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Effects of Processing on Nutritional and Sensory Qualities of Beef Burgers Incorporated With Palm Fats

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ABSTRACT

A study was undertaken to investigate the effects of processing on the nutritional and sensory qualities of beef burgers formulated with palm fats as animal fat analogues. After processing, α-tocopherol and α-tocotrienol levels were significantly decreased, ranging from 46-48% to 36-44% respectively, in beef burgers made with red palm fat (RPF35) and fat blend. The changes in the levels of γ-tocotrienol and δ-tocotrienol after processing in all beef burgers except for the control were not statistically significant (P>0.05). After processing, α-carotene and β-carotene levels were significantly decreased, ranging from 27-40% to 42-54% in beef burgers formulated with fat blend and RPF35. After cooking, α-tocopherol and α-tocotrienol in all cooked beef burgers, except the control, were significantly decreased with levels ranging from 18-50% to 17-46% respectively. The changes in the levels of α-carotene and β-carotene after cooking were also statistically significant (36-47% and 48-62% loss, respectively). Substitution of animal fats with palm-based fats reduced the content of cholesterol in beef burgers. The taste panel was not able to differentiate the sensory attributes such as colour, juiciness and oiliness of beef burgers formulated with palm-based fats and beef fat. Overall levels of carotene and vitamin E were higher in palm fat burgers but losses occurred upon processing and cooking.

INTRODUCTION

Poultry and beef fats are common raw materials added in emulsion-type meat products but they are also high in cholesterol and contaminating microorganisms. As more companies venture into further processing of meat, the prices of animal fats and skin will increase due to increased demand (Babji, Kartini Wati & Tan, 1999).

When consumers demand nutritious foods, meat manufacturers have to focus their production toward processed meats that are lean, low in fat and high in protein content. The high contents of saturated

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fats and cholesterol have been a major problem, resulting in meat products becoming the subject of scrutiny by nutritional, medical, and consumer groups. The American Heart Association (1985) and other health groups have recommended a decrease in the consumption of animal fats. Decreases in calories from fat, from 40% to 30% and in saturated fat intake from 18% to 10% have also been recommended (Carrol, 1998).

Vitamin E compounds (tocopherols and tocotrienols) are well recognised for their effective inhibition of lipid oxidation in foods and biological systems (van Acker, Koymans & Bast, 1993). Many researchers reported that the antioxidant activity of the tocopherols and tocotrienols is mainly due to their ability to donate their phenolic hydrogens to lipid free-radicals (Kamal-eldin & Appelqvist, 1996). While a-tocopherol has been reported to be the most biologically active of all the tocopherols, scientific evidence has shown that, tocotrienols may reduce cholesterol concentrations in people with hypercholesterolaemia, may slow down the progression of atherosclerosis and inhibit the proliferation and growth of human breast cancer cells (Nesaretnam, 2000). Gamma (g), the largest vitamin E homologue in palm oil and delta (d) forms of tocotrienols have been found to exhibit a strong activity against tumour promotion by inhibiting Epstein-Barr virus (Kamen, 2000).

Crude and red palm oil contain between 500 and 700 ppm of carotenoids. The major components are α-carotene (35-37%) and β-carotene (47-56%) (Ooi *et al*., 1996). Carotenoids have been shown in a number of studies to be able to act as a radical scavenging antioxidant. It has been suggested that β-carotene scavenges peroxyl radicals by forming an adduct between β-carotene and the peroxyl radical, yielding a resonance-stabilised carotenoid radical (Burton & Ingold, 1984).

The utilisation of palm fats in meat products was first investigated as alternatives to animal fats in beef burgers and chicken nuggets by Babji *et al*. (1998). They found that there were no significant differences in the cooking losses, texture, juiciness, oiliness and overall acceptance between the burgers prepared with palm fats and beef fat. Meanwhile, Shiota *et al*. (1995) reported that beef patties containing Bungo beef received the highest sensory scores for texture, taste and aroma at the 20% level of total formulation of palm oil and palm mid-fraction.

The aim of this study was to investigate the effects of processing on the nutritional and sensory qualities of beef burgers incorporated with palm fats.

MATERIALS AND METHODS

Four beef burger formulations were compared, each containing 15% fat from either beef fat (control), palm fat [slip melting point (SMP) 41-44^{o}C, iodine value (IV) 45-50], red palm fat (RPF35 with SMP 33-37^{o}C, IV 48-53) or a blend of palm fat and RPF35 at a ratio of 1:1 at 15% fat. Palm fat (white in colour) was supplied by Cargill Fats & Oils Specialty Company and the Red Palm Fat (yellow in colour) was supplied by the Carotino Company. Other dry materials were purchased from local suppliers. Upon arrival, raw fat samples (palm fat, red palm fat and fat blend) were melted at 50^{o}C to determine their vitamin E (AOCS, 1990) and carotene contents (Hart and Scott 1995) before being incorporated into burger formulations.

Processing

Frozen New Zealand beef (Hind quarter) was manually cut using band saw (JG-210) and minced through a 4 mm-diameter grinder plate. The minced beef was stored at -18^{o}C until processing time. Isolated soy protein was blended with water and fat at a ratio of 1:5:5 using a Hobart mixer (N-50 Canada) for 3 minutes

at speed number 3. The emulsion prepared (called pre-emulsion) was kept in the chiller (2-5^{O}C) until ready for use. Salt was added to frozen minced beef and mixing was carried out using Hobart mixer for a duration of 3 minutes (Table 1). Water mixed with tripolyphosphate and spices, potato starch and textured vegetable protein were added and mixed for another 2 min. The pre-emulsion was then added and mixing continued for another 2 min. The finished meat batters were then weighed into 70g portions, and then manually stamped to produce uniform beef burgers. Half of the uniform beef burgers were stored in the freezer at -18^{O}C for 6 months. Samples from another half of uniform burgers were then cooked on a hot plate for 7-8 min until internal temperature of 74 ± 1^{O}C was achieved. Fats from raw and cooked beef burgers were then extracted using a method based on Kinsella *et al*. (1977). The lipid extract was stored at -18^{O}C while awaiting analysis for various nutritional components (vitamin E, carotene and cholesterol). These analyses were carried out after sensory evaluation was finished. Other raw burger samples were kept in the freezer at -18^{O}C for at least 1 night while awaiting sensory evaluation. On the following day of processing time, frozen raw beef burgers were cooked for sensory evaluation (month 0).

Analyses of each burger sample for various nutritional components were determined in triplicate. Two batches of processing were carried out.

Vitamin E analysis

Frozen extracted fats (-18^{O}C) were melted in a water bath at 50^{O}C before diluted with n-hexane prior to analysing vitamin E contents using high performance liquid chromatography (HPLC) (AOCS, 1992). Prepared samples from raw fat, raw burger and cooked burger were injected with a volume of 20µL. Peak responses of the tocopherol and tocotrienol were measured using the fluorescence detector with excitation and emission wavelength set at 290 nm and 330 nm, respectively. The analyses used a Lichrosorb (250 mm x 4 mm) column and the solvent system was hexane:Isopropyl alcohol (99:1) at a flow rate of 1.0 ml/min. Vitamin E content of each burger sample was determined in triplicate. The analyses were replicated twice.

Carotenes Analysis

Carotenes were determined using HPLC according to the method by Hart

Table 1. Beef burger formulations

Ingredient	*Percent*
Beef	49.0
Fat (beef fat, palm fat, red palm fat or fat blend)	15.0
Water	22.5
Textured vegetable protein	5.0
Potato starch	3.0
Isolated soy protein	3.0
Salt	1.1
Sodium tripolyphosphate	0.3
Spices and seasoning	1.1
Total	100.0

and Scott (1995) with some modifications. The HPLC system comprised an isochratic solvent delivery pump (Waters model 1515) coupled with UV detector (Waters model 2487). The column system consisted of 250 mm x 4.6 mm, 5 μm μBondapak octadecylsilane ODS (C_{18}) analytical column (SGE International Company). The mobile solvent system consisted of acetonitrile, methanol and dichlorometane (75:20:5 v/v/v) containing 0.1% butylated hydroxytoluene (BHT). The flow rate was 2.5 ml/min. Samples were injected via a micrometer syringe (model 705 Hamilton) loading injector fitted with a 20 μL loop. Peak responses were measured at 450 nm using a variable wavelength UV/Vis (Breeze System). Carotene content of each burger sample was determined in triplicate. The analyses were replicated twice.

Cholesterol content

Cholesterol content of meat products was determined using the method of Bohac *et al*. (1988). Cholesterol content of each burger sample (0 month and 6 month) was determined in triplicate. The analyses were replicated twice.

Sensory evaluation

Frozen burger samples (0 month and 6 month) of each formulation were thawed for 30 min before cooking prior to conducting sensory evaluation. Sensory evaluation was carried out by 100 untrained consumers consisting of students and staff of the School of Chemical Science and Food Technology, Universiti Kebangsaan Malaysia. They evaluated samples for colour, springiness, juiciness, meaty taste, oiliness and overall acceptance on a 7-point scale (1 = dislike extremely, 4 = neither like nor dislike and 7 = like extremely). Significance was established at $P \leq 0.05$ unless otherwise indicated.

Statistical analysis

Data obtained were tested for significance using Analysis of variance (ANOVA) and Duncan Multiple Range Test with SAS version 6.12 (SAS, 1989).

RESULTS

Vitamin E concentrations in beef burger

The initial amount of total vitamin E detected in beef fat during this study was 4 μg/g. However, this nutrient was completely destroyed after processing. After processing, α-tocopherol levels decreased from 113.5 to 61.5 μg/g (46%) and from 131.0 to 68.0 μg/g (48%) in raw beef burgers substituted with red palm fat (RPF35) and fat blend (Table 2), respectively. However, α-tocopherol only decreased from 129.5 to 125.5 μg/g (3%) in palm fat beef burger after processing. After cooking, α-tocopherol in all cooked beef burgers, except the control, significantly decreased ($P<0.05$), with losses ranging from 18 to 50% (129.5 to 106.5 μg/g and 131.0 to 66.0 μg/g), with cooked palm fat beef burgers recording the highest concentration (106.5 μg/g).

After processing, α-tocotrienol also significantly decreased from 129.0 to 83.0 μg/g (36%), and from 141.0 to 79.5 μg/g (44%) in processed beef burgers formulated with RPF35 and fat blend, respectively. After cooking, α-tocotrienol in all burgers, except the control, was significantly decreased with levels ranging from 73.5 to 109.0 μg/g (17-46% loss). However, after processing, γ-tocotrienol in all burgers, except the control, was not significantly decreased, with level ranging from 184.5-221.0 μg/g (6-11% loss). The changes in the level of γ-tocotrienol in beef burgers formulated with palm fat and fat blend were also not significant ($P>0.05$) after cooking (8-13% loss). However, γ-tocotrienol in beef burger substituted with

Table 2. The concentration of vitamin E homologues in beef burgers formulated with palm based fats before and after processing

Vitamin E homologue (μg/g)	*Processing*	*Fats*			
		Palm fat	*Red palm fat (RPF35)*	*Red palm fat + palm fat (Fat blend)*	*Beef fat (Control)*
α-Tocopherol	Raw fat	$^{p}129.5 \pm 5.0^{a}$	$^{p}113.5 \pm 2.1^{b}$	$^{p}131.0 \pm 8.5^{a}$	$^{p}4.0 \pm 0.3^{c}$
	After Processing	$^{p}125.5 \pm 5.7a^{a}$	$^{q}61.5 \pm 4.4^{b}$	$^{q}68.0 \pm 4.5^{b}$	$^{q}0.0 \pm 0.0^{c}$
	After cooking	$^{q}106.5 \pm 4.7^{a}$	$^{q}54.0 \pm 6.4^{b}$	$^{q}66.0 \pm 6.2^{b}$	$^{q}0.0 \pm 0.0^{c}$
α-Tocotrienol	Raw fat	$^{p}132.5 \pm 7.8^{a}$	$^{p}129.0 \pm 8.5^{a}$	$^{p}141.0 \pm 5.7^{a}$	0.0 ± 0.0^{b}
	After Processing	$^{p}129.5 \pm 4.5^{a}$	$^{q}83.0 \pm 4.8^{b}$	$^{q}79.5 \pm 3.5^{b}$	0.0 ± 0.0^{c}
	After cooking	$^{q}109.0 \pm 5.6^{a}$	$^{q}73.5 \pm 4.9^{b}$	$^{q}76.0 \pm 2.6^{b}$	0.0 ± 0.0^{c}
γ-Tocotrienol	Raw fat	$^{p}200.5 \pm 14.8^{b}$	$^{p}234.5 \pm 0.7^{a}$	$^{p}208.0 \pm 15.8^{b}$	0.0 ± 0.0^{c}
	After Processing	$^{p}196.5 \pm 21.7^{ab}$	$^{q}221.0 \pm 3.4^{a}$	$^{p}184.5 \pm 7.9^{b}$	0.0 ± 0.0^{c}
	After cooking	$^{p}184.0 \pm 4.2^{a}$	$^{r}185.5 \pm 6.3^{a}$	$^{p}181.0 \pm 11.3^{a}$	0.0 ± 0.0^{b}
δ-Tocotrienol	Raw fat	$^{p}39.5 \pm 7.7^{b}$	$^{p}63.5 \pm 5.0^{a}$	$^{p}48.5 \pm 3.5b^{b}$	0.0 ± 0.0^{c}
	After Processing	$^{pq}28.5 \pm 3.5^{c}$	$^{p}61.5 \pm 3.5^{a}$	$^{p}48.0 \pm 3.5^{b}$	0.0 ± 0.0^{d}
	After cooking	$^{q}24.0 \pm 4.8^{b}$	$^{p}54.0 \pm 6.8^{a}$	$^{p}42.5 \pm 6.3^{a}$	0.0 ± 0.0^{c}
Total vitamin E	Raw fat	$^{p}502.0 \pm 21.6^{a}$	$^{p}540.5 \pm 18.6^{a}$	$^{p}528.5 \pm 20.3^{a}$	4.0 ± 0.0^{b}
	After Processing	$^{p}480.0 \pm 17.7^{a}$	$^{q}427.0 \pm 16.3^{b}$	$^{q}380.0 \pm 2.1^{c}$	0.0 ± 0.0^{d}
	After cooking	$^{q}423.5 \pm 16.3^{a}$	$^{r}367.0 \pm 2.6^{b}$	$^{r}365.5 \pm 4.8^{b}$	0.0 ± 0.0^{c}

[a-d] Mean values within the same row bearing different superscripts differ significantly ($P< 0.05$)

[p-r] Mean values within the same column bearing different superscripts differ significantly ($P< 0.05$)

RPF35 was significantly decreased from 234.5 to 185.5 μg/g (21% loss) upon cooking.

Gamma-tocotrienol was present at the highest concentration in raw beef burgers substituted with RPF35. Delta-tocotrienol was the most stable component compared to other vitamin E homologues. The changes in the level of δ-tocotrienol in beef burgers formulated with RPF35 and fat blend was not significant ($P>0.05$) after processing (1-3% loss) and even after cooking (12-14% loss). δ-tocotrienol in beef burger formulated with palm fat was decreased from 39.5 to 28.5 μg/g (27%) and not significant ($P>0.05$) after processing.

Raw beef burgers substituted with palm fat recorded the highest vitamin E concentration after processing, although there was a reduction in Vitamin E from 502.0 to 480.0 μg/g (4% decrease). Greater losses due to processing were observed in burgers made with RPF35 (21% decrease) and fat blend (28% decrease).

Carotene content in beef burger

The amount of α-carotene detected in raw beef burgers formulated with palm fat and beef fat accounted for less than 1 μg/g, respectively. This homologue was completely destroyed after cooking for both treatments. Alpha-carotene was more

stable in raw beef burger made with fat blend compared to raw beef burger incorporated with RPF35. Alpha-carotene concentrations in raw beef burger made with red palm fat (RPF35) decreased from 135.3 to 80.8 μg/g (40%) after processing, while α-carotene levels in raw beef burger made with fat blend were decreased by only 27% (from 50.3 to 36.9 μg/g) after processing (Table 3). On the other hand, after cooking, α-carotene concentrations decreased significantly (P<0.05) from 135.3 to 71.7 μg/g (47%) and from 50.3 to 32.0 μg/g (36%), in beef burger made with RPF35 and fat blend, respectively.

After processing, β-carotene concentrations in beef burgers formulated with RPF35 and fat blend decreased significantly (P<0.05) from 239.0 to 109.4 μg/g (54% loss) and from 86.0 to 50.0 μg/g (42% loss). After cooking, β-carotene concentrations in both cooked beef burgers formulated with RPF35 and fat blend decreased significantly (P>0.05) by 62% (239.0 to 90.5 μg/g) and by 48% (86.0 to 44.6 μg/g), respectively. Even though cooked beef burgers made with RPF35 showed the highest percent loss in β-carotene concentrations, the value retained was still high compared to other treatments. The loss (%) of α-carotene and β-carotene for all raw beef burgers was lower compared to cooked beef burgers.

Upon processing, total carotene decreased from 374.3 to 198.7 μg/g (47%) and from 136.3 to 86.9 μg/g (36%), respectively, for beef burger, which had beef fat substituted with RPF35 and fat blend. Total carotene for cooked beef burger with RPF35 and fat blend decreased by 57% (374.3 to 162.2 μg/g) and 43% (136.3 to 76.6 μg/g), respectively compared with unprocessed samples.

Table 3. Effect of processing on carotene content in beef burgers substituted with palm based fats

Carotenes (μg/g)	*Sample*	*Fats*			
		Palm fat	*Red palm fat (RPF35)*	*Red palm fat + palm fat (Fat blend)*	*Beef fat (Control)*
α-Carotene	Raw fat	$< 1.0 \pm 0.0^{c}$	$^{p}135.3 \pm 0.9^{a}$	$^{p}50.3 \pm 0.4^{b}$	$< 1.0 \pm 0.0^{c}$
	Raw burger	$< 1.0 \pm 0.0^{c}$	$^{q}80.8 \pm 0.8^{a}$	$^{q}36.9 \pm 0.4^{b}$	$< 1.0 \pm 0.0^{c}$
	Cooked burger	0.0 ± 0.0^{c}	$^{r}71.7 \pm 2.6^{a}$	$^{r}32.0 \pm 0.2^{b}$	0.0 ± 0.0^{c}
β-Carotene	Raw fat	$< 1.0 \pm 0.0^{c}$	$^{p}239.0 \pm 1.5^{a}$	$^{p}86.0 \pm 1.0^{b}$	$< 1.0 \pm 0.0^{c}$
	Raw burger	$< 1.0 \pm 0.0^{c}$	$^{q}109.4 \pm 0.6^{a}$	$^{q}50.0 \pm 2.8^{b}$	$< 1.0 \pm 0.0^{c}$
	Cooked burger	0.0 ± 0.0^{c}	$^{r}90.5 \pm 1.5^{a}$	$^{q}44.6 \pm 2.7^{b}$	0.0 ± 0.0^{c}
Total Carotene	Raw fat	$< 1.0 \pm 0.0^{c}$	$^{p}374.3 \pm 0.6^{a}$	$^{p}136.3 \pm 1.3^{b}$	$< 1.0 \pm 0.0^{c}$
	Raw burger	$< 1.0 \pm 0.0^{c}$	$^{q}198.7 \pm 0.9^{a}$	$^{q}86.9 \pm 0.6^{b}$	$< 1.0 \pm 0.0^{c}$
	Cooked burger	0.0 ± 0.0^{c}	$^{r}162.2 \pm 4.1^{a}$	$^{r}76.6 \pm 0.4^{b}$	0.0 ± 0.0^{c}

[a-c] Mean values within the same row bearing different superscripts differ significantly (P<0.05)

[p-r] Mean values within the same column bearing different superscripts differ significantly (P<0.05)

Cholesterol content

The cholesterol content of raw beef burgers made with palm based fats ranged from 24.3-26.4 mg/100 g compared to control at 31.8-35.9 mg/100g at 0 month and at 6 months of storage (Table 4). All burger formulations recorded significantly higher cholesterol content upon cooking. This observation may be due to loss of moisture during cooking, as reported by Kowale *et al*. (1991) in mutton meat. All cooked beef burgers which had beef fat substituted with palm based fats also recorded significantly lower cholesterol contents ranging from 34.3-37.2 mg/100g compared to the control (41.8 mg/100 g) at 0 month of storage. After 6 months of storage, all cooked beef burgers recorded significantly higher cholesterol content compared to 0 month. After 6 months of storage, the cholesterol content of cooked beef burgers made with palm based fat ranged from 27.0-27.7 mg/100 g compared to the control at 35.6 mg/100 g.

Sensory evaluation

Table 5 shows the sensory evaluation scores for beef burgers made with palm fat, red palm fat and a palm fat blend. All cooked beef burgers, which had beef fat substituted with palm based fats, received fairly similar scores and were not significantly different (P>0.05) for colour, juiciness and oiliness from the burgers made with beef fat. There were also no significant differences (P>0.05) observed for consumer preferences in springiness, meat taste and overall acceptance for all beef burger formulations, except for RPF35. Even though beef burgers formulated with palm fat received the highest score for juiciness and oiliness, they were not significantly different (P>0.05) from the other treatments.

DISCUSSION

Vitamin E is degraded during processing and cooking of beef burgers. This study showed that both α-tocopherol and a-tocotrienol decreased faster than the two vitamin E homologues (gamma- and delta) in beef burgers upon cooking. This may be due to their chemical structures, which differ from each other in respect to the degree of methylation of the chromane ring. The presence of more methyl substituents in

Table 4. Cholesterol content (mg/100 g) of beef burgers substituted with palm based fats

Sample	*Storage time (month)*	*Cholesterol content (mg/100 g)*			
		Palm fat	*Red palm fat (RPF35)*	*Red palm fat + palm fat (Fat blend)*	*Beef fat (Control)*
Raw burger	0	$^{q}26.39 \pm 0.35^{b}$	$^{q}26.34 \pm 1.60^{b}$	$^{r}24.82 \pm 2.50^{b}$	$^{q}35.92 \pm 1.24^{a}$
	6	$^{q}25.58 \pm 1.18^{b}$	$^{q}25.57 \pm 0.71^{b}$	$^{r}24.31 \pm 1.34^{b}$	$^{r}31.84 \pm 1.24^{a}$
Cooked burger	0	$^{p}34.25 \pm 0.99^{c}$	$^{p}36.34 \pm 1.12^{bc}$	$^{p}37.16 \pm 0.42^{b}$	$^{p}41.80 \pm 0.42^{a}$
	6	$^{q}27.29 \pm 0.56^{b}$	$^{q}26.95 \pm 0.79^{b}$	$^{q}27.65 \pm 0.30^{b}$	$^{q}35.57 \pm 0.10^{a}$

a-b Mean values within the same row bearing different superscripts differ significantly (P<0.05)

p-r Mean values within the same column bearing different superscripts differ significantly (P<0.05)

Table 5. Sensory attributes of cooked beef burgers as influenced by the addition of palm fat and red palm fat (n=100)

Attribute sensory	*Storage time (month)*	*Fats*			
		Palm fat	*Red palm fat (RPF35)*	*Red palm fat + palm fat (Fat blend)*	*Beef fat (Control)*
Colour	0	4.39 ± 0.19^{a}	4.61 ± 0.25^{a}	4.51 ± 0.20^{a}	4.28 ± 0.29^{a}
	6	4.45 ± 0.26^{a}	4.60 ± 0.26^{a}	4.10 ± 0.37^{a}	4.33 ± 0.23^{a}
Springiness	0	4.74 ± 0.31^{a}	4.23 ± 0.13^{b}	4.57 ± 0.26^{ab}	4.86 ± 0.22^{a}
	6	4.70 ± 0.30^{a}	4.17 ± 0.20^{b}	4.47 ± 0.13^{ab}	4.80 ± 0.22^{a}
Juiciness	0	4.46 ± 0.19^{a}	4.21 ± 0.19^{a}	4.44 ± 0.24^{a}	4.32 ± 0.26^{a}
	6	4.23 ± 0.18^{a}	3.98 ± 0.32^{a}	4.40 ± 0.28^{a}	4.37 ± 0.26^{a}
Oiliness	0	4.55 ± 0.21^{a}	4.12 ± 0.23^{a}	4.29 ± 0.18^{a}	4.38 ± 0.20^{a}
	6	4.37 ± 0.27^{a}	4.18 ± 0.18^{a}	4.18 ± 0.19^{a}	4.28 ± 0.20^{a}
Meat taste	0	4.87 ± 0.17^{a}	4.30 ± 0.28^{b}	4.56 ± 0.23^{ab}	4.98 ± 0.28^{a}
	6	4.80 ± 0.27^{a}	4.30 ± 0.20^{b}	4.52 ± 0.23^{ab}	5.00 ± 0.25^{a}
Overall	0	4.94 ± 0.24^{a}	4.35 ± 0.15^{b}	4.57 ± 0.19^{ab}	4.79 ± 0.17^{a}
	6	4.95 ± 0.23^{a}	4.43 ± 0.20^{b}	4.55 ± 0.28^{ab}	4.82 ± 0.21^{ab}

$^{a-b}$ Mean values within the same row bearing different superscripts differ significantly ($P<0.05$)

the phenolic ring of the α-tocopherol and α-tocotrienol does not only enhance its antioxidant activity, but also increases its lipophilic properties, making the α-homolog the most soluble vitamin E in lipid substrate (van Acker, Koymans & Bast, 1996). Cooking may also destroy the haem pigments and provide a source of free iron, which accelerates lipid oxidation in cooked meats (Tichivangana & Morrissey, 1985).

Alpha-, beta- and total carotene degraded faster in cooked beef burger than in processed beef burger substituted with palm-based fat. The results also showed that β-carotene degraded faster compared to α-carotene in beef burger indicating that the latter was more stable upon processing and cooking. Anguelova & Warthesen (2000) also reported that β-carotene degraded at a slower rate than lycopene but faster than α-carotene.

The reduction of cholesterol values shown in Table 3 for the raw and cooked beef burgers made with palm fats were similar with the values reported by some researchers who used other vegetable oils. The use of peanut oil to replace 60% of the beef fat in frankfurters containing 29% fat reduced the cholesterol content by more than 35% (Marquez *et al*., 1989).

Factors that contribute to the differences in cholesterol contents in meat products include total weight loss during cooking, distribution of the weight loss between evaporation loss and drip loss, and the composition of dripping (Hoelscher *et al*., 1987). The total amount of cholesterol in a steak does not increase due to cooking; in fact, it decreases by the

amount that is included in the cooking drip. However, since cooking does substantially reduce the weight of a steak, primarily through removal of water, the cholesterol content of the cooked steak is increased when it is expressed as a percentage of the cooked weight (Rhee *et al*., 1982). A significant increase in the total cholesterol content during heat processing was due to loss of moisture during cooking and agrees with the reports of Rao *et al*. (1992) in buffalo meat.

Based on the sensory evaluation score shown in Table 5, the panel members were not able to differentiate colour, juiciness and oiliness attributes of all burgers. A similar finding was reported by Tan *et al*. (2001) who concluded that the incorporation of palm fats did not produce significant changes on the sensory attributes rating of frankfurters. Alina, Babji & Yusoff (2000) and Tan *et al*. (2001) suggested the potential use of palm oil products, especially palm olein, as fat sources in the production of comminuted meat products.

CONCLUSION

The percentage of losses of α-tocopherol and α-tocotrienol in beef burgers were higher than γ-tocotrienol and δ-tocotrienol upon cooking. Gamma-tocotrienol was more stable in the processed beef burgers followed by γ-tocotrienol. Alpha-carotene and β-carotene degraded faster in cooked beef burgers than in raw beef burgers which had beef fat substituted with palm based fat. Beta-carotene also degraded faster than to α-carotene in beef burgers indicating that the latter was more stable during processing and cooking. Substitution of animal fats with palm based fats decreased the content of cholesterol in processed beef burgers. The taste panel was not able to differentiate colour, juiciness and oiliness attributes between burgers containing palm fats and burgers made with beef fat. This study showed that substitution of animal fats with red palm fat resulted in lower cholesterol levels and higher levels of vitamin E, α- and β-carotene. Addition of palm-based fats resulted in an increase in the nutritional quality, while maintaining the sensory quality of beef burgers so that they are as acceptable to consumers as beef burgers produced with beef fat.

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