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Determination Of Changes Occurring In Chemical Properties Of Fat Repeatedly Used For Food Frying

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***Abstract*— The physical and chemical properties of oil can be changed during deep frying. To investigate those changes three major oils namely Coconut, Palm(olein) and Sunflower oils were taken and subjected to deep fat frying of meat and potatoes at 185°C. Three frying cycles have been undertaken for each oil. After frying, oil has been taken and analyzed for free fatty acid level, iodine number and composition of fatty acid profiles. Results revealed that major constituent of coconut, palm and sunflower oils was lauric, palmitic and linoleic acids respectively. The FFA values of coconut, palm and sunflower oils were changed from 0.091 to 0.221, 0.086 to 0.171, and 0.060 to 0.121 respectively when meat was fried. And it was changed from 0.091 to 0.234, 0.086 to 0.177, and 0.060 to 0.101 for the same oil when potato was fried. Iodine value of coconut oil has been increased from 8.211 to 12.537 and 8.211 to 8.494 when meat and potato were fried. For palm oil, it has been increased from 54.207 to 70.234 and 54.207 to 75.930 when same commodities were fried. For sunflower oil, it has been increased from 106.486 to 122.465 and 106.486 to 121.854 for frying of same products, meat and potato.**

Peroxide value of palm oil has been increased from 3.466 to 6.172 and 3.466 to 6.790 when meat and potato were fried. For sunflower oil, it has been increased from 7.556 to 13.172 and 7.556 to 12.582 when same commodities meat and potato were fried. Peroxide values of coconut oil have been increased from 0.589 to 2.435 and 0.589 to 2.412 when meat and potato were fried respectively.

When results are compared against ISO requirements, Sunflower oil showed much stability than coconut and palm oils throughout the frying process. The formation of free fatty acid was low in sunflower oil. And also the degrees of un saturation was within the limits. Therefore, the study revealed that sunflower oil is more stable and more suitable for repeated deep-frying process.

Keywords*— *Coconut oil, Palm olein, Sunflower oil, Free fatty acids, Iodine value, Peroxide value

I. INTRODUCTION

Different types of oils such as coconut oil, palm oil, sunflower oil, olive oil, sesame oil, corn oil and soya bean oil are widely being used in edible purposes particularly in deep frying of foods. During frying process, oils undergo numerous changes in physical, chemical and organoleptic properties because frying is taking place at high temperatures possibly at 165-185^{0}C. These changes some instances may course for health hazards and that can be further aggravated if oil is used for repeatedly frying. Moreover, continuously using of fat for deep frying may negatively affect for the quality of oil as well as quality of the fried food product.

Further, if oil is repeatedly used for food frying, the process itself may adversely affects for the shelf life and nutritional quality of fried foods due to development of rancidity in the oil taken up by the products themselves. High frying temperature, associated with the presence of air and moisture, lead to production of breakdown products that include volatile and non-volatile compounds and these products may catalyst for further oxidation of unsaturated fatty acids as well as hydrolysis of lipids. Nevertheless, high temperature may cause for transformation of linear fatty acids into cyclical compounds, development of free fatty acids and polymerization of lipids. The intensity of reactions related to deep fat frying is depending upon duration of frying, method of heat treatment, frying medium and type of the food product itself.

Therefore, in order to protect the health of the consumer, it is essential not only to monitor the quality of oil, but also to determine impact of their byproduct for the well being of the consumer. The general objective of this study was to evaluate the effect of frying on chemical properties of three brands of oils in Sri Lankan market and also to determine whether these oils are suitable for how many frying cycles for deep frying. Moreover, this study envisages determining the changes occurrence on free fatty acid level, Peroxide value, iodine number, and fatty acid composition of oil repeatedly subjected to deep frying.

II. MATERIALS AND METHODS

A. Preparation of sample for the study

Three oils namely coconut, palm (Olein) and sunflower oils were taken and initial free fatty acid level, iodine number and peroxide value were determined according to ISO Standards Initially 250g of potato slices were taken and immersed in hot coconut oil at 170^{0}C for 10min. . Thereafter, 100ml of oil sample was taken and packed in an amber color bottle without leaving a head gap. The remained oil was left for 24hrs without disturbing and again subjected to deep fat frying using 225g of same commodity and again 100ml of oil sample was taken and packed in an amber color bottle without a head gap. The rest portion of the oil was left for 24hrs again and subjected to third frying using 200g of potato slices and 100ml of oil was packed in same manner as previously done. The same frying procedure was followed for frying of chicken meat too. Thereafter, same methodology was followed for palm and sunflower oils in frying of potato and chicken meat too. All treatments were replicated thrice and stored under ambient environmental conditions (28-300C and 76-82% RH) with a view to determine changes occurrence on free fatty acid level, iodine number and peroxide value. Further, these samples were subjected to determine possible changes occurrence in fatty acid profiles of each oil using GC-MS method (Agilent Technologies – 5975C). Determination of Free Fatty acid level, Iodine number and Peroxide value were done according to the test methods of ISO 660 : 2009, ISO 3961 : 2013 and ISO 3960 : 2007 respectively Determination of Fatty acid profiles.

B. Determination of Fatty acid profiles

Determination of fatty acid profiles of oils were done according to the methodology, described in ISO 5508 : 1990 & ISO 5509 : 2000.There in, 0.1g of test portion was taken into a test tube and added 10 ml of heptane . 0.5 ml of methanolic potassium hydroxide was added and shake vigorously for about 30 seconds. About 1g of sodium hydrogen sulfate monohydrate was added to the mixture to neutralize it. After salt has been settled the upper layer containing the methyl ester was decanned by a vial and injected to GC-MS. Identify peaks on chromatogram base on retention data from analyzed standard samples.

III. RESULTS AND DIISCUSSION

A. Free Fatty Acid Level Of Oil

Development of free fatty acids in coconut oil, sunflower oil and palm oil were evaluated after 1st frying, one day after 1st frying, 2nd frying, one day after 2nd frying, 3rd frying and one day after 3rd frying of Potato & Chicken and results are given in Figure 4.1

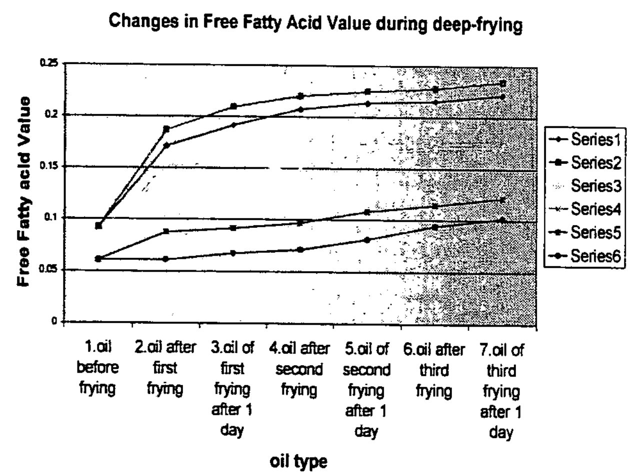

Figure 1: The Change in Free Fatty Acid level during deep-frying

Series 1- Coconut oil, when fried chicken meat
Series 2- Coconut oil, when fried potato

Series 3- Palm olein, when fried chicken meat

Series 4- Palm olein, when fried potato

Series 5- Sunflower oil, when fried potato

Series 6- Sunflower oil, when fried chicken meat

The graphs given in fig. 4.1 clearly indicate that free fatty acid level of three types of oils subjected for deep frying was gradually increasing however at different rates against number of frying cycles and the period left out after frying. Development of Free fatty acids (FFA) in palm oil is relatively lower than that of the other two oils, because FFA values of coconut oil, palm olein and sunflower oil were increased from 0.091 to 0.221%, 0.086 to 0.171%, and 0.060 to 0.121% respectively after chicken meat was fried and it was elevated from 0.091 to 0.234%, 0.086 to 0.177%, and 0.060 to 0.101% against same order of oil after potatoes were fried.

The causes for development of FFA in oil after frying of foods were releasing of water from food to frying oil, somewhat higher frying temperature, number of frying cycles being adapted and accumulation of burn food particles into frying medium.

B. Iodine values of oils after deep frying cycles

Iodine value of coconut, sunflower and palm oils were analyzed after carrying out of three deep- frying cycles with chicken meat and potatoes and results are showing in Figure 4.2

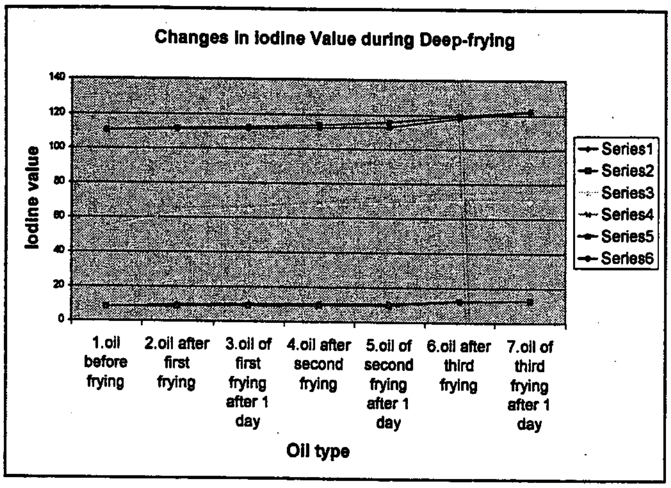

Figure 2: The Change in Iodine value of oils after deep-frying

Series 1- Coconut oil, when fried chicken meat

Series 2- Coconut oil, when fried potato

Series 3- Palm oil, when fried chicken meat

Series 4- Palm oil, when fried potato

Series 5- Sunflower oil, when fried chicken meat

Series 6- Sunflower oil, when fried potato

According to figure 4.2, Iodine values of oils are gradually increasing along with the number of frying however increment of which was taking place at very slow rate. For coconut, palm and sunflower oils iodine values have been increased from 8.211 to 12.537, 54.207 to 70.234 and 106.486 to 122.465 respectively after frying of chicken meat and it was elevated from 8.211 to 8.494, 54.207 to 75.930, 106.486 to 121.854 respectively after carrying out of potato frying. Reason for this phenomenon may be due to incorporation of fat of the food product into the frying medium. Generally, high frying temperature is not favorable for the unsaturated fatty acids, as they usually tends to polymerize at high temperatures with other fatty acids. And outcome of this process is forming of long chain saturated fatty acids.

These fatty acids are relatively heavy and precipitate to the bottom of the frying medium. Hence, iodine value of frying oil is gradually declined with the number of frying cycles carried out using same oil.

C. Peroxide values of oils after deep frying cycles

Changes in Peroxide values of coconut oil, sunflower oil and palm oil were evaluated after deep-frying of chicken meat and potatoes and results are given in Figure 3

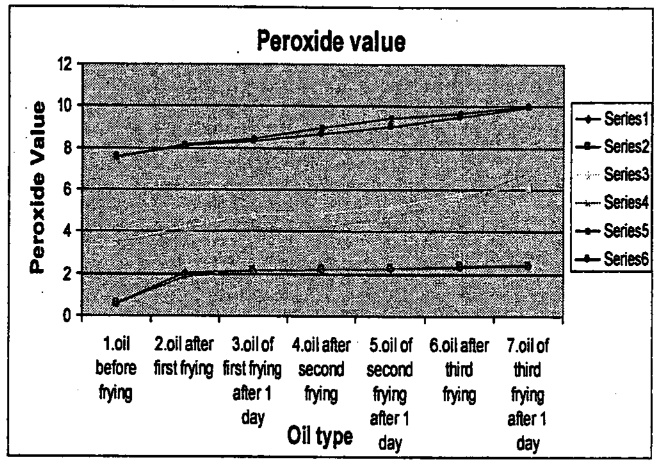

Fig. 3 The Change in Peroxide values of oils after deep-frying

Series 1- Coconut oil, when fried chicken meat
Series 2- Coconut oil, when fried potato

Series 3- Sunflower oil, when fried chicken meat

Series 4- Sunflower oil, when fried potato

Series 5- Palm olein, when fried potato

Series 6- Palm olein, when fried chicken meat

The graphs given in Fig. 4 indicate that peroxide values of Sunflower, coconut and palm oils have been increased from 3.466 to 6.172, 0.589 to 2.435 and 7.556 to 9.993 respectively after chicken meat was fried in the same oil thrice. Whereas, peroxide value was increased from 3.466 to 6.790, 0.589 to 2.412 and 7.556 to 9.973 for the same order of oils, when potato was fried. When food is repeatedly fried in the same oil at high temperatures, the contents of free fatty acids, polyvalent metals and unsaturated fatty acids, cause to decrease the oxidative stability and flavor quality of oil remarkably. Hence, these constituents adversely affect for the vigor of oil due to forming of more short chain and highly volatile fatty products. In general, greater the degree of unsaturation, the greater the liability of fat to oxidative rancidity. When the concentration of peroxides reaches a certain level, complex chemical changes occur and volatile products are formed which mainly responsible for the rancid taste and odor (Egan, Kirk and Sawyer, 1981).

D. Composition of fatty acid profiles of oils after deep frying

Chemical composition of coconut, palm and sunflower oils were measured after carrying out of 3 frying cycles and results are given in the table 1, 2 and 3.

Table

Table 1. Major constituents in coconut oil

Percentage as methyl esters Major constituents in oil	C0 +/-SD	C1+/-SD	C2+/-SD	C3+/-SD
Decanoic methylester	5.647%+/_0.746653	5.812%+/_0.746653	5.582%+/_0.746653	5.499%+/_0.746653
Methyl Tetradecanoat	21.325%+/_0.471275	21.245%+/_0.471275	21.903%+/_0.471275	22.229%+/_0.471275
Hexadecanoic acid methyl ester	9.643% +/_0.165753	9.674%+/_0.165753	9.712%+/_0.165753	10.003%+/_0.165753
(Co – before frying, C1 – after first frying, C2 – after second frying, C3 –after third frying, SD=Standard Deviation)				

Table 2. Major constituents in palm olein

Percentage as methyl esters Major constituents in oil	P_0 +/-SD	P_1 +/-SD	P_2 +/-SD	P_3 +/-SD
Hexadecanoic methylester	43.805% +/_0.746653	42.782% +/_0.746653	43.025% +/-_0.746653	43.190% +/_0.746653
9,12-octadecanoic acid methyl ester	10.156% +/_0.218224	9.683% +/_0.218224	9.795% +/_0.218224	9.712%+/_0.218224
9-octadecanoic acid methyl ester	39.984% +/_0.577533	41.330%+/_0.577533	40.537% +/_0.577533	40.280%+/_0.577533
(Po – before frying, P1 – after first frying, P2 – after second frying, P3 –after third frying, SD=Standard Deviation)				

Table 3. Major constituents in sunflower oil

Percentage as methyl esters Major constituents in oil	S0 +/-SD	S1+/-SD	S2+/-SD	S3+/-SD
Pentadecanoic acid,14-methyl ester	7.376% +/-0.095411	7.563%+/-0.095411	7.542%+/-0.095411	7.535%+/-0.095411
9,12-octadecenoic acid methyl ester	50.044%+/-0.970651	59.881%+/-0.970651	60.090%+/-0.970651	58.072%+/-0.970651
9-octadecenoic acid methyl ester	27.102%+/-0.373322	27.113%+/-0.373322	27.843%+/-0.373322	27.076%+/-0.373322
(So – before frying, S1 – after first frying, S2 – after second frying, S3 –after third frying, SD=Standard Deviation) ;				

According to the data given in tables 1, 2 & 3, different methyl esters have been formed during frying process. The major constituent found in coconut oil is 'Dodeconoic acid' which is commonly known as Lauric acid. In palm oil, major constituent is 'Hexadecanoic acid', known as Palmatic acid. Sunflower oil consist with '9,12-octadecadienoic acid' as major constituent which is known as Linoleic acid. Moreover, these data clearly indicate that there are slight changes occur in the percentages of fatty acids. But the changes of are not significant against the frying cycies of each oils.

This indicates how the lipids get fractioned during frying. Lipids mainly consist of triglycerides, which are esters of one glycerol molecule and three fatty acids. Most edible fats and oils are composed largely of 12 to 20 carbon fatty acids. During frying linear saturated fatty acids, branched, mono-unsaturated, di-unsaturated, and higher unsaturated fatty acids can occur. These differences appear due the chain length, unsaturation degree and position of unsaturation. Oil that contains fatty acids with short chain have lower melting point and are more soluble in water. Whereas, the oils that contain fatty acids with longer chain have higher melting points. Unsaturated acids will have a lower melting point compared to saturated fatty acids of similar chain length

IV. CONCLUSION

Before frying all the oil varieties have been in incompliance with the AOAC requirements. During frying the oil react with the moisture in the food material and undergoes hydrolysis.

During further heating those formed hydrolyzed free fatty acids have been undergo oxidization and formed peroxides. Hence the formed peroxides can form radicals.

Therefore, it have been shown that higher the possibility to form free fatty acids higher the formation of peroxide radicals which are having the ability to cause carcinogenic effect on human body. The study indicates that among three oils used for analysis, sunflower oil shows much more stability in its chemical properties. There for the study shows that sunflower oil were much safer to use in repeated deep-frying than coconut oil and palm oil. Deep-fat frying produces desirable or undesirable flavor compounds and changes the flavor stability and quality of the oil by hydrolysis, oxidation, and polymerization. Tocopherols, essential amino acids, and fatty acids in foods are degraded during deep-fat frying. 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 flavor quality of oil. Antioxidant decreases the frying oil oxidation, but the effectiveness of antioxidant decreases with high frying temperature.

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