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EFFECT OF VEGETABLE OIL BLENDING ON ACRYLAMIDE DURING POTATO DEEP-FRYING

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ABSTRACT

The aim of this study was to determine the effect of various types of deep-frying oil on acrylamide formation in deep-fried potato. Straight cut potato was deep-fried in palm oil (P), coconut oil (C), rice bran oil (RBO), mixture of vegetable oil formula 1 and formula 2 (patent pending) at 150°C and 170°C for 12 minutes as cycle 1 and continuously deep-frying by reusing the same oil as cycle 2. The method used for analysis of acrylamide included solvent extraction and HPLC coupled with DAD. Compared with the control treatment (P), RBO had lowest acrylamide content in cycle 1 at both 150°C and 170°C. However, C showed the highest potential to be used as repeated deep-frying oil at both 150°C and 170°C. The result of this study suggested that the blending of vegetable oil can provide lower acrylamide content in deep-fried food as compared with conventional deep-frying.

Key words: Acrylamide, deep-frying, vegetable oil

INTRODUCTION

Deep-frying is one of the most popular methods in preparation and manufacture of food. Nowadays, the consumption of deep-fried food has been increasing due to the lifestyle of modern consumers in convenience food, snack food, and fast food. Deep-frying is the process that submerging the food in hot oil (150–190°C) (Choe & Min, 2007).

Acrylamide is one of the hazardous substances. It has been classified as carcinogen group 2A, which is probably carcinogenic to humans (International Agency for Research on Cancer, 1994). Acrylamide is a by-product of Maillard reaction which can be formed by the interaction between asparagine amino acid and reducing sugar during heating above 120°C in cooking processes such as baking, frying, and roasting. Majority of food contaminated with acrylamide are French fries, potato chips, coffee, breakfast cereals, and toasts (Bosku, 2011). Apart from acrylamide forming through asparagine and reducing sugar, acrylamide can form from lipid oxidation with the existence of asparagine. By-product of lipid oxidation will produce acrolein which is another substrate for acrylamide formation (Ehling *et al*., 2005; Tripathi *et al*., 2015; Yasuhara *et al*., 2003; Zamora & Hidalgo, 2008).

As a result, using antioxidants is another way to reduce acrylamide content in food. There are three possible roles of antioxidant on acrylamide reduction: radical scavenging activity in lipid oxidation, carbonyl trapping effect, and limitation of sugar degradation in Maillard reaction (Demirok & Kolsarıcı, 2014).

In our modern world, people try to avoid the use of synthetic food additives in food products. Consequently, vegetable oil which have antioxidant properties become another choice for reducing acrylamide. Therefore, the aim of this study was to assess the effect of vegetable oil blending on acrylamide during potato deep-frying.

MATERIALS AND METHODS

Materials

The frozen straight cut 10 mm potato was produced from Lamb Weston BSW Limited Liability Cooperation (Washington, USA). Palm oil was produced from Morakot Industries Public Company Limited (Samut Prakan, Thailand). Rice bran oil was produced from Thai Edible Oil Company Limited

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(Samut Prakan, Thailand). Coconut oil was produced from Patum Vegetable Oil Company Limited (Pathumthani, Thailand). All chemicals and organic solvents were analytical grade and used without further purification.

Frying experiment

A domestic deep-fat fryer 1.2 Liters (Oxygen, China) was used for potato deep-frying. The oil which is used in experiment was palm oil, coconut oil, rice bran oil, blended formula 1, and blended formula 2 (patent pending). Frozen straight cut potato (1 × 1 cm^2 and 8 ± 1 cm long) 250 g was deep-fried in 1.0 L of oil at 150°C and 170°C for 12 minutes and continuously deep-frying another batch by using the used deep-frying oil. After cooling the deep-fried food and deep-frying oil to room temperature, deep-fried food was stored at -20°C for further analysis.

Determination of antioxidant activities of oil

1,1–diphenyl–2–picrylhydrazyl (DPPH) free radical scavenging activity

The antioxidant activities by DPPH free radical scavenging activity was determined based on the method of Chutipanyaporn *et al*., (2014) with some modification. Oil sample was mixed with DMSO (1:1 v/v). Then, 22 µL of prepared sample and 200 µL of 150 µM DPPH reagent dissolved in 95% (v/v) ethanol were mixed and kept in dark for 30 minutes. The reaction was monitored at a wavelength of 520 nm by using a microplate reader (BioTek, USA) and Gen5 data analysis software. Trolox solution (0.01, 0.02, 0.04, 0.08, 0.16, 0.32, and 0.64 mM) was used as a standard. The DPPH free radical scavenging activity was presented as µmol Trolox equivalent (TE) per 100 g of oil.

Oxygen radical absorbance capacity (ORAC)

The antioxidant activities by ORAC was determined based on the method of Ou *et al*. (2001) with some modification. The assay was performed in a 96-well black plate for fluorescence measurement. Oil sample was mixed with DMSO (1:1 v/v). Then, 25 µL of prepared sample was mixed with 150 µL of 40 mM fluorescein solution and incubated at 37°C for 30 minutes. Then 25 µL of 153 mM of AAPH was added. The reaction was monitored at 37°C for 120 minutes by a microplate reader (BioTek, USA) at an excitation wavelength of 485 nm and an emission wavelength of 528 nm with Gen5 data analysis software. Trolox solution (3.125, 6.25, 12.5, 25, 50, and 100 µM) was used as a standard. The oxygen radical absorbance capacity was presented as µmol Trolox equivalent (TE) per 100 g of oil.

Determination of acrylamide content

Acrylamide content was determined based on the method of Khoshnam *et al*. (2010) with some modifications. Homogenized deep-fried potato was defatted with hexane (1:10 v/v). 2.0 g of defatted sample was added with 20 mL of acetone, 100 µL of DI water and sonicated at 40°C for 20 minutes, then filtered through a filter paper, and filtrate solution was evaporated until acetone was dried. MilliQ water (2.0 mL) was added, vortexed and sonicated for 20 minutes for completely dissolving the residue. The sample solution was filtered through a 0.2 µm PTFE membrane filter before injected into HPLC system. The acrylamide content was analyzed by using HPLC equipped with Kinetex 5u C18 100A column (Phenomenex, USA) with dimensions of 250 mm × 4.6 mm × 5 µm and UV-visible detector. Acetonitrile and MilliQ water (20:80) with adjusted pH 3.5 with orthophosphoric acid was used for a mobile phase. The sample was injected 20 µL, set a flow rate 1.0 ml/minute with detection at 225 nm (Run for 10 minutes of each sample). Acrylamide standard (1.5625, 3.125, 6.25, 12.5, 25, 50, 100, and 200 µg/mL) was used as a standard. The acrylamide content was identified by comparing with the acrylamide standard calibration curve.

Statistical analysis

The results were presented as the mean ± standard deviation (SD) and statistically analyzed for analysis of variance using SPSS Statistical Software version 18. The difference between samples were examined by using Duncan's multiple range test and considered to be statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

Determination of antioxidant activities of oil

To determine the antioxidant properties of oil, DPPH free radical scavenging activity and oxygen radical absorbance capacity were used. Between these two assays, the main mechanism are different. DPPH assay is single electron transfer reaction based assay, but for another assay, ORAC, is hydrogen atom transfer reaction based assay (Huang *et al*., 2005). The antioxidant properties of oil were shown in Table 1. For DPPH assay, rice bran oil showed significant highest antioxidant property. Rice bran oil has been reported to be an excellent source of antioxidants, such as Vitamin E (tocopherols and tocotrienols) and γ-oryzanol (Dhavamani *et al*., 2014; Xu & Godber, 1999). On the other hand, in ORAC assay, palm oil showed highest antioxidant property. Palm oil is one of the vegetable oils that

contain Vitamin E and carotenoids (Ribeiro *et al*., 2010; Schroeder *et al*., 2006). Many experts found that carotenoids did not scavenge the DPPH (Kruczek *et al*., 2012; Müller *et al*., 2011). As a result, the antioxidant property of palm oil from ORAC assay was obviously higher that from DPPH assay.

Percent (%) yield

The % yield of deep-fried potato was shown in Table 2. In each deep-frying temperature, there was no significant difference among types of deep-frying-oil and between cycles. The % yield of deep-fried potato at 170°C was lower than that at 150°C. During deep-frying process, heat and moisture transfer are main mechanisms. Water in food will be released in form of steam (Fan *et al*., 2005). In addition, the rate of moisture loss would increase at higher temperature of oil (Manjunatha *et al*., 2014).

Determination of acrylamide content

The acrylamide content of deep-fried potato was summarized in Table 3. At deep-frying temperature 150°C, in cycle 1, deep-fried potato in rice bran oil showed significant lowest acrylamide content followed by blended formula 1, blended formula 2, coconut, and palm oil. While in cycle 2, the lowest acrylamide content was present in deep-fried potato in blended formula 1. Compared between cycle 1 and 2, deep-fried potato in palm oil and rice bran oil showed significant difference between cycles. Only coconut oil showed potential to use as repeated deep-frying oil. There was no significant difference between cycle 1 and 2. This property also presented in deep-fried potato in both blended oils. In case of deep-frying temperature 170°C, acrylamide content of deep-fried potato was higher than that at 150°C with similar trend.

According to Table 1, rice bran oil showed highest antioxidant property in DPPH assay. Hence, deep-fried potato in rice bran oil had lowest acrylamide content. However, the level of acrylamide ascended in cycle 2 since γ-oryzanol prone to degrade during deep-frying from oxidation (Hamid *et al*., 2014; Khuwijitjaru *et al*., 2009). On the other hand, for ORAC assay which can detect carotenoids, palm oil showed highest antioxidant property. There was a study found that carotenoids can play a role as prooxidant when lipid oxidation occurred. Carotenoids will donate hydrogen to lipid peroxy radicals to form β-Carotene peroxy radical, then react with triplet oxygen-producing peroxy radical of carotene peroxide and take hydrogen from lipid molecule. That lipid molecule will transform to lipid radicals and go through further lipid oxidation (Choe & Min, 2009). Because of high

Table 1. DPPH free radical scavenging activity (μmol TE/100 g oil) and oxygen radical absorbance capacity (ORAC) (μmol TE/100 g oil) in different oil samples

Oil	DPPH free radical scavenging activity (μmol TE/100 g oil)	Oxygen radical absorbance capacity (μmol TE/100 g oil)
Palm oil	89.48 ± 0.92[b]	292.11± 8.32[a]
Coconut oil	19.72 ± 2.38[d]	117.47 ± 8.56[d]
Rice bran oil	104.58 ± 2.42[a]	144.42 ± 5.82[b]
Blended formula 1	104.48 ± 5.25[a]	131.39 ± 2.11[c]
Blended formula 2	75.27 ± 3.63[c]	119.20 ± 1.80[d]

[a] Values are mean ± SD (n = 3).
[b] Superscript capital letters indicated the significant difference among oil samples ($p < 0.05$).

Table 2. The % yield of deep-fried potato after deep-frying in different types of oil for 2 cycles at 150°C and 170°C

Type of deep-frying oil	% yield			
	150°C[NS]		170°C[NS]	
	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Palm oil	68.05 ± 0.67	67.24 ± 2.95	61.11 ± 0.56	61.44 ± 0.93
Coconut oil	69.42 ± 2.31	70.16 ± 1.89	60.00 ± 0.89	60.51 ± 1.00
Rice bran oil	67.79 ± 1.86	67.48 ± 0.20	59.76 ± 0.92	60.04 ± 0.96
Blended formula 1	67.10 ± 1.24	66.12 ± 3.12	59.18 ± 0.75	59.94 ± 0.25
Blended formula 2	66.93 ± 1.46	67.78 ± 2.27	60.04 ± 0.25	59.74 ± 0.42

[a] Values are mean ± SD (n = 3).
[b] NS superscript capital letter indicated no significant difference between cycles in each deep-frying temperature ($p \geq 0.05$).

Table 3. Acrylamide content (mg/100g) of deep-fried potato after deep-frying in different types of oil for 2 cycles at 150°C and 170°C

Type of deep-frying oil	Acrylamide content (mg/100 g)			
	150°C		170°C	
	Cycle 1	Cycle 2	Cycle 1^{NS}	Cycle 2
Palm oil	1.64 ± 0.24^{Aa}	2.76 ± 0.34^{Ab}	5.18 ± 0.83	5.79 ± 0.53^{A}
Coconut oil^{NS}	1.07 ± 0.07^{B}	1.31 ± 0.39^{B}	4.74 ± 0.44	4.68 ± 0.16^{B}
Rice bran oil	0.69 ± 0.11^{Ca}	1.23 ± 0.14^{Bb}	3.83 ± 0.22^{a}	4.62 ± 0.24^{Bb}
Blended formula 1^{NS}	0.74 ± 0.04^{C}	0.72 ± 0.02^{C}	4.51 ± 0.79	4.63 ± 0.24^{B}
Blended formula 2^{NS}	0.81 ± 0.06^{C}	0.77 ± 0.14^{C}	4.71 ± 0.13	4.91 ± 0.22^{B}

[a] Values are mean ± SD (n = 3).
[b] Superscript capital letters indicated the significant difference among types of deep-frying oil in each deep-frying condition. Superscript small letters indicated the significant difference between cycles in each deep-frying temperature ($p < 0.05$).
[c] NS superscript at the top of column indicated no significant difference among types of deep-frying-oil in deep-frying condition. NS Superscript at the left side of rows indicated no significant difference between cycles in each deep-frying temperature ($p \geq 0.05$).

amount of carotenoids in palm oil, the acrylamide content of deep-fried potato in palm oil was highest.

In case of coconut oil, it can maintain the level of acrylamide between cycle 1 and cycle 2 due to high of saturated fatty acid, which can resist to oxidation.

CONCLUSION

Acrylamide in deep-fried food is serious problem since it is carcinogenic. Rice bran oil could reduce acrylamide formation due to the presence of anti-oxidants. Furthermore, coconut oil also decreased the acrylamide formation because of its stability. Consequently, the result from this study can be used as information for control the level of acrylamide in deep-fried food.

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