Beyond the Recycle of Raw Chicken Fat

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Abstract: The wasted raw fat of chicken was extracted and recrystallized with slowly stir at various cooling temperature to get a clear out-looking and liquid chicken oil. The recovery percentage of liquid chicken oil is about 100, 87, 78, 49 and 0% at 25, 21, 17, 13 and 9°C. The chicken liquid oil has a new composition of fatty acids than the original oil (p < 0.05) and has a safety range in acid value and peroxide value. The fatty acid ratio of the liquid chicken oil obtained at 13°C to be 1:1.6:0.9 (SFA: MUFA: PUFA) is believed to be good dietary oil. The concept of ideal fatty acid ratio comes from Hayes’ report (1:1.5:1, SFA: MUFA: PUFA) which is also found to mimic to human lipid fatty acid ratio. Statistically evaluation on Hayes’ basis, it showed that the liquid chicken oil scored even better than the extra virgin olive oil. In conclusion, this study not only first open a new gate for the recycle of global raw chicken fat to a dietary oil but also give an evidence that the chicken oil seems more compatible to human lipid on the hypothetic basis of biocompatibility.

Key words: chicken fat, liquid chicken oil, oil separation, fatty acid ratio

1 Introduction

Chicken is the most commonly consumed meat in the world, with daily global consumption of chickens estimated to be 200 million head or more. However, chicken fat is discarded before reaching market, and usually wasted as forage. In fact, 14 million tons of chicken fat is reported to be wasted annually¹. Therefore, it is very important from perspectives of both the environment and the food industry to recycle or better utilize this raw chicken fat.

Dietary fat intake is considered to be a critical factor in the risk of heart disease. It is believed that circulation fatty acid⁵ or FA composition in adipose tissue⁶ is highly associated with progression of cardiovascular disease (CVD). The various FA compositions also have a different effect on the relative composition of gut microbiota⁷,⁸. In general, saturated fat and artificial trans-fats generated from vegetable oils through the hydrogenation process are more resistant to oxidation and have longer self-life. However, these two fats have been found to have adverse effects on human lipoprotein patterns⁹,¹⁰. Therefore, red meat rich in cholesterol and saturated fatty acid, is considered to be not favorable for human health. However, the FA composition and nutritional quality of beef has been improvement by feeding strategy¹¹,¹². Owing to animal fat, the nutritive value of chicken oil for human health is seldom investigated.

Animal fats, which are mostly saturated, stand up better to high heat and last longer than vegetable oils. Reduced oxidation in animal fats also means they are less susceptible to protein oxidation, and contain fewer toxins and carcinogens than those generated by using vegetable oil alone¹³–¹⁵. In fact, prior to the 20th century human consumption of animal oils was extremely common, and animal oils such as butter, lard and tallow are still frequently used for baking or as cooking oil in many places. However, chicken oil is not commonly used in baking or cooking. Moreover, little research has been published on the successful recycling of raw chicken fat for use as dietary oil, or its possible health advantages.

Many efforts have been made to reuse chicken fat by converting it into a better oil such as the acetone method, or harvesting liquid and solid chicken oil through cold precipitation¹⁶,¹⁷. Nevertheless, these studies were not able to find changes of FA in the extracted chicken oil or health benefits in the consumption of chicken oil.

Traditionally, chicken oil as an animal fat appears flocculent at ambient temperatures. It is rumored that flocculent fats will lead to clotting of blood vessels, and they are frequently perceived as being of poor quality. Ironically, chicken is the most highly consumed meat in the world,
and traditional Chinese medicine advocates oily chicken broth as an excellent functional food for healing. Therefore, it would be highly worthwhile to find a method to improve the appearance of chicken oil, and optimize its FA proportion so that it can be successfully adopted as a dietary oil.

In this study, a simple and efficient recrystallization of chicken oil was achieved to obtain a liquid dietary oil. The modified FAs of this liquid chicken oil were evaluated, and scored and discussed on the basis of the Hayes ratio, an average ideal oil ratio, and human lipid referenced ratio. This is the first time such a process has been evaluated, and patents relating to aspects of this study have been filed and approved for the first time in Taiwan.

2 Materials and experiment

2.1 Preparation of chicken oil

The raw fat of chicken (from Kai-Shin Food Co. Ltd., Yunlin, Taiwan) was boiled or fried, then filtered to produce crude chicken oil. This crude oil was vacuumed to remove the moisture or water at 76°C for 60 minutes, yielding a dry oil for the study.

Fifty liters of dry oil were put in stainless steel tanks, and stirred (≤ 5 rpm) with a silicon gasket propeller at cold room. The cooling speed was 1°C/hr or less, while it was cooling to the setting temperature (25, 21, 17, 13, 9°C, respectively). The dry oil was left to stand for 24 hours or longer to ensure stable flocculate precipitate. The liquid oil (α-form) and solid oil (β-form) were recovered with a nylon filter 200#.

2.2 Fatty acid analysis

The fatty acids of the chicken oils harvested in the above process were analyzed along with extra virgin olive oil (The Carrier Four Inc., Taipei, Taiwan), and camellia oil (The God-Ben Oil Inc., Yunlin, Taiwan), according to the FDA Taiwan’s suggested method (NFS-0961800343), using an HP-88 column (Agilent, 100 m × 0.25 mm I.D., 0.2 μm film thickness) with an FID detector, by Shimatzu GC Model-3300.

2.3 Acid value test

The acid values of the liquid chicken oil, the extra virgin olive oil, and the camellia oil, were measured according to the method No. 969.17 as AOAC suggested, titrated with KOH, and measured.

2.4 Iodine value test

The iodine values of the chicken oil, the extra virgin olive oil, and the camellia oil, were measured according to the Wijas as AOAC method No. 993.20 suggested, using iodine chloride and back-titration with sodium thiosulphate using starch T.S. as the indicator.

2.5 Peroxide value test

The peroxide values of the chicken oil, the extra virgin olive oil, and the camellia oil, were determined according to the method No. 965.33 as AOAC suggested, measured as the iodide treated oil to liberate iodine, then titrated with sodium thiosulphate using starch T.S. as indicator.

2.6 Evaluation of the ideal fatty acids ratio

Two ideal fatty acid ratios from Hayes and Reinagel, and a fatty acids ratio from human lipid (re-calculated from Hodson and Skean) were compared, and the one that most closely resembled the average ratio of ideal fatty acids was chosen as a typical ratio for the evaluation of the oils.

The recovery of liquid chicken oil, at 25, 21, 17, 13, 9°C, was compared, and the one that is shown as percentages, or as mean ± SD. The differences among data were assessed by one-way analysis of variance (ANOVA) followed by the pairwise Tukey’s honest significance difference (HSD) test. Statistical calculations were performed using SPSS for Windows (version 10.0.7). A p value < 0.05 was considered statistically significant.

3 Results

3.1 Fatty acid analysis

The recovery of liquid chicken oil, at 25, 21, 17, 13, 9°C, is shown in Table 1. The chicken oil became frozen solid at 10°C; no liquid oil was collected at 9°C, and no fatty acids were detected at this temperature. This shows that the flocculent precipitation of β-form oil increases at cooler temperature, but the relationship of recovery to temperature was non-linear. A typical chromatograph of the harvested chicken oil is illustrated in Figure 1. The detection sensitivity was 0.02% (2 μg/L); the fatty acids chromatography included SFA: myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0), arachidic acid (C20: 0), MUFA: palmitoleic acid (C16:1), oleic acid (C18:1), and linolenic acid (C18:3), α-linolenic acid (C18:3), erucic acid (C22:1), and a mixture of arachidic and eicosapentaenoic acids (C20:3, C22:6).

Table 1: Fatty acid composition of chicken oil, olive oil, and camellia oil.

| Fatty Acid | Chicken Oil | Olive Oil | Camellia Oil |
|------------|-------------|-----------|-------------|
| C14:0      | 3.2         | 1.5       | 0.2         |
| C16:0      | 8.5         | 7.5       | 4.5         |
| C18:0      | 44.5        | 43.0      | 40.0        |
| C20:1      | 7.0         | 5.0       | 3.0         |
| C22:0      | 0.5         | 0.5       | 0.5         |
| C22:1      | 0.5         | 0.5       | 0.5         |
| C22:6      | 2.5         | 2.5       | 2.5         |

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The fatty acid composition of the liquid chicken oils harvested at 25°C (LC 25), 21°C (LC 21), 17°C (LC 17), and 13°C (LC 13) was analyzed and is listed in Table 2. Palmitic acid, oleic acid and linoleic acid ranked as the top three abundant fatty acids in the chicken oil, with 24%, 41%, and 16% on average. There was little linearity in the relationships. While the category of fatty acids changed with temperature variance, palmitic acid seemed to change with the temperature, but the difference was not significant. However, at temperatures ranging from 25°C to 13°C, the proportion of saturated fatty acids harvested declined from 31.6% to 27.6%, while the proportion of polyunsaturated fatty acids increased from 17.0% to 23.4%. The reason for this shift in fatty acids might not lie in any single area of variance, but may indicate a trend, in which the cooler recrystallization process seemed remove some of the fat abundant in the saturated fatty acids. The LC13 and LC17 were significantly different to the LC25 (p < 0.05), compared to the fatty acids of the crude chicken oil (1 : 1.4 : 0.5).

The composition of fatty acids in the liquid chicken oil harvested at 13°C paralleled those of the virgin olive oil, the camellia oil, and the human adipose lipid, as shown in Table 3. The fatty acids of human adipose lipid were courtesy reprinted and calculated from Hodson and Skeaff.

The human adipose lipids had a similar content of linolenic acid (0.8%) as the liquid chicken oil (0.7%), while the virgin olive oil and camellia oil both had linolenic acid content of 0.2%. Both vegetable oils had less linolenic acid than chicken oil or human adipose lipid in general. The chicken oil had γ-linolenic acid 0.2%, while no γ-linolenic acid was found in either of the two vegetable oils.

3.2 Acid value, iodine value, and peroxide value of the oils

The acid value of the extra virgin olive oil was 0.7 ± 0.3 mg KOH/gm, the camellia oil was 0.5 ± 0.2 mg KOH/gm, the chicken oil was 0.4 ± 0.1 mg KOH/gm, and the liquid chicken oil was 0.4 ± 0.1 mg KOH/gm (Table 4). The iodine value of the olive oil was 87 ± 5 gm I/100gm, the camellia oil was 76 ± 6 gm I/100 gm, the chicken oil...
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was 74 ± 6 gm L/100 gm, and the liquid chicken oil was 79 ± 5 gm L/100 gm (Table 4).

The peroxide value of the olive oil was 7 ± 2 meq/kg, the camellia oil was 5 ± 3 meq/kg, the chicken oil was 4 ± 2 meq/kg, and the liquid chicken oil was 5 ± 1 meq/kg (Table 4).

The acid value and the peroxide value of virgin olive oil were higher than those of the chicken oil; however, each type of oil was of high quality when evaluated according to the Taiwan FDA standard of acid value less than 2 mg KOH/gm and peroxide value less than 12 meq/kg.

3.3 Fatty acids ratio and scoring

As shown in Table 5, the average ideal fatty acid ratio 1 : 1.5 : 0.8 was obtained from Hayes, Reinagel, and human adipose lipids. Based on this new average ideal oil ratio, the human adipose ratio (1 : 1.8 : 0.6) had 87% similarity, the Hayes’ ratio (1 : 1.5 : 1) had 93% similarity, and the Reinagel ratio had 92% similarity. Since this is the first time the oil had been scored by the average ideal oil ratio, we took the highest scored ratio of Hayes as a relatively typical standard.

A list of the oils’ scores, based on the Hayes ratio, the average ratio, and the human lipid ratio, is shown in Table 6. The liquid chicken oil harvested at LC13 had the best fit with the fatty acids ratio suggested by Hayes et al. (p > 0.05). The virgin olive oil was 2.7 times higher MUFA than Hayes’ ideal ratio. Surprisingly, the average total scores of the oils by the above three ideal ratios were 68 (C+), 64 (C), 84 (A), and 91 (A+), for the virgin olive oil, the camellia oil, the chicken oil, and the liquid chicken oil, respectively.

4 Discussion

In this study, a liquid chicken oil with new fatty acid composition was obtained through a phase separation from crude chicken oil. The crude chicken oil was a mixture of fats, with a melting point of 24-27°C. We observed that after cool separation, the proportions of SFA and MUFA in α-form oil decreased by 4% and 0.2% respectively, but the PUFA increased by 6.4%. It seems that part of the fat with SFA or MUFA in crude chicken oil, such as palmitic acid and/or oleic acid, tends to transform to β-form oil at lower temperatures (between 13°C and 17°C). These phenomena

Table 2 The fatty acids composition of liquid chicken oil collected after recrystallization process at 25, 21, 17, and 13°C.

| Fatty acids (%) | LC 25   | LC 21   | LC 17   | LC 13   |
|----------------|--------|--------|--------|--------|
| **Saturated fatty acid** |        |        |        |        |
| Lauric a.       | 31.6   | 29.2   | 26.6*  | 27.6*  |
| Myristic a.     | 0.1    | 0      | 0      | 0.1    |
| Palmitic a.     | 6.7    | 5.6    | 3.8    | 5.3    |
| Stearic a.      | 0.2    | 0.1    | 0.2    | 0.4    |
| Arachidic a.    | 6.7    | 5.6    | 3.8    | 5.3    |
| **Monounsaturated fatty acid** |        |        |        |        |
| Myristoleic a.  | 0.1    | 0.1    | 0.1    | 0.1    |
| Palmitoleic a.  | 2.1    | 2.2    | 3.5    | 2.1    |
| Oleic a.        | 41.0   | 45.0   | 43.0   | 41.0   |
| Ecosaeonic a.   | 0.1    | 0.3    | 0.3    | 0.3    |
| **Polyunsaturated fatty acid** |        |        |        |        |
| Linoleic a.     | 16.1   | 18.3   | 18.5   | 21.4   |
| γ-Linolenic a.  | 0.1    | 0.1    | 0.2    | 0.2    |
| α-Linolenic a.  | 2.1    | 2.2    | 3.5    | 2.1    |
| Ecosadienoic a. | 0.1    | 0.1    | 0.1    | 0.2    |
| Ecosatrienoic a.| 0.1    | 0.1    | 0.1    | 0.2    |
| Arachidonic a.  | 0.1    | 0.1    | 0.1    | 0.2    |
| Docosatrienoic a| 0.1    | 0.1    | 0.1    | 0.2    |

SFA : MUFA : PUFA 1 : 1.4 : 0.5 1 : 1.6 : 0.7 1 : 1.8 : 0.8 1 : 1.6 : 0.9

N ≥ 6,* denote significantly different from LC25 (p < 0.05).
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Table 3  The fatty acids composition of the liquid chicken oil harvested at 13°C, the olive oil virgin and
the camellia oil, and human adipose lipid.

| Fatty acids (%) | Liq. Chicken oil | Olive oil | Camellia oil | Human adipose |
|----------------|-----------------|-----------|--------------|---------------|
| Saturated fatty acid | 27.6 | 19.2 | 10.5 | 27.7 |
| Lauric a. | 0.1 | | | |
| Myristic a. | 0.7 | | | 2.8 |
| Palmitic a. | 21.1 | 16.5 | 8.7 | 21.5 |
| Stearic a. | 5.3 | 2.3 | 1.8 | 3.4 |
| Arachidic a. | 0.4 | 0.4 | | |
| Behenic acid | | | 0.1 | |
| Monounsaturated fatty acid | 43.5 | 68.5 | 82.0 | 50.7 |
| Myristoleic a. | 0.1 | | | |
| Palmitoleic a. | 2.1 | 1.8 | 0.1 | 7.2 |
| Oleic a. | 41 | 66.4 | 81.9 | 43.5 |
| Ecosanoenic a. | 0.3 | 0.3 | | |
| Polyunsaturated fatty acid | 23.4 | 16.6 | 7.7 | 15.1 |
| Linoleic a. | 21.4 | 16.4 | 7.5 | 13.9 |
| Linolenic a. | 0.7 | 0.2 | 0.2 | 0.8 |
| Ecisadienoic a. | 0.2 | | | 0.8 |
| Ecosatrienoic a. | 0.2 | | | |
| Arachidonic a. | 0.5 | | | 0.2 |
| Docosatrienoic a. | 0.2 | | | |
| Docosapentaenoic a. | | 0.2 | | 0.1 |
| Docosahexaenoic a. | | | | 0.1 |
| SFA:MUFA:PUFA | 1 : 1.6 : 0.9 | 1 : 4.1 : 0.5 | 1 : 7.8 : 0.7 | 1 : 1.8 : 0.6 |

Table 4  The acid value, iodine values, and the peroxide value of the liquid chicken oil, olive oil,
and camellia oil.

| Acid value (KOH/g) | 0.4 ± 0.1 | 0.4 ± 0.1 | 0.7 ± 0.3 | 0.5 ± 0.2 |
| Iodine value (I₂/100 g) | 74 ± 6 | 79 ± 5 | 87 ± 5 | 76 ± 6 |
| Peroxide value (meq O₂/kg) | 4 ± 2 | 5 ± 1 | 7 ± 2 | 5 ± 3 |

Table 5  The average ratio of the reported ideal ratio and human adipose ratio.

| Ref source | SFA | MUFA | PUFA | Score |
|------------|-----|------|------|-------|
| Hayes      | 1   | 1.5  | 1    | 93    |
| Reingal    | 1   | 1.3  | 0.7  | 92    |
| Human adipose | 1 | 1.8  | 0.6  | 87    |
| Average    | 1   | 1.5  | 0.8  | 100   |

*The ratio suggested by Hayes is the one most similar to the average idea oil ratio than others.
temperature controlling factor can be up to 3.4 times. Organic solvent or to find no change in fatty acids forming of heterogeneous crystal, leading to insignificant place under an uneven temperature that accelerated the oil near the wall-vessel. Eventually the crystallization took process or the flocculation. Moreover, rated easily with other debris during the condensation lipid with a large triacylglycerol molecule that is incorporated into the fat oil crystal, leading eventually to heterogeneous recrystallization. It is known that the structure of fat oil is quite a complicated process, a better-looking liquid and more transparent chicken oil with a better composition of fatty acids was first achieved at 13 or 17°C.

The possible correlation between fatty acids in dietary oil and cardiovascular disease has been discussed for several years. The AHA has recommended reduction in dietary intake of saturated fatty acids to reduce the risk of CVD, and replacement of saturated fat by unsaturated fatty acid can greatly reduce risk. A proper and healthy balance of fatty acids in dietary oil to generate the best LDL/HDL ratio is what people want to know. An ideal fatty acid ratio of SFA : MUFA : PUFA for heart health was reported by Hayes to be 1 : 1.5 : 1. Another similar ratio was proposed by Reinagel at 1 : 1.3 : 0.7. However, no authors have explained the reasons why the ideal fatty acid ratio has been set at these levels. Since total dietary fat intake is one of the factors that affects the composition of adipose tissue, a ratio of 1 : 1.8 : 0.6 (SFA : MUFA : PUFA) in human adipose tissue was obtained by courtesy recalculated from Hodsons’ report, who collected data on the fatty acids of the adipose lipid in 4258 and 3096 healthy men and women, respectively. An average fatty acid ratio of 1 : 1.5 : 0.8 was observed in the reports of Hayes, Reinagel, and Hodsons (Table 6). The average ratio and the human adipose fatty acid ratio or the other authors’ ratio are highly similar (> 87%). Because the Hayes’ ratio (93%) best fitted the average ideal fatty acid ratio, we take Hayes’ ratio as the ideal fatty acid ratio for the further discussion that follows.

The Hayes ratio was taken as a score of 100 for the similarity analysis, and the fatty acid ratios of each oil were compared with the Hayes ratio by statistical weighted method. The results showed that liquid chicken oil had the highest score of 91 and crude chicken oil had second highest score at 84. This result shows that crude chicken oil (84) can be as good as virgin olive oil (which scored 64), and that liquid chicken oil (scored 91) is even superior to virgin olive oil on this basis. Moreover, no matter whether we evaluated the chicken oil by the average ideal ratio or the human lipid ratio, the liquid chicken oil always achieved a grade of A+, while virgin olive oil achieved only C+ (Table 6). This shows that the chicken oil was more similar to or compatible with human lipids. According to the bio-compatibility concept, it seems that humans as a

| SFA | MUFA | PUFA | Hayes ratio | Average ratio | Human adipose ratio | Average score (Grade) |
|-----|------|------|-------------|---------------|---------------------|-----------------------|
| Virgin olive oil | 1 | 4.1 | 0.5 | 62 | 66 | 76 | 68 (C+) |
| Camella oil | 1 | 7.8 | 0.7 | 63 | 59 | 70 | 64 (C) |
| Chicken oil | 1 | 1.4 | 0.5 | 81 | 85 | 87 | 84 (A) |
| Liq. Chicken oil | 1 | 1.6 | 0.9 | 94 | 94 | 85 | 91 (A+) |
species are more suited to the digestion of oil that mimics human oil, or so called ideal oil, and in this case, the liquid chicken oil is the best fit. According to this finding, it seems that the best fit oil for olive tree is olive oil, and so the best fit for humans would be human oil, but since it is difficult to obtain human oil, in this study the chicken oil is the best fit or most compatible oil for humans. It seems that the best fit oil for olive tree is olive oil, and so chicken oil is the best fit.

In conclusion, in this study, a simple phase separation method was first reported to give a method of recycling raw chicken fat into an ideal dietary oil. The fatty acid composition of liquid chicken oil was highly compatible with human lipids, and was also a good fit with the ratio of an ideal dietary oil. It is hoped that more studies will be conducted in the future to further explore these phenomena.

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