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Review

Heated vegetable oils and cardiovascular disease risk factors

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ABSTRACT

Cardiovascular disease (CVD) is one of the leading major causes of morbidity and mortality worldwide. It may result from the interactions between multiple genetic and environmental factors including sedentary lifestyle and dietary habits. The quality of dietary oils and fats has been widely recognised to be inextricably linked to the pathogenesis of CVD. Vegetable oil is one of the essential dietary components in daily food consumption. However, the benefits of vegetable oil can be deteriorated by repeated heating that leads to lipid oxidation. The practice of using repeatedly heated cooking oil is not uncommon as it will reduce the cost of food preparation. Thermal oxidation yields new functional groups which may be potentially hazardous to cardiovascular health. Prolonged consumption of the repeatedly heated oil has been shown to increase blood pressure and total cholesterol, cause vascular inflammation as well as vascular changes which predispose to atherosclerosis. The harmful effect of heated oils is attributed to products generated from lipid oxidation during heating process. In view of the potential hazard of oxidation products, therefore this review article will provide an insight and awareness to the general public on the consumption of repeatedly heated oils which is detrimental to health.

Contents

1. Introduction

According to a health statistics gazetted by the World Health Organisation [1], non-communicable diseases (NCDs) will be causing more than three quarters of all deaths in 2030. Of the NCDs, cardiovascular disease (CVD) represents a major risk to worldwide deaths, in which the numbers of mortality from CVD are expected to skyrocket from 17.1 million in 2004 to 23.4 million in 2030.

CVD is collectively defined as a disease that affects the heart and blood vessels. CVD includes coronary heart disease, stroke, rheumatoid heart disease and Chagas disease. While rheumatoid heart disease and Chagas disease are caused by infections, the aetiology of coronary heart disease is closely associated with the development of atherosclerosis [2,3]. CVD develops slowly due to long-term exposure to several behavioural risk factors such as cigarette smoking, lack of exercise,

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constant stress, overweight and consuming diet with high saturated fat contents [4–6]. Nevertheless, nutritional oil quality is also recognised as an important player in the aetiology of CVD [7,8].

In general, the practice of reusing oil which has been repeatedly heated during food preparation is widespread. This practice is not confined only to roadside food stalls, but also in more established food outlets in big cities [9]. It is well-established that heating of dietary oils and fats results in lipid oxidation [10]. Lipid oxidation involves the oxidative destruction of fatty acid chains, consequently leading to the generation of polar compounds and other secondary side products. Furthermore, vitamin E, which is a natural antioxidant, in the oil also deteriorates after repeated heating [11]. Lipid oxidation does not only spoil the taste, smell and colour of oil, but intake of the oil may also impose unmitigated threat to health [12]. Previous reports have highlighted a direct relationship between CVD risk and consumption of cooking oil polar compounds [13–15].

However, the safety of reusing oil in food preparation is still rather questionable, partly due to limited human studies and some contradictory findings in animals [16]. Because heated oil contains a complex chemical environment, it is thus difficult to clearly identify the respective effects of each oxidation product. Yet, since dietary lipid intake is closely related to the pathogenesis of CVD, it is imperative to understand the effects of repeatedly heated vegetable oil on CVD risk factors. By means of comprehensively consulting the published literatures, we reviewed the current knowledge concerning some important experimental and clinical effects related to the intake of reheated oil on CVD risk factors including blood pressure, serum lipids and endothelial dysfunction. A better understanding in the mechanisms of reheated oil pathologies helps to serve as a guide to consumers with regard to the proper usage of vegetable oils in the preparation of a healthy meal.

2. Heated vegetable oils

2.1. Effects of heating on vegetable oils

In deep-fat frying, the oil is usually heated to an extreme temperature of 180 °C and above. At the same time, it is also being exposed to moisture and air, resulting in a vast spectrum of chemical reactions collectively known as lipid oxidation. The chemical reactions in lipid oxidation have been previously described excellently in some articles [17,18]. It is a complex phenomenon provoked by oxygen in the presence of initiators such as heat and free radicals [19]. Heated oil undergoes chemical reactions which include oxidation, hydrolysis, polymerisation and isomerisation. The reactions are deleterious to the stability of fatty acids and other biochemical parameters of the oil [20,21]. Thermally heating oil has been shown to elevate the percentage of free fatty acid value (15-fold), acid value (14-fold), peroxide value (8-fold), *p*-anisidine value (39-fold), total oxidation value (19-fold), thiobarbituric acid reactive substance (TBARS) value (8.5-fold), and *trans* fatty acid isomer value (2.5-fold) compared to the control [22]. Lipid oxidation can degrade the sensory property of the oil by darkening its colour, increasing its viscosity, causing foam and spoiling its flavour.

As primary lipid oxidation products such as peroxides and hydroperoxides are unstable, they react rapidly with each other to form secondary lipid oxidation products. The products include volatile (alcohols, aldehydes, acids, ketones etc.) and non-volatile compounds (carbonyls or dimeric, trimeric, polymeric and cyclic fatty acids etc.). While volatile compounds might be lost during the process of frying, the potentially hazardous non-volatile polar compounds however deposit in cooking oil [23], worsening the nutritional safety of the oil. Both volatile and non-volatile products may have important effects on cardiovascular physiology (Table 1). From the nutritional viewpoint, the non-volatile products of lipid oxidation may play a more important role in CVD because they remain in the oil and are then absorbed by the food and ingested. The majority of these products are collectively known as polar compounds. The content of polar compounds in heated oil has been associated with endothelial dysfunction [31] and hypertension [15]. Thermally oxidised oil was found to increase plasma lipid peroxidation in Sprague–Dawley rats [32]. Oxidative stress after the intake of deep-frying oil was also reported in human subjects [33]. Excessive presence of oxidation products damages cellular functions by reacting with some physiologically critical macromolecules such as DNA, protein and lipid. Oxidative damage is one of the important deteriorative mechanisms implicated in CVD induced by heated oil, which includes cell injury, enzyme damage and nucleic acid mutagenicity.

2.2. Awareness of using heated vegetable oils in food preparation

A large amount of oil is often needed in deep frying. Therefore people often keep the used frying oil for future usage. This habit happens not only in household kitchens but also in industrial sectors. Recycling frying oil in daily food preparation is thought to minimise the expense on food preparation without taking into consideration the potential harmful effects on health. Although majority of the general public (70.0%) realise that the quality of cooking oil does not remain the same after deep frying [9], recycling frying oil is still widely practised in the society.

Public awareness regarding the hazard of using recycled cooking oil is still not satisfactory in developing and under-developed countries. About 40–63% of people admitted using the same portion of cooking oil repeatedly [9,34,35]. A chemical analysis of the oils showed the presence of high levels of free fatty acid (range, 0.84–1.4112 compared with 0.42 in the fresh oil) and peroxide (range 14.7–16.6 compared with 9.0 in the fresh oil) values [35]. About 91.0% of the respondents had not been educated on food quality and safety issues [35]. A study conducted in Japan found that restaurant frying oils were used at 180 °C for 3 h/day for five consecutive days before discarding those oils [36].

The effects of thermal process on the safety of edible oils have drawn tremendous attention from investigators worldwide. During the recent 7th International Symposium on Deep-Fat Frying held in San Francisco, USA, scientists have reaffirmed that the best indices for assessment of used oils are total polar materials (TPMs) and polymeric triglycerides by using recognised methods [37]. Peroxide value, free fatty acid value, and anisidine value should not be used as regulatory indices when it comes to monitoring and comparing the degree of degradation of different frying oils. The cut-off point for rejection of reused frying oil has been proposed to be set at a content range of 20–27% for polar compounds [38], which with the implementation of Hazard Analysis and Critical Control Point (HACCP) regulation has been currently employed in the national food laws in several European countries [39].

However, the index does not represent the thorough bunch of products from lipid peroxidation as 25% of polar compounds in cooking oil correspond to a much higher content of triacylglyceride oligomers [40]. In addition, some secondary oxidation products might possess potential harm to the human body. Recently, a study has found significant concentrations of toxic aldehydes present in the oil albeit the 25% limit for polar compounds is not reached in the oil [41]. These findings suggest that the limit may overlook and allow the other formations of potentially hazardous compounds. Since the products of lipid oxidation are closely associated with CVD risk factors, the quality of the vegetable oil consumed daily unquestionably affects the cardiovascular system.

3. Intake of heated vegetable oils and CVD risk factors

3.1. Hypertension

Epidemiological data has shown that lifestyle factors such as dietary habit are the main driving factors of the high prevalence of hypertension [42]. The quality and quantity of fats and oils in diet are important in determining the risk of CVD [43]. Various studies in humans and animals have been done to determine the role of reused cooking oil in