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Influence of rendering temperature on quality of rendered chicken oil from visceral fat tissue

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Abstract

The objective of the present work was to determine the influence of rendering temperature on the quality of rendered chicken oil from visceral fat tissue. The visceral fat tissue was extracted using a dry rendering method at 80, 100, and 120°C, then the rendered chicken oil was sampled to determine their quality parameters including peroxide value (PV), iodine value (IV), free fatty acid (FFA), and fatty acid profile. Results showed that the chicken oil rendered at 120°C had higher yield than those rendered at 80 and 100°C. For the colour values in terms of L*, a*, and b* value, it was found that the chicken oil rendered at 80°C had the highest L* value (lightness) compared to 100 and 120°C ($p \leq 0.05$). The a* value (redness) showed no significant difference at all rendering temperatures ($p > 0.05$). Moreover, the rendering temperature at 120°C had higher b* value (yellowness) than 80 and 100°C. The chicken oil rendered at 120°C had the lowest iodine value (IV) compared with 80 and 100°C. The free fatty acid (FFA) of chicken oil rendered at 120°C was higher than 100 and 80°C ($p \leq 0.05$). The PV of chicken oil rendered at 80, 100, and 120°C were 5.85, 8.40, and 7.97 meq/kg, respectively. The rendering temperature at 120°C had the highest TBARS followed by 100 and 80°C, respectively. The content of unsaturated fatty acid was 64.26 - 65.66 g/100 g. The most abundant fatty acids found were oleic acid (43.06 - 43.94 g/100 g), followed by palmitic acid (23.53 - 24.27 g/100 g), and linoleic acid (14.85 - 15.40 g/100 g).

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Introduction

The production of broiler meat in Thailand increased from 1.60 million tons in 2020 to 1.66 million tons (3.30% increase) in 2021 (DTN, 2021). By-products from the poultry industry such as head, feather, blood, viscera, skin, and fat are 37% (Lin and Tan, 2017). The skin and fat tissues are approximately 6 - 8%. Chicken fat can be used as inedible and edible fats, which can be used for cooking (Lin, 1998) and biodiesel fuel (Ding *et al*., 2007). Additionally, unsaturated fatty acids are a major fat found in chicken oil (Pereira *et al*., 1977), and saturated fatty acid content in chicken oil is higher than vegetable oil (Lee and Foglia, 2000). In the food industry, chicken fat is extracted from chicken fat tissue such as skin and abdominal fat tissue (Li and Bi, 2009) using the rendering method. Rendering is the processing of high fat raw material into purified fats like lard or tallow. There are many types of methods such as frying, wet rendering, and dry rendering (Sheu and Chen, 2002). In the dry rendering process, the fat tissue is heated in the absence of water at the appropriate temperature. Rendering temperature is a major factor on the rendering efficiency and quality of the oil. Cheng *et al.* (1993) reported that the yield of chicken oil increased as the rendering temperature increased. Moreover, oil extraction by microwave has been studied in many studies. A few studies on the dry rendering of chicken fat from visceral fat tissue have been conducted in recent years. There were studies on skin fat and rendering temperatures ranging from 40 - 105°C (Pereira *et al*., 1976; Sakunde *et al*., 2020). Therefore, it is necessary to determine the appropriate rendering temperature. The present work thus aimed to determine the influence of rendering temperature on the quality of rendered chicken oil from visceral fat tissue. Additionally, the chemical quality and fatty acid profile of rendered chicken oil were also monitored.

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Materials and methods

Materials and chemicals

The frozen broiler visceral fat tissue (Frozen Meat Barn Co., Ltd., Songkhla, Thailand) was ground, packaged, and stored at -18°C. All the chemicals used were of analytical grade, such as sodium thiosulphate, *p*-anisidine, and thiobarbituric acid, and purchased from Sigma-Aldrich (Germany). Chloroform and sodium hydroxide were purchased from RCI Labscan (Thailand). Potassium iodine was purchased from Ajax Finechem (New Zealand).

Extraction of rendered chicken oil

The fat tissues were thawed at room temperature for 3 h. The oil extraction of broiler abdominal fat tissues was performed using the dry rendering process carried out at various temperatures (80, 100, and 120°C) for 20 min. The skin slurry was filtered to remove the solids.

Determination of rendering yield

The rendering yield of chicken oil was determined according to Sheu and Chen (2002) using Eq. 1:

$$\text{Yield (\%)} = (\text{weight of rendered chicken fat} / \text{weight of chicken skin}) \times 100 \quad \text{(Eq. 1)}$$

Determination of rendered chicken oil quality
Colour

The chicken oil (50 mL) at 25°C was carried out to determine the colour values (L*, a*, and b*) using a colorimeter (Hunter Lab Color Flex EZ, USA). The L* value (lightness) indicates the darkness (0) or brightness (100), a* value indicates the greenness (-a*) or redness (+a*), and b* value indicates the blueness (-b*) or yellowness (+b*) of the oil.

Iodine, free fatty acid, and peroxide values

Iodine value (IV) was determined following the Wijs method (AOCS, 2004). Approximately, 3.00 g of chicken oil was mixed with 20 mL of cyclohexane and 25 mL of Wijs solution. The mixture was continuously shaken for 30 min, then mixed with 20 mL of aqueous KI solution (15%, v/v) and 100 mL of water. Afterwards, the mixture was titrated with 0.1 N of sodium thiosulphate using starch solution as an indicator.

Free fatty acid value (FFA) was measured following the AOAC (2000). Approximately, 7.00 g of chicken oil was mixed with 2 mL of phenolphthalein solution and a few drops of 0.1 M NaOH; 50 mL of ethanol was then added to the mixture, and shaken until a permanent faint pink solution remained, which was then titrated with 0.25 N NaOH.

Peroxide value (PV) was measured following the AOAC (2000). Approximately, 5.00 g of chicken oil was dissolved in 30 mL of acetic acid-chloroform (3:2) solution; the saturated KI solution and distilled water were then added and shaken. The mixture was titrated with 0.01 N sodium thiosulphate using starch solution as an indicator.

Thiobarbituric acid reactive substances (TBARS)

The determination of TBARS was determined according to Qiu *et al*. (2015). Briefly, 0.1 mL of the oil was mixed with 5 mL of thiobarbituric acid (TBA) solution, and heated in a water bath at 95°C for 10 min. Thereafter, the samples were allowed to cool down to room temperature for 10 min, and centrifuged at 10,000 *g* for 15 min. The absorbance of the supernatant was measured at 532 nm using a UV spectrophotometer.

Fatty acid profile

The fatty acid profile of chicken oil was determined using a GC system (AOAC,1997). The flame ionisation detection (FID) system was used. The oil sample (1 µL) was injected with a split ratio of 1:50. The carrier gas was Helium (1 mL/min), and controlled at 103.4 kPa, while hydrogen and air were used for FID, and held at 275.6 kPa. Identification of fatty acids in the oil was performed by comparing the retention times of reference standards.

Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA), and the differences between means were evaluated by Duncan's multiple range test.

Results and discussion

Rendering yield

The rendering yields of chicken oil at 80, 100, and 120°C are displayed in Table 1. An increase in the yield of chicken oil was found with an increase in

Table 1. Rendering yields of chicken oil at different extraction temperatures.

Temperature (°C)	Yield (%)
80	70.36 ± 0.06[c]
100	72.83 ± 0.03[b]
120	73.08 ± 0.04[a]

Values are mean ± standard deviation. Means followed by different lowercase superscripts in the same column are significantly different ($p \leq 0.05$).

the rendering temperature. The oil yield at 120°C was higher than those rendered at 80 and 100°C. The result indicated that the rendering process with high temperatures could improve the solubility of lipids. Additionally, the rendering process at high temperatures could recover the high amount of animal fat, which broke the adipocyte membrane, and released the oil (Piette *et al*., 2001). Efthymiopoulos *et al.* (2018) stated that the oil extraction process with high temperatures can destroy the cohesive and adhesive interactions between oil, oil-matrix molecules, and molecules. The diffusion rate of the lipids can be increased. Cheng *et al*. (1993) reported that the yield of oil extracted from abdominal fat tissue increased when the rendering temperature increased.

Quality of rendered chicken oil

Colour

The colour (L*, a*, and b*) of rendered chicken oil at different extraction temperatures is shown in Table 2. It was found that the chicken oil rendered at 80°C had the highest L* value (lightness) compared with 100 and 120°C ($p \leq 0.05$). There was no significant difference in the a* value (redness) at all rendering temperatures ($p > 0.05$). Moreover, the rendering temperature at 120°C had higher b* value (yellowness) than 80 and 100°C. The results indicated that high rendering temperature affected the colour of chicken oil. Sheu and Chen (2002) reported that high temperatures stimulated the Maillard browning reaction and destruction of pigment. The significant differences in oil colour might have been due to the Maillard browning reaction during the rendering process. The oxidative breakdown products of fatty acids reacted with amino groups of the polar head of phospholipids (Zhang *et al.*, 2013). Moreover, the temperature is the primary factor that induces the Maillard browning reaction in foods (Martins *et al*., 2000).

Table 2. Colour (L*, a*, and b*) of rendered chicken oil at different extraction temperatures.

Temperature (°C)	Colour value		
	L*	a*	b*
80	5.04 ± 0.29[a]	0.57 ± 0.02[a]	10.93 ± 0.08[a]
100	2.32 ± 0.26[b]	0.59 ± 0.05[a]	10.92 ± 0.26[a]
120	2.47 ± 0.43[b]	0.64 ± 0.36[a]	10.42 ± 0.24[b]

Values are mean ± standard deviation. Means followed by different lowercase superscripts in the same column are significantly different ($p \leq 0.05$).

Iodine, free fatty acid, and peroxide values

The iodine values (IV), free fatty acids (FFA), and peroxide values (PV) of rendered chicken oil at different extraction temperatures are shown in Table 3. The results found that the chicken oil rendered at 120°C had the lowest iodine value (IV) compared with 80 and 100°C. The IV indicates the degree of unsaturated fats and oils (Naz *et al*., 2005). It was observed that the IV decreased with increasing rendering temperature. A decrease in IV indicated that the number of double bonds decreased, and lipid oxidation occurred. This was due to the double bonds being destroyed by oxidation and polymerisation during heat treatment (Cuesta *et al*., 1991). In addition, high IV indicates chemically unstable fats due to the double bond in unsaturated fatty acids that are reactive to oxidation (Shin *et al*., 2019). Murphy (2012) reported that extraction temperature affected IV; low temperature yields high IV of oil.

The FFA of chicken oil rendered at 120°C was higher than 100 and 80°C ($p \leq 0.05$). High rendering temperature might have induced lipid degradation resulting in the formation of free fatty acids. The ester bond of triacylglycerol is destroyed by lipase; these reactions can be stimulated by high temperatures. The FFA was high in the oil, and might have caused

Table 3. Iodine values, free fatty acids, and peroxide values of rendered chicken oil at different extraction temperatures.

Temperature (°C)	Iodine value (g I_2/100 g oil)	Free fatty acid (mg KOH/g oil)	Peroxide value (meq O_2/kg oil)
80	23.31 ± 0.80[a]	1.10 ± 0.10[b]	5.85 ± 0.08[b]
100	23.50 ± 1.61[a]	1.23 ± 0.06[b]	8.40 ± 0.60[a]
120	20.85 ± 0.77[b]	1.43 ± 0.12[a]	7.97 ± 0.43[a]

Values are mean ± standard deviation. Means followed by different lowercase superscripts in the same column are significantly different ($p \leq 0.05$).

further oxidation, and led to the development of an off-taste and flavour in the oil (Chew and Nyam, 2020). Moreover, the high rendering temperature may lead to lipid oxidation and produce free fatty acids and free radicals, which can develop into volatile compounds (Suseno *et al*., 2015). Zhuang *et al*. (2022) reported that with the increase in heating temperature, the content of saturated fatty acids also increased. The formation of lipid oxidation in oil significantly increased with the increase in temperature (100 - 200°C).

Peroxide value (PV) refers to the rancidity of oil through the initiation product of lipid oxidation. Results showed that the PV of chicken oil rendered at 80, 100, and 120°C were 5.85, 8.40, and 7.97 meq O_2/kg oil, respectively. This indicated that the rendering temperature significantly influenced the PV of chicken oil ($p \leq 0.05$). The PV increased with an increase in the temperature of the rendering process. This result might have been due to heat stimulating lipid oxidation; free radicals react with oxygen to generate peroxide compounds. Furthermore, water molecules move quickly when extraction temperature increases; the hexagonal structure forms and releases the trapped oxygen. Suseno *et al*. (2015) reported that the PV increased when the extraction temperature increased, and the critical point occurred at 100°C. Piette *et al*. (2001) reported that the lipid oxidation rate increased with increasing extraction temperature. The fat extracted at 50 and 80°C had PV lower than the fat extracted at 100 - 105°C.

TBARS

Lipid peroxidation is the reaction of oxygen with unsaturated fatty acids, which produces a variety of oxidation products such as hydroperoxides (LOOH), malondialdehyde (MDA), propanal, and hexanal (Ayala *et al*., 2014). The thiobarbituric acid reactive substances (TBARS) is a method for the determination of lipid peroxidation. The TBARS of rendered chicken oil through various renderings are shown in Table 4. It was found that rendering temperature at 120°C had the highest TBARS followed by 100 and 80°C, respectively. It was indicated that increasing rendering temperature increased the lipid oxidation. The utilisation of a rendering temperature of 120°C negatively affected the quality of rendered chicken oil. This might have been due to chicken fat being exposed to heat at high temperatures and the presence of oxygen, where lipid oxidation occurred to generate the oxidation compounds (Labropoulos *et al.*, 2013). Furthermore, lipid oxidation and malondialdehyde (MDA) formation can be affected by the quantity and degree of fatty acids. Zhuang *et al.* (2022) reported that the MDA content increased with an increase in temperature. The oil heated at 150°C had higher MDA content than 100°C.

Table 4. TBARS values of rendered chicken oil at different extraction temperatures.

Temperature (°C)	TBARS (mg MDA/kg)
80	0.56 ± 0.01[c]
100	0.64 ± 0.03[b]
120	0.82 ± 0.06[a]

Values are mean ± standard deviation. Means followed by different lowercase superscripts in the same column are significantly different ($p \leq 0.05$).

Fatty acid profile

The fatty acid profiling was carried out for the rendered chicken oil at 80, 100, and 120°C (Table 5). It was found that the rendered chicken oil (all treatments) contained unsaturated fatty acids higher than saturated fatty acids. The oxidative stability of

the oil is related to the fatty acid composition in oil; high proportion of polyunsaturated fatty acids can lead to rapid lipid oxidation (Symoniuk *et al*., 2019). Results showed that the content of saturated fatty acids was 29.74 - 30.86 g/100 g. The content of unsaturated fatty acids was 64.26 - 65.66 g/100 g. The most abundant fatty acids found were oleic acid (43.06 - 43.94 g/100 g), followed by palmitic acid (23.53 - 24.27 g/100 g), and linoleic acid (14.85 - 15.40 g/100 g). Meeker (2006) reported that poultry fat contained high unsaturated fatty acids including oleic acid (40%), linoleic acid (19%), and saturated fatty acids including palmitic acid (22.5%) and stearic acid (5.5%). Saldarriaga *et al.* (2020) reported that chicken fat had higher content of unsaturated fat (65.5%) than saturated fat (30.3%). Furthermore, the results in the present work found that the contents of palmitic and stearic acids increased with increasing rendering temperature. While palmitoleic, oleic, and linoleic acids decreased with increasing rendering temperature. The unsaturated fatty acid including *cis*-11-eicosenoic and arachidonic acids of rendered chicken oil seemed to increase when the rendering temperature increased. This might have been due to the hydrolysis of fatty acids at high extraction temperatures, which can cause changes in fatty acid composition (Suseno *et al*., 2015). Zhuang *et al*. (2022) reported that the heating process changed the fatty acid content of oil, which mainly affected their polyunsaturated fatty acid fractions. Moreover, with the increase in heating temperature, the content of saturated fatty acids also increased. Furthermore, unsaturated fatty acids through fission and oxidation generated saturated and monounsaturated fatty acids, which coincided with oxidative product formation (Li *et al*., 2017).

Table 5. Fatty acid profiles of rendered chicken oil at different rendering temperatures.

Fatty acid	Amount (g/100 g)		
	80°C	100°C	120°C
Saturated fatty acid			
Lauric acid (C12:0)^{ns}	0.36 ± 0.02	0.34 ± 0.04	0.35 ± 0.03
Myristic acid (C14:0)^{ns}	0.81 ± 0.02	0.78 ± 0.04	0.82 ± 0.06
Palmitic acid (C16:0)	23.53 ± 0.03^{b}	23.57 ± 0.07^{b}	24.27 ± 0.02^{a}
Stearic acid (C18:0)	5.04 ± 0.04^{b}	5.05 ± 0.01^{b}	5.42 ± 0.02^{a}
Total saturated fatty acid	29.74 ± 0.08^{b}	29.74 ± 0.06^{b}	30.86 ± 0.07^{a}
Unsaturated fatty acid			
Palmitoleic acid (C16:1)	4.68 ± 0.07^{a}	4.50 ± 0.08^{b}	4.46 ± 0.03^{b}
Oleic acid (C18:1)	43.75 ± 0.01^{a}	43.94 ± 0.16^{a}	43.06 ± 0.11^{b}
Linoleic acid (C18:2)	15.40 ± 0.04^{a}	15.08 ± 0.07^{b}	14.85 ± 0.04^{c}
Gamma-Linolenic acid (C18:3)^{ns}	0.21 ± 0.03	0.20 ± 0.01	0.21 ± 0.04
Alpha Linolenic acid (ALA) (C18:3)^{ns}	0.74 ± 0.04	0.73 ± 0.03	0.74 ± 0.02
cis-11-Eicosenoic acid (C20:1)^{ns}	0.45 ± 0.05	0.46 ± 0.02	0.47 ± 0.01
cis-11,14-Eicosadienoic acid (C20:2)^{ns}	0.16 ± 0.02	0.17 ± 0.03	0.16 ± 0.01
cis-8,11,14-Eicosatrienoic acid (C20:3)^{ns}	0.10 ± 0.02	0.13 ± 0.03	0.11 ± 0.01
Arachidonic acid (C20:4)^{ns}	0.17 ± 0.01	0.18 ± 0.03	0.20 ± 0.02
Total unsaturated fatty acid	65.66 ± 0.13^{a}	65.39 ± 0.10^{b}	64.26 ± 0.02^{c}

Values are mean ± standard deviation. Means followed by different lowercase superscripts in the same column are significantly different ($p \leq 0.05$). ^{ns} indicate non-significant difference ($p > 0.05$).

Conclusion

Significant changes in chicken oil qualities were affected by the rendering temperature. It was concluded that the high rendering temperature could produce higher yield of chicken oil from abdominal fat tissue. The yield of chicken oil obtained through 120°C was higher than 100 and 80°C. The chicken oil obtained using dry rendering at 120°C had significantly higher free fatty acid (FFA), peroxide

value (PV), and TBARS, whereas lower iodine value (IV) did not result in an increase. The most abundant fatty acids found in all treatments were unsaturated fatty acids including oleic and linoleic acids. Further studies should focus on the changes in rendered oil qualities during storage.

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