Underlying Health Risks of Frying Oils: Lipid Oxidation

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INTRODUCTION

As we know, deep fried foods can taste delicious, not to mention the finger-licking good taste of Kentucky Fried Chicken, with its savoury aroma lingering in the air. The frying method forms a brownish crusty layer on the food surface that contributes to the distinctive fried flavour, resulting in more palatable and desirable food. That is the reason why frying is extensively used in the making of various domestic food products currently available in the market. In principle, frying is a dehydration process that involves rapid heating and mass transfer when the food is immersed into hot oil at temperatures above the boiling point of water, *i.e.* between 150^{0}C and 190^{0}C (Azmil Haizam and Razali, 2014; Jaarin and Kamisah, 2012). The ease of operation, convenience and economic viability of the frying process have resulted in the popularity of fried food products.

Despite the distinctive savoury taste of fried food, we know less about the impact of different oils used on the quality of the fried foods; this may lead us to think about the impact of frying on health. Heating oil at a high temperature results in several complex chemical reactions, which are largely affected by the heating temperature, duration of heating, type of frying materials and oils, presence of antioxidants and pro-oxidants in the oil matrix, as well as the amount of oxygen available (Jaarin and Kamisah, 2012). In order to further reduce the operational cost in a commercial setting as well as for household frying, repeated heating of the same batch of vegetable oil has usually been practised. This has led to the formation of free reactive oxygen species, which are responsible for imposing oxidative stress on the body, a prerequisite to inflammation.

In this regard, what is the most suitable frying medium for both household and commercial use? In our country, as well as in Southeast Asian countries in particular, palm oil, touted as the most stable frying oil due to its semi-saturated properties, has now been gradually replaced by unsaturated vegetable oils as the healthier choice of cooking oil. In view of the general perception that unsaturated vegetable oils are a good choice for frying purposes due to their abundant omega-3 and omega-6 properties, public awareness on the health impact of these oils is needed.

OXIDATION OF VEGETABLE OILS

Unfortunately, when vegetable oils are repeatedly heated at high temperatures during the frying process, undesirable chemical reactions such as oxidation and hydrolysis take place in the oils, producing free radicals and oxidised products that affect the sensory, functional and nutritional qualities of the frying oils (Razali, 2003). For those who have the misconception that unsaturated oils are good and safe for cooking, it will surprise them to know that oxidation actually happens more commonly in repeatedly heated unsaturated oils. This results in lipid peroxidation and the production of toxic compounds that have deleterious effects on human health.

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Oxidation, the main process of oil deterioration, involves the interaction between unsaturated fatty acids and oxygen, causing rancidity in the oil with accompanying unpleasant flavours and smells. Peroxidation is the primary oxidative deterioration process of lipids, in which the carbon-carbon double bonds of unsaturated fatty acids are attacked by oxidants such as free radical oxygen species (Ayala *et al.*, 2014). Lipid peroxidation removes hydrogen from a carbon of unsaturated fatty acids and replaces it with oxygen, producing lipid proxyl radicals and hydroperoxides (Choe and Min, 2006). These oxidative products can be absorbed into the fried food products, leading potentially to negative health impacts.

STABILITY OF VEGETABLE OILS

There is a way to protect ourselves from the potential negative health effects of consuming oxidised oil. Oil stability is often associated with the ability of the oil to withstand high temperatures during frying without undergoing oxidation. Therefore, this characteristic should be taken into consideration when choosing which healthy vegetable oil to buy. A vegetable oil with a higher saturated fat content is more stable for frying in comparison with unsaturated oils such as soyabean, corn and sunflower oils. In fact, the number of double bonds in fatty acids distinguishes the extent of oil oxidation, with an oil containing a higher level of polyunsaturated fatty acids (PUFA) being more susceptible to oxidative reactions as opposed to oils which are rich in saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) (Azmil Haizam and Razali, 2014). Nevertheless, oil stability is not determined only by the degree of saturation of the fatty acids; other factors like the positioning of the fatty acids in the triacylglycerols (TAG) and the presence of unsaponifiable constituents such as alcohols, hydrocarbons, fat-soluble vitamins and phytosterols can also influence the stability of the oil (Azmil Haizam *et al.*, 2016).

Saturated oils are more stable and thus safer for repeated heating as compared with unsaturated oils. This will probably shock many people who are reading this and who have believed the myth that unsaturated oils are 'the best oils for cooking'. Why are unsaturated oils prone to deterioration through heating? This is because unsaturated oils can be readily oxidised by free radicals or pro-oxidants at the carbon-carbon double bonds of the fatty acids, which are abundant in PUFA such as linoleic acid (C18:2) and linolenic acid (C18:3). In Malaysia, palm and soyabean oils are the most commonly used vegetable oils in households and by industry for deep frying purposes. Soyabean oil contains about five times more PUFA compared with palm oil; indeed, more than 70% of soyabean oil consists of PUFA and MUFA (Jaarin and Kamisah, 2012). By contrast, palm oil contains a balanced ratio of saturated (45%) and unsaturated fatty acids (55%) (Awney, 2011).

People will definitely wonder what gives 'artery-clogging' saturated oils advantages over unsaturated oils during cooking. The higher saturated fat content in palm oil contributes to its stability against the oxidative reactions due to repeated heating. Fresh and repeatedly heated soyabean oil has a greater peroxide value than palm oil, remembering that peroxide value is one of the indicators for the oxidative stability of oils. The higher value suggests that soyabean oil is more susceptible to peroxidation than palm oil (Jaarin and Kamisah, 2012). As a result, palm oil is a highly preferred vegetable oil for high temperature cooking, and it is found to be a good alternative for hydrogenated oils that are associated with *trans* fatty acids.

MEASUREMENT OF OXIDATION LEVELS IN VEGETABLE OILS

Measuring oxidation levels in vegetable oils involves testing for the primary and secondary breakdown products. There are several methods commonly used to determine the oxidation levels in vegetable oils, namely, the peroxide value (PV), p-anisidine value (p-AV) and the free fatty acid level.

Peroxide Value (PV)

Peroxide value (PV) measures the formation of hydroperoxides, which are primary products formed from the lipid oxidation process of unsaturated fatty acids (Azmil Haizam *et al.*, 2016). PV is also used to assess the extent to which spoilage has taken place in a cooking oil based on the degree of rancidity of the oil caused by auto- and photo-oxidation (Kaleem *et al.*, 2015). Hence, it is used as a measurement of the quality of oils. Regardless of oil composition, the recommended initial PV for cooking oil is less than 1 mequiv O_2 kg^{-1}. Nonetheless, PV is regarded as an unstable measurement of oil

oxidation during repeated heating because the hydroperoxides produced during primary oxidation are destroyed at high temperatures and new peroxides are formed during the cooling process and storage. Therefore, p-AV appears to be a more reliable measurement for oil oxidation (Azmil Haizam *et al.*, 2016).

p-Anisidine Value (p-AV)

Oil oxidation is not just a single reaction, but a complex series of reactions. During oil oxidation, the breakdown of hydroperoxides will further produce secondary oxidation products such as aliphatic aldehydes, ketones, alcohols, acids and hydrocarbons. These secondary products are more stable during the heating process (Poiana, 2012). The intensity of secondary oxidation is denoted by p-AV. This parameter basically measures the formation of aldehydes present in cooking oil and addresses the integrity of oil resistance during the heating process (Azmil Haizam *et al.*, 2016).

Free Fatty Acids (FFAs)

Hydrolysis occurs during the heating process of oil, in which the parent molecules, TAG, are broken down into free fatty acids (FFAs). This reaction accelerates with an increase in heating temperature and with excessive amounts of moisture in the food (Azmil Haizam *et al.*, 2016). Hydrolysis of oil occurs more readily in vegetable oils with short carbon chains and unsaturated fatty acids than those with long carbon chains and saturated fatty acids. This is due to the higher water solubility of the short carbon chains and unsaturated fatty acids (Choe and Min, 2007). FFAs can also be formed from cleavage and oxidation of unsaturated bonds in the oil structure that disintegrate the ester bonds of TAG structures (Azmil Haizam *et al.*, 2016). Hence, FFA content is one of the indicators of oil deterioration. Moreover, FFAs are pro-oxidants and promote secondary oxidation of the oil by increasing the rate of breakdown of hydroperoxides due to the presence of the carboxylic groups in their structure (Choe and Min, 2007).

HEALTH RISKS OF OXIDISED OILS

Most people cannot resist the temptation of delicious fried foods. In Southeast Asian countries, fried foods are often found in the menu of households and restaurants due to the eating preference of the people. However, fried foods contain a considerable amount of oxidised oil holding hazardous reactive oxygen species as a result of repeated heating during the frying process. Long-term consumption of repeatedly heated vegetable oils can be detrimental to human health, primarily by severely weakening the human antioxidant defence system, and leading to many chronic diseases such as hypertension, diabetes, vascular inflammation and coronary heart diseases (CHD).

When people continuously consume oxidised oil, their bodies are constantly exposed to a significant level of oxidative stress, resulting from an imbalance between an oxidative defence system and the formation of oxidising substances, including free radicals (Goswami *et al.*, 2015). This situation is no different from exposing ourselves to toxic substances without any protection, and can cause oxidative damage to biomolecules such as DNA, proteins, lipids and carbohydrates in the body, eventually leading to many chronic diseases including atherosclerosis, cancer, diabetes, rheumatoid arthritis, stroke, aging and other degenerative diseases (Uttara *et al.*, 2009).

In addition, PV is relatively high in repeatedly heated oils and may be associated with the significant increase in plasma lipid peroxidation. This is supported by several animal studies, in which it was reported that a reduction in serum and hepatic vitamin E content was observed in rats that were fed with a diet containing repeatedly heated oil. Another study reported that oxidised oils can also bring about negative consequences to liver health. When rats were fed with a combination of repeatedly heated soyabean and rapeseed oils, they showed hepatic damage with a significant elevation of the marker enzymes for liver function (Azmil Haizam *et al.*, 2016).

The health consequences caused by oxidised oils are worse than we think, especially when it comes to women who are in the postmenopausal state. A recent scientific study was conducted on female rats without ovaries to produce oestrogen, mimicking the postmenopausal state in women, which is considered as one of the most susceptible state for risk factors relating to oxidative stress. It was reported that the diet containing soyabean oil which had been heated five times significantly increased the plasma lipid peroxidation levels

of the female rats in comparison with palm oil heated the same number of times (Abbas and Elsamanoudy, 2011). Therefore, this finding suggests that long-term consumption of repeatedly heated soyabean oil is harmful to health and may further increase oxidative stress in postmenopausal women. The results are attributed to the higher level of PUFA present in the soyabean oil, which are more susceptible to oxidation as compared with palm oil (Azmil Haizam *et al.*, 2016).

CONCLUSION

Repeated heating of vegetable oils has become a common practice due to a low level of awareness by the public of the consequences of this practice. Apparently, repeatedly heating oils for frying food should not be regarded as a good strategy for saving money. This is because vegetable oils, especially unsaturated oils, become highly detrimental to health when the oils are heated repeatedly, during which various hazardous oxidative products are formed from the lipid oxidation process. In this regard, the media and scientific publications have a role to play in consumer education by raising awareness and understanding in lipid nutrition. The use of palm oil has possibly less deleterious effects on health compared with unsaturated oils due to its oxidative stability against repeated heating.

REFERENCES

ABBAS, A M and ELSAMANOUDY, A Z (2011). Effects of 17β-estradiol and antioxidant administration on oxidative stress and insulin resistance in ovariectomized rats. *Canadian Journal of Physiology and Pharmacology, 89(7)*: 497-504.

AWNEY, H A (2011). The effects of Bifidobacteria on the lipid profile and oxidative stress biomarkers of male rats fed thermally oxidized soybean oil. *Biomarkers, 16(5)*: 445-452.

AYALA, A; MUÑOZ, M F and ARGÜELLES, S (2014). Lipid peroxidation: production, metabolism, and signaling mechanisms of malondialdehyde and 4-hydroxy-2-nonenal. *Oxidative Medicine and Cellular Longevity, 2014*.

AZMIL HAIZAM, A T and RAZALI, I (2014). Versality of palm-based oils for industrial frying. *Palm Oil Developments, 60*: 10-13.

AZMIL HAIZAM, A T; RAZALI, I and AINIE, K (2016). Effect of frying on the palm oil quality attributes - A review. *J. Oil Palm Res., 28(2)*: 143-153.

CHOE, E and MIN, D B (2006). Mechanisms and factors for edible oil oxidation. *Comprehensive Reviews in Food Science and Food Safety, 5(4)*: 169-186.

CHOE, E and MIN, D (2007). Chemistry of deep-fat frying oils. *Journal of Food Science, 72(5)*: R77-R86.

GOSWAMI, G; BORA, R and RATHORE, M (2015). *Oxidation of cooking oils due to repeated frying and human health*. Paper presented at the 2nd International Conference on Science, Technology and Management, New Delhi.

JAARIN, K and KAMISAH, Y (2012). *Repeatedly heated vegetable oils and lipid peroxidation*: INTECH Open Access Publisher.

KALEEM, A; AZIZ, S; IQTEDAR, M; ABDULLAH, R; AFTAB, F R; SHAKOORI, F R and NAZ, S (2015). Investigating changes and effect of peroxide values in cooking oils subject to light and heat. *FUUAST Journal of Biology, 5(2).*

POIANA, M A (2012). Enhancing oxidative stability of sunflower oil during convective and microwave heating using grape seed extract. *International Journal of Molecular Sciences, 13(7)*: 9240-9259.

RAZALI, I (2003). Oil absorption, polymer and polar compounds formation during deep-fat frying of french fries in vegetable oils.

UTTARA, B; SINGH, A V; ZAMBONI, P and MAHAJAN, R (2009). Oxidative stress and neurodegenerative diseases: a review of upstream and downstream antioxidant therapeutic options. *Current Neuropharmacology, 7(1)*: 65-74.