Improving omega-3 fatty acid content in deep-fat fried sweet potato

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**Abstract**

The fatty acid compositions of deep fat fried products depend on type of frying oil used. Improving the levels of essential fatty acids, principally omega-3 fatty acids (linolenic acid), can be effectively achieved by frying in blended oils instead of using a single oil. The aim of this research was to increase linolenic acid content in deep fat fried sweet potato by using blended oils (rice bran oil and canola oil). The fatty acid compositions, tocopherols and gamma-oryzanol contents of rice bran oil (RBO), canola oil (CNO) and blended oils (RBO:CNO-1=90:10 v/v, RBO:CNO-2=80:20 v/v) were determined using HPLC method. The physical properties of the oils were also determined. Thin sticks of sweet potato (8x8x80 mm) were blanched and dried to a moisture content of 67±2%. The dried-blanched sweet potatoes were deep fried in selected blended oil at 170°C for 3.5 min. The fatty acid compositions, tocopherols and gamma-oryzanol contents of the fried product were determined. The results show that the chemical and physical properties of the frying oils depended significantly on the type oils and the blending proportions. The blended oils, RBO:CNO-1 and RBO:CNO-2, had higher linolenic acid content than the rice bran oil (p≤0.05). RBO:CNO-2 contained significantly higher linolenic acid and tocopherols contents, and possessed a smoke point higher than RBO:CNO-1. The sweet potato fried in RBO:CNO-2 had moisture, oil and total solid contents as 29.82%, 7.47% and 92.20%, respectively. It retained proper nutrition values (i.e., linolenic acid 1.33g/100 g extracted oil, linoleic acid 14.61g/100 g extracted oil, δ-tocopherol 2.30 mg/kg extracted oil, γ-tocopherol 64.94 mg/kg extracted oil, α-tocopherol 145.21 mg/kg extracted oil and gamma-oryzanol 871.78 mg/kg extracted oil). This study shows the effectiveness of using the blended oils (RBO:CNO-2; 80:20 v/v) to improve omega-3 fatty acid level and natural antioxidants in fried sweet potato, which is considered to be a healthier snack.

**Introduction**

Frying is a process of cooking and drying through contact with hot oil and it involves simultaneous heat and mass transfer, wherein the heat is transferred from hot oil to the product, water is evaporated and oil is absorbed. Crust formation and browning take place giving the product an attractive golden appearance and crispy mouthfeel (Pahade and Sakhale, 2012). Deep fat frying is a process of immersing food in hot oil with a contact among oil, air and food at a high temperature of 150 to 190°C (Serjouie et al., 2010). Oil uptake is one of the most important quality parameters of fried food, which is incompatible with recent consumer trends towards healthier food and low fat products (Dueik et al., 2012). Fried food is extensively consumed worldwide because of its desirable flavor, golden color and crispy texture (Al-Khusaibi et al., 2012). Fried foods are most widely available in the market as snacks such as French fries, chicken nuggets and patties to name a few. Fried products based on potato are major businesses globally; McDonald’s alone serves about 3.5 MMT of French fries to approximately 33 million customers worldwide every day (Moreira et al., 1999). French fries are a universally popular snack globally. They are appreciated for their taste and texture (van Loon et al., 2007).

Previous studies have demonstrated that diets with high contents of oleic and linolenic acids were associated with low levels of low-density lipoprotein cholesterol in blood plasma and they may reduce the incidence of coronary heart diseases (Nestel et al., 1994; Noakes et al., 1996). Omega-3 fatty acid (linolenic acid) therapy continues to show great promise in primary and, particularly in secondary prevention of cardiovascular diseases (Lavie et al., 2009). The quality of the products from deep fat frying depends not only on the frying conditions but also on the type of oils and foods (Debnath et al., 2012). Rice bran oil (RBO) obtained from the rice milling process is used extensively in Asian countries.
(Orthoefer 1996) and in Thailand, RBO obtained from the brown outer layer of the rice kernel, have been used for generations (Sakunpak et al., 2014). RBO is one of the most nutritious and healthy edible oils because it contains an abundance natural bioactive phytoceuticals such as oryzanol and tocopherols which play important roles in preventing some diseases (Rajam et al., 2005), and also extending the shelf life of fried foods. Oryzanol is an antioxidant compound and is associated with decreasing plasma cholesterol, lowering serum cholesterol and decreasing cholesterol absorption (Patel and Naik, 2004). Tocopherols have been reported to increase the oxidative stability of vegetable oils rich in polyunsaturated fatty acid (PUFA) during frying (Al-Khusaibi et al., 2012). The high oxidative stability of RBO makes it preferred oil for frying and baking applications (Gunstone, 2004; Choudhary and Grover, 2013). Canola oil (CNO) is frying oil with low erucic acid content (<2%) and high smoking point. An important feature of this oil is its high content of linolenic acid (18:3n-3) and linoleic acid (18:2n-6), which are essential dietary fatty acids (Al-Khusaibi et al., 2012). Therefore, CNO oil can potentially be used to blend with RBO to increase the linolenic acid content of fried foods, especially fruit and vegetable which contain less omega-3 fatty acid.

Thai vegetable and fruit chips are snack products generally processed during peak season to add value. These snacks form good alternatives to French fried and nuts, particularly in the Thai diet (Ahromrit and Nema, 2010). Sweet potato is a nutritious food, low in fat and protein, but rich in carbohydrate. It is consumed as boiled roots and has traditionally been fried in Thailand. The sweet potato is easy to grow and cheaper than other crops but it is still poorly utilized. Sweet potato flour is used as a minor ingredient in products such as cakes, breads and noodles. Furthermore, sweet potato noodle is not much preferred by customers because of high cooking loss and moderately elastic qualities (Thao and Noomhorm, 2011). Potato, nut and sesame allergies in children have been reported (Dreborg et al., 1983; Castells et al., 1986; Scott et al., 2010). Cooked potato can be an allergenic food in a selected group of infants with atopic dermatitis reported by Majamaa et al. (2001) and Liliane et al. (2002). A number of foods are responsible for the majority of food-induced allergic reactions in children, namely wheat, soybean, cow’s milk, egg, peanut, and fish (Sampson et al., 1999). Cases of allergy to cooked and fried sweet potatoes have not been reported. Sweet potato is potential as allergy-friendly sweet potato fries. French fries made from sweet potato is an interesting alternative snack to the traditional potato fries. The aim of this research was to increase linolenic acid content and natural antioxidants in deep fat fried sweet potato by using blended oils (RBO and CNO) which is considered as a healthier snack.

Materials and Methods

Materials

The sweet potato tubers (Ipomea batatas Lam) were obtained from a local market in Khon Kaen Province, Thailand. Chemical compositions of the sweet potatoes were analyzed following the methods of AOAC (2000), Nelson (1944) and Somogyi (1952). Color measurements (L*, a* and b* values) was measured by UltraScan XE (Hunter LAB., USA) and the browning index (BI) was calculated (Saricoban and Yilmaz, 2010). Differential scanning calorimetry data (gelatinization temperature and enthalpy) were determined following the methods of Ahromrit et al. (2007).

Canola oil (CNO) and rice bran oil (RBO) were purchased from Tesco Lotus, in Khon Kaen Province, Thailand. Two vegetable oils, namely CNO and RBO were blended to prepare two different oil blends, i.e. RBO:CNO-1=90:10v/v and RBO:CNO-2=80:20v/v.

Preparation of sweet potato strips

The sweet potato tubers were washed, peeled and cut manually into 8 x 8 x 80 mm strips. The strips were blanched in 0.5% aqueous solution of CaCl\(_2\) at 80±3°C for 5 min, drained and dried in a convection oven at 150±3°C for 12 min to reduce the surface moisture (Initial moisture=67±2%wb) for frying.

Frying conditions

A commercial deep fat fryer (model TEF-8DL, ETON STANDARD CO., LTD, Guangdong China) with temperature control of ±1°C was used. The fryer was filled with 4 L of oil and equipped with a 2-kW electric heater. The dried-blanched sweet potato strips to oil ratio was kept at 1.20 w/v and fried at a temperature of 170±2°C for 210 s. The frying started 15 min after the oil temperature reached 185±2°C and stabilized. The strips were removed from the oil and drained for 10 min over a wire screen; when most of the surface oil had been drained off, the chips were transferred to an absorbent towel and .

Physicochemical analyses of fresh oils

The four oil types (CNO, RBO, RBO:CNO-1 and RBO:CNO-2) were analysed for acid (Kardash and Turyan, 2005), iodine and peroxide values using
AOAC (2000) methods. Viscosity was measured by using a Brookfield DV-II+ viscometer with spindle S-1 maintained at 30±1°C (Ali et al., 2014) and smoke was determined according to the Method No. Cc 9a- 48 (AOCS 1998). Color was measured by UltraScan XE (Hunter LAB., USA) and browning index (BI) was calculated (Saricoban and Yilmaz, 2010). The fatty acids was measured by HPLC (Bodoprost and Rosemeyer, 2007), tocopherols and gamma-oryzanol (Chen and Bergman, 2005; Imsanguan et al., 2008) was measured by HPLC (Waters 2690 Alliance, USA).

Physicochemical analyses of fried sweet potatoes

The moisture, oil, and total solid content were measured by AOAC 2000. The oils in fried samples were extracted following the methods of Wasti and Refique (2013). The fatty acids (Bodoprost and Rosemeyer, 2007), tocopherols and gamma-oryzanol (Chen and Bergman, 2005; Imsanguan et al., 2008) of extracted oil from fried sweet potato were measured by HPLC. Color of the fried products was measured by a UltraScan XE (Hunter LAB., USA) and browning index was calculated (Saricoban and Yilmaz, 2010). The maximum cutting force (Ftmax) needed to cut each sample was determined from the maximum peak force expressed as hardness (N) (Tajner-Czopek et al., 2008).

Statistical analysis

Statistical analyses were performed using SPSS statistical software (version 19 for windows) and are presented as mean values with standard deviations. Differences between mean values were established using Duncan’s multiple range tests at a confidence level of 95%.

Results and Discussion

Physicochemical properties of sweet potato

The sweet potato used in this study contained 10.82±0.53%db reducing sugar, 0.31±0.01%db fat content, 3.11±0.02%db crude fiber, 71.13±0.34%wb moisture content, 28.87±0.01%wb total solid content, and 45.46 BI. The gelatinization enthalpy, onset temperature and peak temperature of samples were 3.18±0.19 J/gdb, 85.40±0.02°C and 88.02±0.02°C, respectively.

Physicochemical properties of fresh oils

The colors of oils were different depending on the pigment contained in the materials that it may affect on the appearance and color of fried products. Pigment in rice bran oil is brownish which influenced on the color of blended oil. The results show that the blended oils had lower BI than the RBO (p≤0.05) because CNO was added to blended oil that had lowest BI (Table 1).

<table>
<thead>
<tr>
<th>Type of oils</th>
<th>Browning Index (BI)</th>
<th>Viscosity (mPas)</th>
<th>Smoke point (°C)</th>
<th>Iodine value (g I2/100 g oil)</th>
<th>Peroxide value (meq O2/kg oil)</th>
<th>Acid value (mg KOH/g oil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNO</td>
<td>13.19 ± 0.04</td>
<td>63.33 ± 0.06</td>
<td>256.20 ± 1.69</td>
<td>113.83 ± 2.27</td>
<td>5.38 ± 0.30</td>
<td>0.17 ± 0.01</td>
</tr>
<tr>
<td>RBO</td>
<td>22.39 ± 0.00</td>
<td>68.30 ± 0.00</td>
<td>237.29 ± 2.49</td>
<td>94.53 ± 1.31</td>
<td>2.48 ± 0.79</td>
<td>0.27 ± 0.00</td>
</tr>
<tr>
<td>RBO:CNO-1</td>
<td>20.61 ± 0.02</td>
<td>67.77 ± 0.06</td>
<td>221.17 ± 0.76</td>
<td>99.05 ± 1.10</td>
<td>2.95 ± 0.30</td>
<td>0.29 ± 0.01</td>
</tr>
<tr>
<td>RBO:CNO-2</td>
<td>19.80 ± 0.05</td>
<td>67.37 ± 0.06</td>
<td>233.93 ± 4.31</td>
<td>99.67 ± 0.80</td>
<td>3.31 ± 0.65</td>
<td>0.28 ± 0.01</td>
</tr>
</tbody>
</table>

Different letters (a-d) in the same column are significantly different (p≤0.05)
and RBO:CNO-1. There was no significant difference between the smoke point of RBO:CNO-2 and that of RBO (p>0.05). Smoke point decreases with increase in free fatty acid content thus addition of 10-20% CNO decreased the smoke point of the blended oil.

Iodine value (IV) is an index of the unsaturation, which is the most important analytical characteristic of oil (Choudhary and Grover, 2013) caused by the extent of oxidation and degree of heat treatment received during oil processing (Mandloi et al., 2014). Decrease in the IV is consistent with the decrease in double bonds when oil becomes oxidized. As shown in Table 1, CNO (113.83 gI₂/100g oil) had highest IV and blended oils (99.05-99.57 gI₂/100g oil) had higher IV than RBO (94.53 gI₂/100g oil) (p≤0.05), the more rapid the oil tends to be oxidized, particularly during deep-fat frying.

Peroxide value (PV) is a measurement of oxidation during storage and the freshness of lipid matrix. In addition, it is a useful indicator of the early stages of rancidity occurring under mild condition and it is a measured of the primary lipid oxidation products. Thus, greater PV indicates higher oxidation of the oil (Choudhary and Grover, 2013). Acceptable levels for all oil samples should be below 10 meqO₂/kg oil following Notification of Ministry of Public Health, No.205/2000 (Ministry of Public Health, 2000). The PV values of all fresh oils in this study are below 10 meqO₂/kg oil (Table 1).

Acid value (AV) is a measurement of the free fatty acids in the oil. Normally, fatty acids are found in the triglyceride form, however, during processing the fatty acids may hydrolyze into free fatty acid. The higher the AV, the lower the oil quality is. Acceptable AV levels for all oil are below 0.6 mgKOH/g oil (Ministry of Public Health, Notification of Ministry of Public Health No.205/2000; Choudhary and Grover, 2013). All fresh oils used in this study had AV below 0.6 mgKOH/g oil (Table 1).

The results show that addition of CNO improved linolenic acid and oleic acid contents, but reduced gamma-oryzanol content (p≤0.05). RBO:CNO-1 (1.33%) and RBO:CNO-2 (1.63%), had higher linolenic acid content than that of RBO (0.77%) (p≤0.05). Furthermore, RBO:CNO-2 contained significantly higher linolenic acid than RBO:CNO-1 but oleic acid content was not significantly different (Table 2). It was observed slightly high SFA values occurred in blended oils but there was not significantly comparing with RBO (p>0.05). Improving the levels of essential fatty acids, particularly omega-3 fatty acids (linolenic acid), can be effectively achieved by frying in blended oils instead of using a single oil. An important feature of the blended oil is its high content of linolenic and linoleic acids, which are essential dietary fatty acid and also have positive health impact (Chu and Kung, 1998; Lavie et al., 2009; Al-Khusaibi et al., 2012). The trouble of high PUFA content is the low thermal stability at frying temperatures, which reduces the useful life of the oil for deep fat frying (Warner, 2009). The results revealed that PUFA of RBO:CNO-1 and RBO:CNO-2 were 25.55 and 23.20%, respectively. Thus, RBO:CNO-2 containing less PUFA is chemically more stable, and hence, such this oil is considered to be more suitable for frying of sweet potato.

In the case of tocopherols content, addition of CNO (10-20%) enhanced tocopherols content (Table 3). CNO was a rich source of tocopherols. The antioxidant activity of α-tocopherol, γ-tocopherol has also been reported to be a strong antioxidant for vegetable oil products (KamalEldin and Appelqvist, 2013).
The result of tocopherols content was revealed that a significant increase was observed with an extension of 15% in the case of RBO:CNO-1 and 36% in RBO:CNO-2 comparing with RBO (p<0.05). This gives the RBO:CNO-2 an oxidation stability advantage as a positive effect of tocopherols on qualities of frying oil and fried products is claimed. Warner (2009) showed an effect of tocopherols on the stability of tortilla chips fried with different oils. The blended oils suffered minimal reductions in grammaryzanol. The RBO was a good source of grammaryzanol (1,399.35+33.40 mg/kg); however, the blended oils still maintained high grammaryzanol (1,048.23-1,172.55 mg/kg). This study shows that RBO:CNO-2 can combine good oxidative stability and nutritional quality. Consequently, RBO:CNO-2 contains significantly higher linolenic acid and tocopherol contents, and possesses a smoke point higher than those of RBO:CNO-1. Therefore, RBO:CNO-2 was selected as the frying medium.

Effect of frying oil types on changes of fatty acid compositions in fried sweet potato

The nutrition of oils extracted from fried sweet potato deep fried in four oils at 170°C for 3.5 min are shown in Table 4. The fatty acid compositions, tocopherols and grammaryzanol of deep fat fried products depend on type of frying oil used. Improving the levels of linolenic acid, δ-tocopherol, γ-tocopherol and α-tocopherol can be effectively achieved by frying in blended oil: RBO:CNO-2 instead of using a single oil: RBO. Several researchers

### Table 3. Concentrations of tocopherols and grammaryzanol in the fresh oils

<table>
<thead>
<tr>
<th>Type of oils</th>
<th>Δ (mg/kg&lt;sub&gt;α&lt;/sub&gt;)</th>
<th>Y (mg/kg&lt;sub&gt;α&lt;/sub&gt;)</th>
<th>α (mg/kg&lt;sub&gt;α&lt;/sub&gt;)</th>
<th>γ-grammaryzanol (mg/kg&lt;sub&gt;α&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNO</td>
<td>11.23 ± 1.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>301.05 ± 2.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>265.23 ± 3.70&lt;sup&gt;b&lt;/sup&gt;</td>
<td>ND</td>
</tr>
<tr>
<td>RBO</td>
<td>3.75 ± 0.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>67.96 ± 0.74&lt;sup&gt;b&lt;/sup&gt;</td>
<td>147.73 ± 6.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.399 ± 33.40&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>RBO:CNO-1</td>
<td>3.96 ± 0.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>90.43 ± 0.75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>157.13 ± 5.79&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.172.56 ± 6.79&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>RBO:CNO-2</td>
<td>4.91 ± 0.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>115.58 ± 2.53&lt;sup&gt;b&lt;/sup&gt;</td>
<td>177.49 ± 6.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.048.23 ± 21.74&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Different letters (a-d) in the same column are significantly different (p≤0.05)

ND = Not detected

### Table 4. Relevant nutritional constituents of oils extracted from fried sweet potato, deep fried in the fresh oils at 170°C for 3.5 min

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>CNO</th>
<th>RBO</th>
<th>RBO:CNO-1</th>
<th>RBO:CNO-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linolenic acid&lt;sup&gt;**&lt;/sup&gt;</td>
<td>5.02 ± 0.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.64 ± 0.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.03 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.33 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Linoleic acid&lt;sup&gt;**&lt;/sup&gt;</td>
<td>5.75 ± 0.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.80 ± 1.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.45 ± 0.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.61 ± 1.07&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oleic acid&lt;sup&gt;**&lt;/sup&gt;</td>
<td>18.73 ± 0.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.08 ± 0.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.56 ± 0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.81 ± 1.13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Palmitic acid&lt;sup&gt;**&lt;/sup&gt;</td>
<td>1.32 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.92 ± 0.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.11 ± 0.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.79 ± 0.36&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Stearic acid&lt;sup&gt;**&lt;/sup&gt;</td>
<td>0.45 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.56 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.23 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.67 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>δ-tocopherol&lt;sup&gt;***&lt;/sup&gt;</td>
<td>5.98 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.13 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.31 ± 0.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.30 ± 0.31b&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>γ-tocopherol</td>
<td>227.77 ± 0.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.02 ± 0.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.15 ± 1.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>64.54 ± 0.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>α-tocopherol&lt;sup&gt;***&lt;/sup&gt;</td>
<td>187.71 ± 2.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>128.30 ± 0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>146.66 ± 3.82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>145.21 ± 1.92&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grammaryzanol&lt;sup&gt;***&lt;/sup&gt;</td>
<td>ND</td>
<td>1,251.00 ± 0.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>849.68 ± 0.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>871.78 ± 28.53&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Different letters (a-d) in the same row are significantly different (p≤0.05)

ND = Not detected

** unit = g/100g<sub>extracted oil</sub>  *** unit mg/kg<sub>extracted oil</sub>
have investigated the possibility of using canola oil blended with other vegetable oils (Al-Khusaibi et al., 2012; Farhoosh and Kenari, 2009). Increase in the CNO ratio of blended frying oil is consistent with the increase in linolenic acid and tocopherols contents of the fried sweet potatoes. The present of CNO (10-20%) in frying medium did not influence on gramma-oryzanol content of the fried product (p>0.05). Sweet potatoes fried in RBO:CNO-2 had higher essential fatty acids and tocopherols contents than those of sweet potatoes fried in RBO:CNO-1. This is in agreement with Sebedio et al. (1990) who reported that the bulk oil and oil absorbed by French fries were similar in fatty acid composition. Moreover, Sweet potatoes fried in RBO:CNO-2 remained a rich of gramma-oryzanol content (871.78 ± 28.53 mg/kg) which is considered as a healthier snack.

Comparison of selected quality attributes of sweet potato fries in RBO:CNO-2 and commercial French fries

Selected attributes of commercial French fries and fried sweet potatoes (RBO:CNO-2 at 170°C for 3.5 min) are shown in Table 5. There was no significant difference between moisture content of the fried sweet potato and that of the commercial French fries (p>0.05) but it showed significantly lower oil content (p<0.05). Available fried sweet potatoes in the market (Thailand) are the batter-coated products which contained higher oil contents than that of fried sweet potato and commercial French fries (data not shown). Color and texture characteristics of local products (data not shown) also varied due to frying process, oil quality and coating method. Many studies have been reported in relation to types of raw material, frying oil, coating and frying conditions with oil absorption, quality characteristics of fried products (van Loon et al.,2007; Tajner-Czopek et al.,2008; Ahromrit and Nema, 2010; Pahade and Sakhale, 2012). Crust of the fried sweet potatoes was also developed, which reduce oil uptake. Crust formation is a result of several changes (i.e. physical changes, gelatinization and protein denaturation) (Dana and Saguy, 2006). The fried sweet potato had higher hardness value and browning index than the commercial French fries because the nature of sweet potatoes and potatoes was different (i.e. color, reducing sugar, starch content, crude fibre) and frying conditions.

Conclusion

This study examined the compositions of blended frying oils and changes occurring in oil extracted from sweet potato deep fried in the oils at 170°C for 3.5 min. The blended oil RBO:CNO-2 contained significantly higher linolenic acid and tocopherols contents, which is considered to be very desirable from a health point of view. Moreover, this oil contained less PUFA than that of RBO:CNO-1 that RBO:CNO-2 can be considered as value-added oils for sweet potato fries. The smoke point of RBO:CNO-2 was higher than that of RBO:CNO-1; indicating frying stability and the useful life of the oil for deep fat frying. Thus, blended frying oils can combine good stability with significant nutritional benefits over individual oils. Sweet potatoes deep fried in RBO:CNO-2 had higher linolenic acid (omega-3 fatty acid), oleic acid, tocopherols contents than those of products fried in RBO:CNO-1 and RBO. Higher level of tocopherols in the fried product with RBO:CNO-2 gives the benefit by minimizing the formation of degradation of products. Moreover, it was also rich in gamma-oryzanol content which made the fried product a healthier snack. It was noted omega-3 fatty acid content in fried sweet potatoes can be improved by using the blended frying oil: RBO:CNO-2.

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