 min at speed 6. The slurry was then centrifuged at 6000 rpm for 10 min and filtered into a centrifuge tube. The volume was filled up to 8 mL with trichloroacetic acid/water (1:1). Subsequently, 2 mL aliquot of this solution was transferred into another tube and was mixed with 2 mL of TBA solution (0.5 mol/L). The mixture was then heated at 100°C in boiling water for 10 min until a pink color developed. The mixture was cooled and the absorbance was measured at 532 nm by using UV-VIS spectrophotometer (Varian-Cary 100, USA) in order to calculate the TBA value by using appropriate formula.

#### DATA ANALYSIS

Data obtained was tested for significance by using ANOVA and Turkey's post hoc test with IBM SPSS Statistics version 20 (USA). The results were presented as mean  $\pm$  standard

deviation. Significance level was set at  $p < 0.05$ . All measurements were carried out in triplicate ( $n=3$ ).

## RESULTS AND DISCUSSION

### PROXIMATE COMPOSITION

Proximate analyses of beef patties packed with different types of plastic are presented in Tables 1 and 2. Generally, there were no differences in the trend of changes for most of the nutrients analyzed for beef patties packed with either biodegradable or non-biodegradable plastics after 3 months of storage. Moisture content was significantly decreased ( $p < 0.05$ ) after storage for all types of packaging materials. After storage, the moisture content was in the range from 35.0 to 35.4% for raw patties and 29.0 to 30.2% for cooked patties. The reduction of moisture content for both raw and cooked beef patties may be due to the moisture migration from the internal region to the surface of patty in the form of small ice crystals/frost during storage period. Biopolymers are generally characterized by a relatively high permeability to oxygen and water vapor (Avella et al. 2005). Although bio-based packaging materials have been shown to prevent moisture loss according to Cutter (2006), but there was no significant different in moisture loss for all types of packaging materials used in this present study.

Fat content was also decreased for both raw and cooked beef patties after storage. Polyethylene (PE) packaging recorded the lowest fat content after storage for both raw (11.8%) and cooked patties (10.0%) as compared to the other three biodegradable packaging with the fat content ranging from 12.2 to 14.4% and 10.2 to 11.1% for raw and cooked patties, respectively. This indicated that biodegradable packaging (PES, OXO and PLA) were able to retain fat better than conventional polyethylene packaging after 3 months of storage. This was in agreement with previous finding by Wan Rosli et al. (2013) who studied

TABLE 1. Nutritional composition of raw beef patties packed with different types of packaging materials

Nutrient composition	Storage time (months)	PE (control)	PES	PLA	OXO
Moisture (%)	0	<sup>p</sup> 53.13 $\pm$ 0.22 <sup>a</sup>	<sup>p</sup> 53.14 $\pm$ 0.23 <sup>a</sup>	<sup>p</sup> 53.12 $\pm$ 0.22 <sup>a</sup>	<sup>p</sup> 53.11 $\pm$ 0.20 <sup>a</sup>
	3	<sup>q</sup> 35.03 $\pm$ 0.47 <sup>a</sup>	<sup>q</sup> 35.00 $\pm$ 0.56 <sup>a</sup>	<sup>q</sup> 34.99 $\pm$ 0.40 <sup>a</sup>	<sup>q</sup> 35.41 $\pm$ 0.51 <sup>a</sup>
Protein (%)	0	<sup>p</sup> 18.49 $\pm$ 0.23 <sup>a</sup>	<sup>p</sup> 18.47 $\pm$ 0.22 <sup>a</sup>	<sup>p</sup> 18.46 $\pm$ 0.23 <sup>a</sup>	<sup>p</sup> 18.49 $\pm$ 0.23 <sup>a</sup>
	3	<sup>p</sup> 19.16 $\pm$ 0.99 <sup>b</sup>	<sup>p</sup> 20.16 $\pm$ 0.20 <sup>ab</sup>	<sup>p</sup> 21.38 $\pm$ 0.31 <sup>ab</sup>	<sup>p</sup> 21.57 $\pm$ 1.33 <sup>b</sup>
Fat (%)	0	<sup>p</sup> 16.64 $\pm$ 1.96 <sup>a</sup>	<sup>p</sup> 16.64 $\pm$ 1.96 <sup>a</sup>	<sup>p</sup> 16.62 $\pm$ 1.94 <sup>a</sup>	<sup>p</sup> 16.64 $\pm$ 1.96 <sup>a</sup>
	3	<sup>p</sup> 11.79 $\pm$ 0.86 <sup>a</sup>	<sup>p</sup> 14.43 $\pm$ 2.56 <sup>a</sup>	<sup>p</sup> 12.22 $\pm$ 0.42 <sup>a</sup>	<sup>p</sup> 13.53 $\pm$ 2.23 <sup>a</sup>
Ash (%)	0	<sup>p</sup> 1.79 $\pm$ 0.07 <sup>a</sup>	<sup>p</sup> 1.78 $\pm$ 0.06 <sup>a</sup>	<sup>p</sup> 1.79 $\pm$ 0.07 <sup>a</sup>	<sup>p</sup> 1.78 $\pm$ 0.07 <sup>a</sup>
	3	<sup>p</sup> 1.77 $\pm$ 0.05 <sup>a</sup>	<sup>p</sup> 1.49 $\pm$ 0.25 <sup>a</sup>	<sup>q</sup> 1.34 $\pm$ 0.23 <sup>a</sup>	<sup>q</sup> 1.35 $\pm$ 0.19 <sup>a</sup>
Calorific value (kcal/100 g)	0	<sup>p</sup> 596 $\pm$ 2.08 <sup>a</sup>	<sup>p</sup> 597 $\pm$ 2.06 <sup>a</sup>	<sup>p</sup> 596 $\pm$ 2.08 <sup>a</sup>	<sup>p</sup> 596 $\pm$ 2.08 <sup>a</sup>
	3	<sup>p</sup> 600 $\pm$ 1.99 <sup>a</sup>	<sup>p</sup> 599 $\pm$ 3.15 <sup>a</sup>	<sup>p</sup> 597 $\pm$ 4.49 <sup>a</sup>	<sup>p</sup> 602 $\pm$ 0.90 <sup>a</sup>

PE = polyethylene, PES = polyethylene/thermostable Sago, PLA = polylactic acid, OXO = oxo-biodegradable

<sup>a-b</sup> Mean values within the same row bearing different superscripts differ significantly ( $p < 0.05$ )

<sup>p-q</sup> Mean values within the same column bearing different superscripts differ significantly ( $p < 0.05$ )

TABLE 2. Nutritional composition of cooked beef patties packed with different types of packaging materials

Nutrient composition	Storage time (months)	PE (control)	PES	PLA	OXO
Moisture (%)	0	<sup>p</sup> 45.02±0.39 <sup>a</sup>	<sup>p</sup> 45.12±0.39 <sup>a</sup>	<sup>p</sup> 45.20±0.22 <sup>a</sup>	<sup>p</sup> 44.11±0.32 <sup>a</sup>
	3	<sup>q</sup> 30.11±0.20 <sup>a</sup>	<sup>q</sup> 30.16±0.31 <sup>a</sup>	<sup>q</sup> 29.00±0.12 <sup>a</sup>	<sup>q</sup> 29.73±0.43 <sup>ab</sup>
Protein (%)	0	<sup>p</sup> 24.70±3.20 <sup>a</sup>	<sup>p</sup> 24.66±3.20 <sup>a</sup>	<sup>p</sup> 24.57±3.20 <sup>a</sup>	<sup>p</sup> 24.58±0.23 <sup>a</sup>
	3	<sup>p</sup> 23.34±1.28 <sup>b</sup>	<sup>p</sup> 23.01±1.35 <sup>a</sup>	<sup>p</sup> 24.16±0.50 <sup>a</sup>	<sup>p</sup> 24.45±0.37 <sup>a</sup>
Fat (%)	0	<sup>p</sup> 18.64±1.40 <sup>a</sup>	<sup>p</sup> 18.45±1.36 <sup>a</sup>	<sup>p</sup> 18.56±1.24 <sup>a</sup>	<sup>p</sup> 18.44±1.16 <sup>a</sup>
	3	<sup>p</sup> 9.95±0.96 <sup>b</sup>	<sup>q</sup> 10.19±0.20 <sup>ab</sup>	<sup>p</sup> 11.07±0.17 <sup>a</sup>	<sup>p</sup> 10.44±0.34 <sup>a</sup>
Ash (%)	0	<sup>p</sup> 1.97±0.14 <sup>a</sup>	<sup>p</sup> 1.98±0.15 <sup>a</sup>	<sup>p</sup> 1.98±0.15 <sup>a</sup>	<sup>p</sup> 1.97±0.10 <sup>a</sup>
	3	<sup>p</sup> 2.01±0.04 <sup>a</sup>	<sup>p</sup> 2.11±0.05 <sup>a</sup>	<sup>q</sup> 2.09±0.06 <sup>a</sup>	<sup>q</sup> 2.09±0.33 <sup>a</sup>
Calorific value (kcal/100 g)	0	<sup>q</sup> 588±1.08 <sup>a</sup>	<sup>q</sup> 589±1.06 <sup>a</sup>	<sup>q</sup> 587±1.08 <sup>a</sup>	<sup>q</sup> 589±1.08 <sup>a</sup>
	3	<sup>p</sup> 600±0.70 <sup>a</sup>	<sup>p</sup> 596±0.85 <sup>a</sup>	<sup>p</sup> 596±1.23 <sup>a</sup>	<sup>p</sup> 599±3.43 <sup>a</sup>

PE = polyethylene, PES = polyethylene/thermostable Sago, PLA = polylactic acid, OXO = oxo-biodegradable

<sup>ab</sup> Mean values within the same row bearing different superscripts differ significantly ( $p < 0.05$ )

<sup>pq</sup> Mean values within the same column bearing different superscripts differ significantly ( $p < 0.05$ )

the stability of nutritional composition and physical traits of chicken patty containing oyster mushroom packed with biodegradable and non-degradable packaging materials. In beef patties, fat was more easily removed during cooking, probably due a low density meat protein matrix and this is in agreement with previous research (Suman & Sharma 2003). Cooking may promote nutrient loss due to chemical reactions, interactions among constituents and solubility in cooking medium and thermal degradation (Manzi et al. 2004). Another possible reason for the reduction of fat content of cooked patties is due to the oxidation of fat in the beef patties upon storage (Wan Rosli et al. 2013).

#### LIPID OXIDATION MEASUREMENTS

Lipid oxidation values of beef patties packed with different types of packaging materials are presented in Tables 3 and 4. Generally, the TBARS values in all patties packed with either PES, PLA and OXO were not significant different. Thiobarbituric acid reactive substances (TBARS) values were ranging from 0.2 to 0.3 mg MDA eq/kg lipid for raw patties and 0.3 to 0.5 mg MDA eq/kg lipid for cooked patties.

On the other result, after 3 months of frozen storage, beef patties recorded an increment in peroxide values (PV)

ranging from 6.7 meq active oxygen / kg sample to 9.3 meq active oxygen / kg sample for all raw patties (Table 3) and 8.4 meq active oxygen / kg sample to 13.2 meq active oxygen / kg sample for all cooked patties (Table 4). Even though raw patties packed with PES and PLA recorded the lowest values of PV (6.73 and 7.78 MDA eq/kg) after storage but there were not significant different with other treatments.

In addition, cooked patties packed with polyethylene (Table 4) which recorded significantly ( $p < 0.05$ ) higher PV (13.2 meq active oxygen / kg sample) than initial PV (5.4 meq active oxygen / kg sample). This may attributed to the higher permeability to gas of high-density polyethylene (Marsh & Bugusu 2007) as oxygen availability plays an important role for the development of lipid peroxidation in raw and cooked meat (Min & Ahn 2005). Even though all patties packed with PES, PLA and OXO recorded slightly lower PV values (8.4 – 12.2 meq active O<sub>2</sub>/kg) compared to PE (13.2 meq active O<sub>2</sub>/kg) but the values were not statistically different ( $p > 0.05$ ).

No significant increment in lipid oxidation indices was probably attributed to the antioxidant activity of isolated soy protein used as an ingredient for beef patties formulation. Similar findings were documented by Romijn

TABLE 3. Lipid oxidation indices of raw beef patties packed with different types of packaging materials

Lipid oxidation index	Storage time (months)	PE (control)	PES	PLA	OXO
TBARS (mg MDA eq/kg lipid)	0	<sup>p</sup> 0.22±0.01 <sup>a</sup>	<sup>p</sup> 0.23±0.02 <sup>a</sup>	<sup>p</sup> 0.23±0.22 <sup>a</sup>	<sup>p</sup> 0.22±0.02 <sup>a</sup>
	3	<sup>q</sup> 0.24±0.07 <sup>a</sup>	<sup>q</sup> 0.30±0.18 <sup>a</sup>	<sup>q</sup> 0.34±0.18 <sup>a</sup>	<sup>q</sup> 0.23±0.07 <sup>a</sup>
Peroxide value (meq active oxygen/kg sample)	0	<sup>q</sup> 3.58±1.18 <sup>a</sup>	<sup>p</sup> 3.58±1.20 <sup>a</sup>	<sup>p</sup> 3.57±1.21 <sup>a</sup>	<sup>p</sup> 3.56±1.13 <sup>a</sup>
	3	<sup>p</sup> 7.82±2.28 <sup>a</sup>	<sup>p</sup> 6.73±2.18 <sup>a</sup>	<sup>p</sup> 7.78±2.26 <sup>a</sup>	<sup>p</sup> 9.33±2.77 <sup>a</sup>

PE = polyethylene, PES = polyethylene/thermostable Sago, PLA = polylactic acid, OXO = oxo-biodegradable

<sup>ab</sup> Mean values within the same row bearing different superscripts differ significantly ( $p < 0.05$ )

<sup>pq</sup> Mean values within the same column bearing different superscripts differ significantly ( $p < 0.05$ )



et al. (1991) who reported that the incremental addition of commercial isolated soy protein produced progressive decreases in TBARS values in the cooked ground beef. This findings implied that biodegradable packaging not only helps to slow food deterioration, but also extends the food product's shelf life (Cutter 2006).

The higher TBARS and PV values of cooked patties compared with the raw ones showed that cooking induced lipid oxidation. Heating causes lipid peroxidation by disruption of muscle cell structure, inactivation of antioxidant enzymes and release of oxygen and iron from myoglobin (Min & Ahn 2005). The disrupted membranes by heating are readily exposed to oxygen, followed by rapid lipid peroxidation (Igene et al. 1985). Furthermore, high temperature provides reduced activation energy for oxidation and breaks down preformed hydroperoxide into free radicals, which promotes further lipid peroxidation processes and off-flavor development (Kanner 1994).

#### PHYSICAL TRAITS MEASUREMENTS

Physical characteristics of beef patties packed with different types of packaging materials are presented in Table 5. Cooking yield was significantly ( $p < 0.05$ ) higher after 3 months of storage for all patties. They recorded the cooking yield values ranging from 88.5 to 89.5%. Cook losses were mainly due to water and fat decreases and these losses depend on the mass transfer process during

thermal treatment (Vittadini et al. 2005). In this present study, the percent of cooking yield during cooking was comparatively higher than the other study. For example, previous study reported that cooking loss of cooked beef patties contained 10-20% of fat were ranging from 30-39% (Elif Bilek & Turhan 2009). This present study only used 15% fat in patty formulation and the cooking loss was less than 20% as compared to the study by Elif Bilek and Turhan (2009). Higher fat content around 29-30% in the common patty formulation will lead to the losses of higher percentage of fat during cooking (Wan Rosli et al. 2013). From this result, it can be proposed that cooking loss increased proportionally with fat content in patty formulation (Wan Rosli et al. 2013). As the fat content increases, the mean free distance between fat cells decreases, raising the likelihood of fat coalescing and then leaking out from the products. Therefore, high fat food products tend to lose great amounts of fat during cooking whilst low fat meat products lose relatively little fat (Tornberg et al. 1989). Cook losses also depend on other variables such as composition, additives, cooking methods, oven temperature and sample dimensions (Vittadini et al. 2005).

Diameter reduction values were in the range from 8.7 to 8.8% before storage for all patties packed with different packaging materials. However, after storage for 3 months, the percentage of diameter reduction was unchanged for both patties packed with either PE (8.1%) or OXO (7.9%).

TABLE 4. Lipid oxidation indices of cooked beef patties packed with different types of packaging materials

Lipid oxidation index	Storage time (months)	PE (control)	PES	PLA	OXO
TBARS (mg MDA meq/kg lipid)	0	<sup>p</sup> 0.38±0.08 <sup>a</sup>	<sup>p</sup> 0.39±0.08 <sup>a</sup>	<sup>p</sup> 0.37±0.07 <sup>a</sup>	<sup>q</sup> 0.38±0.06 <sup>a</sup>
	3	<sup>p</sup> 0.53±0.32 <sup>a</sup>	<sup>p</sup> 0.44±0.23 <sup>a</sup>	<sup>p</sup> 0.30±0.10 <sup>a</sup>	<sup>p</sup> 0.52±0.03 <sup>a</sup>
Peroxide value (meq active oxygen/kg sample)	0	<sup>q</sup> 5.39±1.26 <sup>a</sup>	<sup>q</sup> 5.38±1.20 <sup>a</sup>	<sup>q</sup> 5.37±1.21 <sup>a</sup>	<sup>q</sup> 5.39±1.16 <sup>a</sup>
	3	<sup>p</sup> 13.24±1.62 <sup>a</sup>	<sup>p</sup> 11.52±1.56 <sup>a</sup>	<sup>p</sup> 8.36±1.76 <sup>a</sup>	<sup>p</sup> 12.24±2.39 <sup>a</sup>

PE = polyethylene, PES = polyethylene/thermostable Sago, PLA = polylactic acid, OXO = oxo-biodegradable

<sup>a,b</sup> Mean values within the same row bearing different superscripts differ significantly ( $p < 0.05$ )

<sup>p,q</sup> Mean values within the same column bearing different superscripts differ significantly ( $p < 0.05$ )

TABLE 5. Physical traits of beef patties packed with different types of packaging materials

Physical traits (%)	Storage time (months)	PE (control)	PES	PLA	OXO
Cooking yield	0	<sup>q</sup> 86.19±0.83 <sup>a</sup>	<sup>q</sup> 85.18±0.73 <sup>a</sup>	<sup>q</sup> 86.20±0.63 <sup>a</sup>	<sup>p</sup> 86.18±0.73 <sup>a</sup>
	3	<sup>p</sup> 88.46±0.09 <sup>a</sup>	<sup>p</sup> 89.47±0.92 <sup>a</sup>	<sup>p</sup> 88.99±0.88 <sup>a</sup>	<sup>p</sup> 88.52±0.09 <sup>a</sup>
Moisture Retention (%)	0	<sup>q</sup> 73.35±0.16 <sup>a</sup>	<sup>q</sup> 73.25±0.15 <sup>a</sup>	<sup>p</sup> 72.97±0.28 <sup>a</sup>	<sup>p</sup> 72.99±0.39 <sup>a</sup>
	3	<sup>p</sup> 76.04±0.92 <sup>b</sup>	<sup>p</sup> 77.13±2.43 <sup>a</sup>	<sup>p</sup> 73.75±0.82 <sup>a</sup>	<sup>p</sup> 74.32±1.34 <sup>a</sup>
Diameter Reduction (%)	0	<sup>p</sup> 8.74±2.29 <sup>a</sup>	<sup>p</sup> 8.75±2.36 <sup>a</sup>	<sup>p</sup> 8.76±2.39 <sup>a</sup>	<sup>p</sup> 8.74±2.16 <sup>a</sup>
	3	<sup>p</sup> 8.06±0.53 <sup>b</sup>	<sup>q</sup> 5.28±0.85 <sup>b</sup>	<sup>q</sup> 4.98±0.92 <sup>b</sup>	<sup>p</sup> 7.88±0.53 <sup>a</sup>

PE = polyethylene, PES = polyethylene/thermostable Sago, PLA = polylactic acid, OXO = oxo-biodegradable

<sup>a,b</sup> Mean values within the same row bearing different superscripts differ significantly ( $p < 0.05$ )

<sup>p,q</sup> Mean values within the same column bearing different superscripts differ significantly ( $p < 0.05$ )

These results indicated that different types of packaging did not affect diameter reduction of beef patties.

Moisture retention values were in the range from 73.8 to 77.1% after storage (Table 5). Moisture retention values increased after storage for all beef patties but they were not significantly ( $p>0.05$ ) different except for polyethylene/thermoplastic sago starch plastic (PES) which recorded significantly higher ( $p<0.05$ ) moisture retention value (77.1%) than initial moisture retention value (73.4%). To improve starch-based polymer properties, researchers have often blended starch with hydrophobic polymers in the form of petroleum polymers (Mitrus et al. 2009). Thus, the application of low density PES plastic with better mechanical properties and higher water resistance is beneficial in terms of retaining the moisture content of beef patties and this explained for its significant higher moisture retention compared to the other types of plastics used in this present study.

#### CONCLUSION

Generally, there were no differences in most of the nutrients analyzed and lipid oxidation values of beef patties packed with either biodegradable or non-biodegradable plastics after 3 months of frozen storage. Biodegradable plastics were able to retain moisture without jeopardizing the diameter reduction of beef patties during storage. In summary, the trend of changes in proximate compositions, lipid oxidation values and physical traits of beef patties packed with biodegradable plastic were comparable with conventional polyethylene packaging. The application of biodegradable packaging of beef patties is considered acceptable and can be further improved.

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