The Pharma Innovation Journal 2017; 6(10): 196-199

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating 2017: 5.03
TPI 2017; 6(10): 196-199

www.thepharmajournal.com
Received: 14-08-2017
Accepted: 15-09-2017

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Change in physicochemical properties of edible oil during frying: A review

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Abstract
Edible oils from plant, animal, or synthetic origin, are used in frying, baking, and other forms of cooking, and in salad dressings and bread dips. Plant-derived edible oils consist of carboxylic acids with long hydrocarbon chains, in contrast to petroleum-based oils which lack the carboxyl group on the end. The carboxyl group makes the oils edible, providing a site for human enzymes to attack and break down the chain in a process called beta-oxidation. There are a wide variety of cooking oils from plant sources such as olive oil, palm oil, soybean oil, canola oil (rapeseed oil), corn oil, peanut oil and other vegetable oils, as well as animal-based oils like butter and lard. This paper incorporates a comparative study of different types of frying oils by their physicochemical properties and compositional qualities. There are numerous health benefits of frying oils which has been covered in the paper along with the future of edible oils in India.

Keywords: Edible oils, carboxyl group, physicochemical properties, health benefits.

1. Introduction

Lipids and triacylglycerol naturally occur in oils and fats. Their chemical composition contains saturated and unsaturated fatty acids and glycerides. Edible oils are vital constituents of our daily diet, which provide energy, essential fatty acids and serve as a carrier of fat soluble vitamins (Erum Zahir *et al*., 2014) [26]. Cooking oil is typically a liquid at room temperature, although some oils that contain saturated fat, such as coconut oil, palm oil and palm kernel oil are solid.

Fat frying is one of the oldest and popular food preparations. Fried foods have desirable flavour, colour and crispy texture, which make deep-fat fried foods very popular to consumers. Frying is a process of immersing food in hot oil with a contact among oil, air, and food at a high temperature of 150 to 190ºC. The simultaneous heat and mass transfer of oil, food and air during fat frying produces the desirable and unique quality of fried foods. Frying oil acts as a heat transfer medium and contributes to the texture and flavour of fried food (Hassan A. Mudawi *et al*., 2014) [15]. Numerous types of edible oils of plant and animal origin are used in frying, depending on regional availability. Palm oil is often used in Southeast Asia, coconut and groundnut oil in the Indian subcontinent, and olive oil in the Mediterranean region. During the last five decades, the Western food industry has become increasingly dependent on the frying process to manufacture a variety of snack foods. Fried foods such as potato chips, french fries, and fried fish and chicken have gained worldwide popularity (Farkas B.E. *et al*., 1996) [10].

According to Erum Zahir, the quality of Corn and Mustard oils was analyzed by evaluating physicochemical properties such as density, viscosity, boiling point, peroxide, iodine and saponification values. Results are presented in Table 1. Oils with lower values of viscosity and density are highly appreciable to consumers. In order to design an advanced technological process these properties are very important parameters.

From the results obtained as presented in Table 1 the saponification value of palm kernel oil (280.5±56.1 mg KOH/g) is higher than those obtained for coconut oil (257.5±6.5 mg KOH/g) and groundnut oil (191.5±3.5 mg KOH/g) and since the higher the saponification value, the higher the unsaturated level of the oil, it can thus be inferred that palm kernel oil possess more unsaturated fatty acids than groundnut and coconut oils. It also indicates that the molecular weight of palm kernel oil is less than those of groundnut and coconut oils (Theodore, 1983) [23]. The iodine value obtained for palm kernel oil (i.e., 15.86±4.02 mgKOH/g) is also higher than those obtained for coconut and groundnut oils (8.5±1.5 mgKOH/g) and 9.4±1.2 mgKOH/g) depicting a higher level of unsaturated (Pearson, 1976) [19]. The peroxide value of palm kernel oil (i.e., 14.3±0.8 mEq/kg) is considerably much higher than those obtained for coconut and groundnut oils which are negligible. This is an indication of the degree of spoilage of palm kernel oil which probably is more liable to rancidity more than the coconut and groundnut oils. This is not unexpected as a result of the inferred higher level of unsaturation. Rancidity begins to be noticeable when the peroxide value is well above 10 mEq/kg (Pearson, 1976) [19]. Furniss (1978) [11] indicated that the lower the molecular weight of an oil, the higher is its unsaturation. The result showed that palm kernel oil has specific gravity of 0.904 compared to those of coconut oil (0.91±0.03) and groundnut oil (i.e., 0.915 ±0.0055) indicating that the molecular weight of palm kernel oil is lower than those of coconut and groundnut oils. The acid value obtained for palm kernel oil (i.e., 2.7±0.3 mg KOH/g) is lower than those obtained for coconut and groundnut oils (i.e. 5.5±0.5 mg KOH/g and 9.0±0.5 mg/KOH/g, respectively) indicating the lower level to which the glycerides in the oil had been decomposed by lipase action (Pearson, 1975) [18]. Therefore palm kernel oil is still in good condition and probably edible since its acid value is less than the values obtained for coconut and groundnut oils.

For Sunflower Oil, the high iodine value portrays that it is rich in unsaturated fatty acid which implies that it will have short oxidative storage stability because according to Perkins the oxidative and chemical changes in oils during storage are characterized by increase in FFA content and a decrease in the total unsaturation of oils (Perkins 1992) [21]. Free Fatty Acid values was lower for the oil as compared to the value recommended by FAO/WHO which may be attributed to the variation in variety, and climatic conditions which is evident in the iodine value. The slightly low saponification value in oil could be attributed to the low FFA content. The acid and peroxide values were within the FAO/WHO standard for edible vegetable oils. The specific gravity shows that the oil is less dense than water.

Table 1: Physicochemical characteristics of edible oils

Physicochemical properties	Palm Kernel Oil	Coconut Oil	Groundnut Oil	Corn Oil	Mustard Oil	Sunflower Oil	Peanut Oil
Saponification value (mg KOH/g)	280.5±56.1	257.5±6.5	191.5± 3.5	153.8	125.6	182.233	_
Acid value (mg KOH/g)	2.7±0.3	5.5±0.5	9.0±0.5	_	_	0.953	
Free fatty (FFA) (mg KOH/g)	1.35±0.15	2.75±4.5	4.5±0.25	0.125(%)	_	0.042(%)	0.150
Peroxide value (mEq/kg)	14.3±0.8	_	_	0.162	0.83	6.322	2.000
Iodine value (mgKOH/g)	15.86±4.02	8.5±1.5	9.4±1.2	15.96	8.10	119.921	
Specific Gravity value (S.G)	0.904	0.91±0.003	0.9155±0.0055	_	_	0.915	0.9146
Refractive index	1.412^{o}	1.449±0.001	1.47±0.001	1.4750	_	_	1.471
Viscosity				112 (millipoise)	117.27 (millipoise)	28.3(at30^{o}C)	41.00 (centipoise)
Odour	Burnt Smell	Pleasant	Pleasant	_	_	_	_
Colour	Burnt Brown	Pale yellow	Very pale brown	25(R) 0.9(Y)	_	25(R) 0.4(Y)	1.3(R) 10(Y)
Stability	Soluble in non-polar solvent	Soluble in non polar solvent	Soluble in non polar solvent	_	_	_	_
Ester Value(mg KOH/g)	277.8±56.4	252±6.5	182.5±3.0	_	_	182.138	_
Source	Amira, P. Olaniy i*et al.*,2014 [2]	Amira, P. Olaniyi *et al.*, 2014 [2]	Amira, P. Olaniyi *et al.*, 2014 [2]	Erum Zahir *et al.*, 2014 [26]	Erum Zahir *et al.*, 2014 [26]	Hassan A. Mudawi, 2014 [15]	Muna Abass Fadlelseed and Ahlam Ahmed Hussain, 2016

1.1 Necessity of checking the quality of frying oil

Deep frying is one of the most common methods used for the preparation of food. Repeated frying causes several oxidative and thermal reactions which results in change in the physicochemical, nutritional and sensory properties of the oil (Che Man and Jasvir, 2000) [8]. During frying, due to hydrolysis, oxidation and polymerization processes the composition of oil changes which in turn changes the flavour and stability of its compounds (Gloria and Aguilera, 1998) [13]. During deep frying different reactions depend on some factors such as replenishment of fresh oil, frying condition, original quality of frying oil and decrease in their oxidative stability (Choe and Min, 2007) [9]. Atmospheric oxygen reacts instantly with lipidand other organic compounds of the oil to cause structural degradation in the oil which leads to loss of quality of food and is harmful to human health (Bhattacharya *et al*., 2008) [6].

Therefore, it is essential to monitor the quality of oil to avoid the use of abused oil due to the health consequences of consuming foods fried in degraded oil, to maintain the quality of fried foods and to minimize the production costs associated with early disposal of the frying medium (Vijayan *et al*., 1996) [24].

1.2 Physicochemical changes occurring in oil during frying

Oil is an excellent heating medium, because it allows high rates of heat transfer intofoods being cooked. However, the frying process also causes a number of chemical and physical changes in the oil. These changes not only influence the heating characteristics, but also bring about changes in the sensory and nutritional characteristics of foods (Farkas B.E. *et al*., 1996) [10]. Physicochemical changes in the oil are due to three factors:

- Oxidative stability is very important factor in oil quality especially for frying therefore the frying oil must have high oxidative stability during use (Tabee, *et. al*., 2008) [22].
- Hydrolytic changes due to water vapours from the product undergoing frying (Gertz and Klostermann, 2002) [12]
- Thermal changes due to oil being maintained at high temperatures.

Volatile compounds produced during frying influence the organoleptic quality of the food. Non-volatile compounds in the oil are important, because they migrate into the food undergoing frying and are subsequently ingested. These non-volatile compounds are also the basis of several analytical procedures used to measure alterations in the oil due to frying (Farkas B.E. *et al*., 1996) [10]. The reactions in deep-fat frying depend on factors such as replenishment of fresh oil, frying conditions, original quality of frying oil, food materials, type of fryer, antioxidants, and oxygen concentration. High frying temperature, the number of frying, the contents of free fatty acids, polyvalent metals, and unsaturated fatty acids of oil decrease the oxidative stability and flavour quality of oil. Antioxidants decrease the frying oil oxidation, but the effectiveness of antioxidant decreases with high frying temperature (Hassan A. Mudawi *et al*., 2014) [15].

1.3 Physicochemical changes occurring in food during frying

Frying time, food surface area, moisture content of food, types of breading or battering materials, and frying oil influence the amount of absorbed oil to foods (Moreira *et al*., 1997) [14].

Foods fried at the optimum temperature and time have golden brown colour, are properly cooked, crispy, and have optimal oil absorption (Blumenthal *et al*.,1991) [7]. However, under-fried foods at lower temperature of shorter frying time than the optimum have white or slightly brown colour at the edge, and have un-gelatinized or partially cooked starch at the centre. The under-fried foods do not have desirable deep-fat fried flavour, good colour, and crispy texture. Over-fried foods at higher temperature and longer frying time than the optimum have darkened and hardened surfaces and a greasy texture due to the excessive oil absorption (Hassan A.Mudawi *et al*., 2014) [15].

1.4 Edible oil used in frying foods

Some of the commonly used oils in industrial applications involving food frying are reviewed. In addition to the oils mentioned, many modified, fractionated, or hydrogenated oils are used in frying that provide required performance in terms of process, cost, and quality characteristics.

1.5 Tests performed and their importance

Physicochemical properties of oils are determined to know the quality, purity and identification. Characteristic properties are properties that depend on the nature of the oil. These are used to characterize oil, irrespective of location or sources of origin (Amira *et al*., 2014) [2].

Iodine value is a measure of the degree of unsaturation or double bonds among the fatty acid present in the oil therefore it does not tell precisely the fatty acids composition of any oil. Iodine value or number is useful as a guide to check adulteration of oil and also as a process control of oil.

Peroxide value is used in determining the degree of spoilage. The standard peroxide value for edible oils which have not undergone rancidity must be well below 10 meq/kg (Pearson, 1976) [19].

Free fatty acid value is often used as general indication of the condition and edibility of oils (Pearson, 1976) [19]. Saponification value is a rough index of the molecular weight of the fat or oil. The smaller the saponification value the higher the molecular weight. It also indicates the quantity of alkali required for conservation of a definite amount of fat or oil into soap. It is used to check the adulteration of fat and oils (Theodore, 1983) [23]. Esterification value is the difference between the saponification value and the free fatty acid value of the fats and oils.

Refractive index is the degree of refraction of a beam of light that occurs when it passes from one transparent medium to another. The refractive index of an oil can be estimated with the aid of a refractometer in degrees, at 20°C usually. The value obtained is unique for a particular oil and can therefore be used to check adulteration and purity of oil (Pearson, 1981) [20].

Specific gravity is determined and calculated at temperature 20°C as a ratio of mass in air of a given volume of the oil or fat to that of the same volume of at 20°C (Theodore, 1983) [23]. It can reveal the extent of adulteration and may be used as a means of acceptance of oils as raw materials as well as determination of size of pumps and piping in plant installation. The relative density of most oil range between 0.89 and 0.92 at 20°C (Theodore, 1983) [23].

Other variable properties of oil include solubility, freezing point, colour, odour and boiling point. Oil spoilage can be prevented through exclusion of air, addition of antioxidants, addition of chelation agents and hydrogenation (Furniss, 1978) [11].

2. Conclusion

Based on the results, all the physicochemical characteristics of all oils can be seen and it is observed that it gets changed due to the five consecutive frying processes. The present review paper was written using one item of food which is potatoes, while so many other items exist and they may give different results if tested, especially in connection with physical characteristics. Therefore, similar studies using other food items are recommended. More research is needed in this field to cover more types of oils other than this oil especially Rice Bran Oil and its blend with other oil due to its high antioxidant content.

3. Acknowledgement

The authors are hereby acknowledging the Honorable Managing Director of JIS Group for financial support and inspiration.

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