

# The Effect of Cooking Method on the Amount of Fat in an Egg

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## Summary

Eggs are commonly consumed because they are an inexpensive, readily available source of high-quality protein, but they also contain a significant amount of fat. During the cooking process, the fat in eggs can be oxidized through a process called lipid oxidation, which can cause serious health problems including heart disease and can destroy essential fatty acids and vitamins in eggs. This study assesses the effect of different cooking methods on the amount of fat in an egg. Lipid solvent extraction with acetone was used to test the hypothesis that hard-boiled eggs will contain the least amount of extracted fat (indicating the most oxidized fat) compared to raw and fried eggs. We determined the amount of fat in 36 egg yolk samples, with 12 samples for each cooking method. The results supported the hypothesis and showed that heat oxidizes the fat in eggs. We found that the amount of fat in an egg is inversely proportional to the amount of heat applied to it. This information can raise awareness of harmful health consequences of consuming eggs exposed to high temperatures during cooking and encourage consumers to cook eggs using methods that do not require the egg to be heated to very high temperatures.

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## Introduction

Lipids are a diverse group of organic compounds that include fats, oils, waxes, phospholipids, and steroids (1). They are hydrophobic molecules composed of one glycerol and three fatty acids. The head of each fatty acid is a hydrophilic carboxyl group, and the tail is a hydrophobic hydrocarbon chain. Lipid oxidation is the oxidative deterioration of lipids that plays a role in the causation of several diseases including heart disease – the leading cause of death in the United States (1, 2, 3).

Fats are the most common type of lipid; they are typical molecules that fall into three main groups: saturated, monounsaturated, and polyunsaturated. Saturated fats contain fatty acids with covalent single-bonded carbons. Monounsaturated fats contain exactly one double bond, known as a *cis* bond, that creates a kink in the fatty acid; polyunsaturated fats contain multiple *cis* bonds that can

be converted to *trans* bonds during a process called hydrogenation (4).

In the human body, lipids are a secondary source of energy (after carbohydrates) and function as storage centers for energy, building blocks for cell membranes, insulation for various organs, and as a crucial part of cell signaling (5). The Recommended Daily Allowance (RDA) for fat in a 2000 calorie diet is 65 grams, 25 grams or less of which should be saturated fat (6).

Since lipids control important body functions, a lack of fats can be severely damaging to the body. Lipid deficiency can lead to improper nutrient absorption, especially for Vitamins A, E, D, and K, as well as altered brain function, potentially leading to depression and other mental disorders (7). Lipid excess in the diet is a major contributor to obesity, which can lead to other severe conditions such as hypertension, impaired heart function, cancer, impaired immune function, kidney diseases, bone disorders, unhealthy cholesterol levels, and atherosclerosis. Increased blood levels of cholesterol, a lipoprotein found in various foods such as eggs, is an effect of obesity and is one cause of atherosclerosis (8, 9). The average large egg contains 186 milligrams of cholesterol (3).

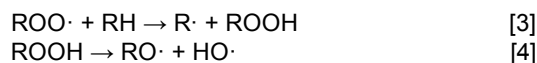
In 2013, more than 1.4 billion eggs were produced for retail purposes in the United States (10). Eggs are commonly consumed because they are an inexpensive, readily available source of high-quality proteins (11). Eggs are most often eaten hard-boiled (cooked to 82°C), fried (cooked to 71.1°C), poached, scrambled, or baked (12, 13). In addition to protein, eggs contain several fats that play an important role in the human body (12). The average large egg contains 4.8 grams of total fat and must be heated to a minimum of 71.1°C for safe consumption (12, 13). During the cooking process, the chemical structure of the fats in eggs is altered through a process known as lipid oxidation (or lipid peroxidation) that has harmful effects on the human body (14, 15).

Lipid oxidation is a radical chain reaction that occurs mostly in fatty acids with double bonds, such as unsaturated fats (2, 14, 15). It occurs in three phases: initiation, propagation, and termination. During initiation, a free radical is formed when an existing free radical or reactive oxygen species reacts with elements in the lipid, as seen in the following equations (14, 16):

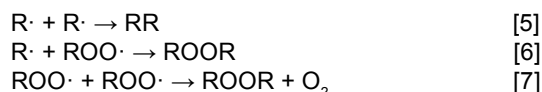


where R represents the fat and  $\cdot$  represents a free electron (denoting a free radical). Initiation begins the process of lipid oxidation and has a very high activation energy that can be provided by light or heat with a temperature of

66°C or above (14, 17). Next, in propagation, the free radical reacts with other stable molecules in the lipid to form new free radicals, altering the original chemical structures of the stable molecules (14, 18):



The process ends in termination, when two free radicals react to form a stable product (5, 18):



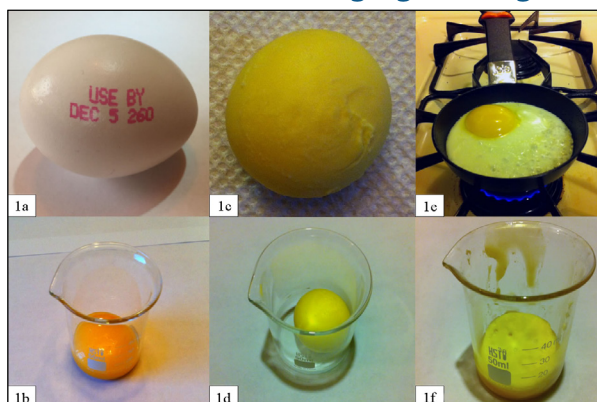
In foods, lipid oxidation can cause a rancid flavor and a change in color or texture. During the lipid oxidation process, essential fatty acids and vitamins contained in lipids are lost, causing health risks such as toxic compounds, growth retardation, and heart diseases (15).

Since lipid oxidation usually occurs at around 66°C and all cooked eggs are heated to at least 71.1°C, the lipids in all cooked eggs will be oxidized to some degree (13, 17).

The purpose of this experiment is to determine how the cooking method affects the amount of fat contained in an egg. Since eggs are very popular due to their high protein content, it is important to analyze how the lipids that are also in eggs are impacted by exposure to heat during cooking (11). This investigation will establish which cooking method (boiling or frying) causes eggs to contain the least amount of extracted fat.

Based on the above background research, we formulated the following hypothesis: hard-boiled eggs will contain the least amount of extracted fat (indicating the most oxidized fat), because hard-boiled eggs are cooked to the highest temperature among the cooking methods tested, better initiating the lipid oxidation process.

The results of this experiment showed that hard-boiled eggs contained the least amount of extracted fat, followed by fried eggs. The amount of fat extracted from the egg yolks was inversely proportional to the amount of heat applied, supporting the hypothesis. Since a lower amount of extracted fat implies a higher amount of oxidized fat, the hard-boiled eggs had the most oxidized fat, while the fried eggs had slightly less oxidized fat.



**Figure 1:** (a) Raw egg and (b) raw egg yolk in 50 milliliter beaker before lipid extraction. (c) Hard-boiled egg and (d) hard-boiled egg yolk in 50 milliliter beaker before lipid extraction. (e) Fried egg and (f) fried egg yolk in 50 milliliter beaker before lipid extraction.

## Results

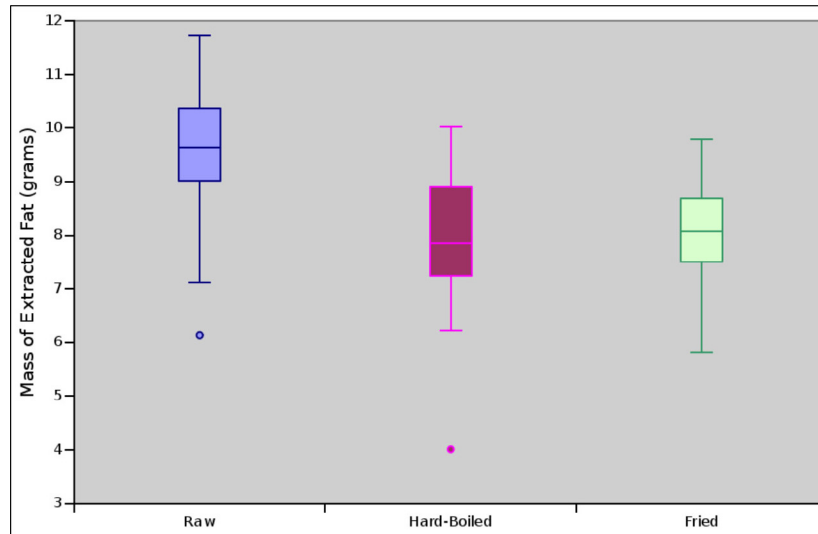
In this investigation, we tested the amount of fat in each egg yolk sample (the dependent variable) using lipid solvent extraction with acetone. A total of 36 samples were used, with 12 samples for each cooking method: raw, hard-boiled, and fried (Figure 1a-f). The cooking method was the independent variable, and several other parameters were kept constant in order to obtain accurate results: type of egg used (large white eggs), part of egg tested for fat (yolk), solvent used to extract fat (acetone), amount of acetone used (20 milliliters total), the time allowed for each egg sample to dry after the fat had been extracted (approximately 24 hours), and the scale used to make measurements. We compared the amount of fat extracted from the hard-boiled and fried eggs to the fat in the raw egg control group.

The results of this experiment showed that the hard-boiled eggs (heated to approximately 82°C) contained the least amount of extracted fat overall (mean of 7.778 grams), followed by the fried eggs (heated to approximately 71.1°C) with slightly more extracted fat (mean of 8.008 grams). We found that the raw eggs contained the most extracted fat, with a mean extracted fat value of 9.427 grams (Table 1 and Figure 2). Thus, the amount of heat applied to the eggs during cooking is inversely proportional to the amount of extracted fat.

Figure 2 compares the mass of extracted fat of the three cooking methods on a box plot.

Cooking Method	Mean Mass of Extracted Fat (grams)	Median Mass of Extracted Fat (grams)
Raw	9.427	9.64
Hard-Boiled	7.778	7.84
Fried	8.008	8.075

**Table 1: Mean and median values for the mass of the fat extracted from each sample in each cooking method.** In both the mean and median, the raw eggs contained the most amount of extracted fat, indicating the least amount of oxidized fat. Among the cooking methods where heat was applied to each sample, the fried eggs contained most amount of extracted fat, indicating the least amount of oxidized fat. The hard-boiled eggs contained the least amount of extracted fat overall, indicating the highest amount of oxidized fat.



**Figure 2: Box plot of the amount of extracted fat in the raw, hard-boiled, and fried egg samples.** The whiskers for each cooking method denote the upper and lower fence values for each sample type. It is clear that the hard-boiled eggs contained the least amount of extracted fat, followed by fried eggs. The raw eggs contained the most amount of extracted fat, but there is one outlier in the raw egg category that is below the median values for extracted fat in both the hard-boiled and fried eggs. This indicates that the raw egg control group contained the least amount of oxidized fat, followed by fried eggs.

## Discussion

The results of this investigation support the hypothesis that hard-boiled eggs contain the least amount of extracted fat after being cooked, compared to raw and fried eggs. Both the hard-boiled and fried eggs contained significantly less extracted fat than the raw egg control group. Research suggests that lipid oxidation requires a high activation energy that can be provided by heat exposure and usually occurs at temperatures above 66°C, and this was also seen in this experiment (17).

Lipid solvent extraction with acetone does not detect the presence of oxidized lipids since their chemical structures have been altered. A lower amount of fat extracted from an egg sample thus implies a higher amount of oxidized fat in the egg. Therefore, hard-boiled eggs also contain the most oxidized fat. The consumption of oxidized lipids can cause various health problems, including heart disease and growth retardation, so the consumption of oxidized fats in eggs should be limited (15).

In order to obtain accurate data, variables that could have interfered with the results were kept constant. The same type of egg was used in each sample, the containers in which the samples were stored were identical, the same amount of acetone was used in the lipid extraction, and all of the egg samples were tested under the same conditions.

The two outliers observed in this data set were most likely a result of human error while conducting the experiment. When the acetone was poured out of the sample along with the extracted fat, some clusters of egg yolk may have been accidentally poured out with the acetone. This might have caused the mass of the egg yolk alone (after the lipids had been extracted) to not

include some egg yolk fragments. In addition, the time allowed for the egg yolk in each sample to dry after the fat was extracted may have differed by a few minutes on each day of experimentation. Although this error may not have accounted for a major source of human error, it may have contributed to the observation that some extracted fat samples appeared dryer than others.

Another observation is that the acetone did not mix as well with the hard-boiled and fried egg yolks as it did with the yolks of the raw eggs. This may be an indication of the altered chemical structures of the fats in the egg yolks of the cooked eggs, further supporting the hypothesis of this experiment.

We chose acetone as the solvent in this experiment as it extracts only saturated, monounsaturated, and polyunsaturated fats from a sample, which are the fats found in the greatest quantity in eggs (12, 19). In addition, acetone is more readily available than other solvents for lipid extraction. However, it may have reacted with various lipids in the egg yolk during the extraction, producing artefacts that added to the substances extracted from each sample, thus increasing the mass of extracted fat (19). This could have confounded the results and caused the discrepancy between the average fat in an egg yolk and the average extracted fat for each sample type in this investigation.

Another confounder could be related to the use of cooking spray for preparing the fried eggs tested in this study. The fried eggs were cooked with a small amount of non-stick cooking spray, which contains a minute amount of fat (canola oil) (20). The amount of fat is between 0 and 0.5 grams per 1/3 second serving and is rounded down to 0 grams on the cooking spray label, but between 1 and 3 servings of the cooking spray were

applied, which suggests that the amount of additional fat is between 0 and 1.5 grams. This small amount of fat may have slightly increased the amount of fat extracted from the fried eggs (21). However, the soy lecithin used as an emulsifier in the cooking spray is acetone-insoluble, so it did not affect the results of this experiment (22).

In conclusion, the results support the hypothesis that hard-boiled eggs contain the least amount of extracted fat after cooking, as compared to raw and fried eggs. The amount of extracted fat in a cooked egg is inversely proportional to the amount of heat applied to it during the cooking process. This suggests that the fat in eggs is oxidized when exposed to heat, which can cause serious health problems.

There are important practical applications of this study, including raising awareness of the consequences of consuming eggs that have been exposed to high levels of heat. Heart disease, the leading cause of death in the United States, is one of the effects of consuming oxidized fats, so it is important to warn people of the health risks that are caused by heating eggs to high temperatures while cooking (12, 15). A warning could be added to egg cartons to warn consumers of this risk. In order to minimize the harmful effects of lipid oxidation caused by cooking eggs at a high temperature, consumers could cook eggs using methods that do not require eggs to be heated to a very high temperature such as consuming fried eggs rather than hard-boiled eggs. In addition, the harmful effects of lipid oxidation can be minimized by consuming foods that contain antioxidants, such as orange juice and blueberries (23).

In the future, studies with a larger sample size can be conducted to assess the lipid oxidation when using other cooking methods such as poaching and scrambling, as well as heating hard-boiled and fried eggs to various temperatures. The effect of cooking methods on other types of eggs such as brown eggs can also be studied. The use of other solvents to extract lipids from the egg samples should also be tested in order to avoid error and impurities in the extraction.

## Methods

Lipid extraction is a technique used to determine the amount of fat in a sample. It involves using a solvent to dissolve and remove all lipid substances in a sample and calculating the difference in the mass of the sample before and after the lipid was extracted. The most common type of lipid extraction is solvent extraction, which requires an appropriate solvent to be selected such as hexane, ether, or acetone (24, 25).

In this investigation, we employed the lipid solvent extraction method with acetone as the solvent to determine the amount of fat in each egg yolk sample tested. We tested three groups of twelve eggs each: raw eggs, fried eggs, and hard-boiled eggs. **Figure 1a-f** show the three cooking methods tested. The Grade A large white eggs tested were purchased at the same time, and all of the three dozen-egg cartons had the same lot number. The acetone used to extract fat (Klean-Strip) did not contain any additional chemicals.

The digital scale used to determine the mass of each sample had a resolution of 0.01 grams (26). The mass of each egg sample was collected before and after the lipid was extracted. The difference between the two values was the mass of the fat extracted from the egg, as seen in the following formula, which was used for all egg sample types:

$$M = (Y_1 - B) - (Y_2 - B) \quad [8]$$

where M is the mass of extracted fat,  $Y_1$  is the initial mass of the beaker and yolk,  $Y_2$  is the final mass of the beaker and yolk, and B is the mass of the beaker alone. Before beginning the lipid extraction, we measured the mass of the beaker alone.

To test the raw eggs for fat, one raw egg yolk was first separated from the white and placed into a 50 milliliter beaker. We measured the mass of the beaker and yolk using a digital scale. The solvent used to extract the fat was then added by pouring 10 milliliters of acetone into the beaker. The acetone and yolk were stirred for 1 minute with a glass rod, and the mixture was allowed to settle for another minute. We then poured the liquid acetone out of the beaker, while keeping the solid yolk in the beaker. We repeated the extraction procedure for the same sample with another 10 milliliters of acetone. Before collecting the final mass, we allowed the yolk inside the beaker to settle for approximately 24 hours. After any remaining acetone in the sample had evaporated, we determined the mass of the beaker and yolk using the scale. We used the formula described above to determine the final mass of the fat extracted from the egg yolk sample. After the first sample, we tested 11 more raw egg samples.

To determine the amount of fat in the hard-boiled eggs, each sample was cooked before the lipid extraction. One raw egg was placed into a cooking vessel and covered with cold water. The vessel and egg were heated on a stove on the "high" setting until the water began to boil, raising the temperature of the egg sample to approximately 82°C (27). We then removed the vessel from the stove and was allowed to sit for 12 minutes. After the egg had cooled, it was taken out of the vessel and the yolk was separated from the white and placed in a 50 milliliter beaker. We performed the extraction procedure twice with a total of 20 milliliters of acetone and the sample was allowed to dry for about 24 hours. The mass of the yolk and beaker were once again recorded and the mass of the fat extracted was determined using the formula above. We tested 11 other hard-boiled egg samples.

To test the fried eggs, we heated each sample to approximately 71.1°C before the fat was extracted (27). A thin layer of non-stick cooking spray was applied to a pan over "medium-high" heat on a stove. A raw egg was cracked into the pan and cooked on the "low" setting of the stove for 5 minutes. After flipping the egg in the pan, we heated it for 30 seconds and separated the yolk from the egg whites and placed the yolk in a 50 milliliter beaker. The sample was then weighed with the beaker. We performed the extraction procedure twice to remove

all fat from the fried egg and the remaining solvent was allowed to evaporate for approximately 24 hours. Finally, the mass of the yolk and beaker were once again recorded and the mass of the fat extracted was determined using the formula above. We tested another 11 fried egg samples for fat using the same cooking and extraction procedures.

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