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Assessment of Effect of Repeated Heating of Oil on the Quality and Stability of Frying Oils

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ABSTRACT

Cooking oils play a crucial role in various culinary applications and have become an ubiquitous component of the modern diet, especially when it comes to frying. However, the process of repeated frying cycles exposes cooking oils to high temperatures, which leads to a range of physicochemical transformations. In this study four samples of used(fried) oils - sunflower oil and palm oils were collected and analysed to which the result revealed significant alternations in the physiochemical properties such as pH (6.2-5.5), density (0.88-0.95g/ml), peroxide values (17.6-23meq/kg), iodine values(61-75gI2/100g) and acid values (14.1-16.4mgKOH/g) etc, compared to standard values, indicating notable transformations like rancidity , high oxidation, unsaturation and acidic nature etc, in the oils due to repeated frying cycles. Also, the p value calculated for all the analysis was found below the established threshold ($\alpha \leq 0.05$), emphasizing the statistical significance of these changes. These major changes in oil samples indicates that cooking at high temperatures or repeated use of oil for frying purpose effects the quality and safety of cooking oils.

Keywords: physiochemical, peroxide, unsaturation, threshold, statistical, sensory, significance value, palm oil, sunflower oil

1. INTRODUCTION

Frying is a popular cooking method used worldwide to enhance the flavour, texture, and appearance of various food products. One crucial aspect of achieving desirable fried food characteristics is the quality and stability of the frying oil. As oil is repeatedly heated during frying, it undergoes chemical and physical changes, which can affect the overall quality of the oil and the fried products, frying is a process of immersing food in hot oil with a contact among oil, air, and food at a high temperature of 150 °C to 190 °C (Dobarganes,Cand Ma´rquez-Ruiz,G., 2015).Though deep frying provides us with palatability but repeated use of oils for frying purpose has adverse effect as high temperatures are used in deep frying which cause formation of harmful substance due to breakdown of compounds present in oils, also changes its appearance causing an increased viscosity and dark colour, which ultimately many physiochemical changes the fatty acid composition, peroxide values and iodine values indicating high unsaturation, rancidity and change in nutritional value of the oils (Nayak et al., 2016).

The formation of different toxic compounds and other by-products such as (acrylamide, polycyclic aromatic hydrocarbons (PAH'S) etc) in the used oils are associated with various diseases such as diabetes,

obesity, cardiovascular diseases, and cancer etc (Li et al, 2019). Also, the pH of oils decreases from standard neutral value to acidic due to hydrolysis of triglycerides (Baig et al ,2022). Repeated use of oil is done by either adding new oil to the used oil and also because it is cost effective, this is done where there is large need of oil in restaurants, food courts etc, changing the oil every time for fresh frying is not possible at large levels which is a costly process. When deep-frying in heated oil, the water extracted from the food produces steam, which triggers the hydrolysis of the fat (Mir-Bel et al., 2012). During frying, the food absorbs a lot of oil (from 5 to 40 %) and releases some lipids to the frying fat (Kochhar, 2016). Mainly a comparison between sunflower and palm oil is done as they are common oils used at different places like restaurant where the oils are used multiple times, then local shops and the house where there is less use or repetition of oil compared to restaurants and local shops.

The qualitative analysis of these oils shows how oils behave on continuous use which shows the degradation of oil, saturation, rancidity etc. Sunflower oil contains two of the most abundant types of fatty acids: oleic and linoleic acid, which can be reduced through neutralization. The fatty acid profile of sunflower oil also includes palmitic, stearic, eicosenoic, and linolenic acids, with linoleic and oleic acids present in higher proportions compared to others. On the other hand, the presence of free fatty acids in palm oil is traditionally determined through titration against potassium hydroxide. If lipases are not inactivated rapidly by heating, the level of free fatty acids in palm oil can rise, which affects the quality of the oil. The smoke and boiling point of oils states whether the oils are capable of being used for frying purposes as the is decrease in these values as temperature increases.

The rate of formation of cooking oil decomposition products depends on the type of food being fried, the type of oil used and the design of the fryer, etc. The presence of food particles accelerates the darkening of the oil during the process; deep-frying fats react with food ingredients, proteins and carbohydrates, forming desirable and undesirable flavours (Mir-Bel et al., 2012). Extensive thermal-oxidative degradation of fats during long deep-frying not only reduces the sensory quality of the fried food, but can also reduce its nutritional value (Mba et al., 2017). Therefore, the deep-frying process must be carefully controlled, especially the oil temperature, the frying time, the creation of physical barriers on breaded foods, the control of the polarity of deep-frying fats with frequent oil changes (Zeleňáková et al., 2019). It is necessary to change the deep-frying process by adjusting the temperature, frying time or method to reduce the fat absorption into the food, to develop the desired sensory properties of the fried food and to minimize the formation of thermal degradation products and interactions that cause unpleasant taste and potential safety problems (acrylamide) (Gertz, 2014; Guerra-Hernandez, 2016).

The reactions in oil rich 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 (Goswami G., 2015). To prevent these changes in physiochemical properties of oils which has a significant impact on the quality and safety of oil, the oils can be either sent for recycling or may be discarded through various methods. The Repurpose Used Cooking Oil (RUCO) initiative was started by India's food safety regulator, the Food and Safety Standards Authority of India (FSSAI), to combat the growing diversion of UCO back into food supply. The goal is to develop a legal and regulatory framework to shift UCO away from the food chain and towards other waste-to wealth industries including bio-fuels, soaps, and oleo-chemicals (Govease N.,2022).

2. MATERIAL AND METHODS

2.1. SAMPLE COLLECTION

The samples were collected from nearby locality of New bowenpally, secunderabad, India. From various places like(A)Restaurant, (B)Dhaba, (C)Local Street food shop and (D)Home. Fried oils used multiple times was collected, the oil samples collected from restaurant and Dhaba was more used compared to local street shops and house. The samples collected are of two types palm oil collected from restaurant and local street shop and sunflower oil collected from Dhaba and home, as these oils were commonly used for the purpose of frying in the locality, the measurement of oil sample collected was about each 300ml for the study and analysis. Reason for sample collections**:** The reason of oil sample collection was there were commonly used as frying oils and to perform various analysis on the sample to know the quality of used oils and their effects on consumption.

2.2. PHYSIOCHEMICAL ANALYSIS

2.2.1. Density

The density of oil samples was calculated by mass of the sample per unit volumes

Density of oil sample = wt. of oil in grams / Volume of oil in ml

The oil sample used for measure of density was 10 ml (Kumar et al, 2018).

2.2.2. Boiling point measurement

The boiling point of oil samples were measured by a thermometer ±1 °C. The boiling point depends upon the degree of unsaturation of fatty acids (Zahir et al, 2017).

2.2.3. pH

pH of the oil samples was measured by using pH meter.

2.2.4. Smoking point

Every oil has a smoke point, or the temperature at which the fatty acids start to break down and burn. While repeated exposure to the by-products from heating an oil past its smoke point can have negative effects on your health (and change the flavour of your food). It is done by noting down the temperature at which smoke arises while heating oil (Zahir et al, 2017).

2.2.5. Oil absorptivity

Oil absorption is the measure of how much oil a substance can absorb or hold, and it is often used in the food industry to determine the quality of ingredients like flour, starch, and other powders. Weight a known amount of the substance (e.g., 10 grams), add a measured amount of oil (e.g., 10 millilitres) to the substance and mix thoroughly, let the mixture sit for a specific amount of time (e.g., 5 minutes), after the designated time has elapsed, weigh the mixture to determine the weight gain. Calculate the oil absorption by dividing the weight gain by the weight of the original substance and multiplying by 100.

The formula for calculating oil absorption is: Oil Absorption =

[(Weight of Mixture - Weight of Substance) / Weight of Substance] x 100 (Momoh et al, 2017).

2.2.6. Colour

The colour of the oil samples was noted before frying and after frying of oil samples.

2.2.7. Peroxide value

Peroxide value is used as a measure of the extent to which rancidity reactions have occurred (Mengistie et al, 2018). Weight about 2 ml of oil sample in 250ml of conical flask. Add 30 mL acetic acid chloroform solvent mixture and swirl to dissolve. Add 0.5 ml of saturated KI (potassium iodide) solution and allow to stand with occasional stirring for 1 minute and then add 30 ml of distilled water. Keep in dark room for 10-15 minutes. Titrate with 0.1N sodium thiosulphate adding gradually with constant and vigorous shaking till yellow colour almost disappears. Add 0.5 ml starch indicator solution continue shaking vigorously till the end point is liberated (blue colour). Titrate against thiosulphate solution until blue colour disappears. Conduct a blank test (the blank titration must not exceed 0.1 ml of 0.1 N of sodium thiosulphate solution) (FSSAI manual, 2021).

Calculate the values obtained by following formula:

$$\text{Peroxide value} = S\text{-}B \times N \times 100 / \text{Wt. of sample}$$

S= titrate value of 0.1 N sodium thiosulphate
B= blank titrate value
N = normality of sodium thiosulphate

2.2.8. Acid value

It is used to determine or measure the amount of presence of free fatty acids present in fats and oils and is a good indicator of oil degradation caused by hydrolysis or enzymes. Accurately weigh 1gram of oil sample in a 250ml Erlenmeyer flask. Add carefully 50 ml of neutralised ethanol (1:1 ratio of ethanol and ether), and add 2 ml of phenolphthalein indicator. Shake to dissolve and titrate against standard 0.1N KOH (potassium hydroxide) solution. Shake vigorously until end points is reached which is indicated by light pink colour that persist for 30 seconds. Record the volume of titrate used. Repeat the first three steps with triplicate values and record the reading) (FSSAI manual, 2021).
Calculation:

$$\text{Acid Value} = \text{titrate value} \times 5.61 \times N/W$$

Where, V = Volume in mL of standard Potassium hydroxide or sodium hydroxide used
N = Normality of the Potassium hydroxide solution or Sodium hydroxide solution; and
W = Weight in g of the sample

2.2.9. Fatty acid percentage

This can be calculated with the help of values obtained from acid value chemical analysis based on the type of free fatty caid present in the oil sample (FSSAI manual, 2021). which is calculated as follows

- Free fatty acid as oleic acid % by weight = $28.2 \times V \times N/W$
- Free fatty acid as linoleic acid % by weight = $28 \times V \times N/W$
- Free fatty acid as steric acid % by weight = $28.4 \times V \times N/W$
- Free fatty acid as palmitic acid % by weight = $25.6 \times V \times N/W$

Where;
V = Volume in mL of standard Potassium hydroxide or sodium hydroxide used
N = Normality of the Potassium hydroxide solution or Sodium hydroxide solution
W = Weight in g of the sample.

2.2.10. Iodine value

It is used to measure the degree of unsaturation in the oil sample. Weigh 0.2 to 0.4 grams of the oil sample in a clean and dry iodine flask. Add 10 mL of chloroform and 25 mL of Hanus iodine solution (iodine monochloride in acetic acid) to the flask. Stopper the flask and shake it vigorously for 30 seconds. Allow the flask to stand in a dark place for 30 minutes to complete the reaction. Add 25 mL of 10% w/v potassium iodide solution and 150 mL of distilled water to the flask. Titrate the excess iodine with 0.1 N sodium thiosulfate solution, using 1% starch solution as an indicator (FSSAI manual, 2021).
Calculate the iodine value of the oil sample using the following formula:
Iodine value = (B-A x Normality of sodium thiosulfate x 12.7) / Weight of oil sample taken
Where, S= titrate value of 0.1 N sodium thiosulphate, B= blank titrate value

2.3. SENSORY ANALYSIS

A panel of 20 trained members are selected for sensory evaluation of papad cooked in the oil samples collected. The method used for evaluation is 5 -point hedonic scaling method for descriptive sensory analysis of attributes like aroma, taste, appearance and texture. All the rating were recorded in the score card. Sensory evaluation of used oil involves assessing the sensory attributes of cooking oil that has been subjected to repeated heating and frying cycles. It aims to determine the changes that occur in the sensory properties of the oil as a result of its usage and degradation over time.

2.4. STATISTICAL ANALYSIS

To determine the difference between the physiochemical analysis of all four samples collected of oils ANOVA statistical analysis was done considering standard threshold p value i.e., ($\alpha \leq 0.05$). The statistical analysis was done on almost all physiochemical properties to know whether the values obtained are significant or not, statistical analysis (considering heat as independent variable of oil samples and physiochemical properties as dependent variables) one way ANOVA was performed in Excel sheet using data analysis.

3. RESULT AND DISCUSSION

EFFECT OF FRYING ON PHYSIOCHEMICAL PROPERTIES OF OIL

3.1.Density

According to the data represented in Table 1 the density values obtained ranged from 0.95-0.9 g/ml at room temperature 27ºc. The density values recorded in home sample (sunflower oil) is 0.95g/ml highest, Dhaba (sunflower oil) is 0.94g/ml and lowest in restaurant and local shop (palm oil sample) is 0.9g/ml each. Whereas the standard value of palm oil according to Codex Alimentarius Standard, for palm oil is 0.889–0.895 g mL−1at 20◦C and the standard value for sunflower oil density according to Codex Alimentarius standard is 0.916- 0.923 x=20º C. (Codex Alimentarius standards, 2022). The observed density of sunflower oil samples is more than the density of palm oil samples due to the unsaturated fatty acids. The density values recorded are slightly higher than the standard values, the variation in the values is due the fatty acid composition, and other frying conditions (like material used, food fried etc). Oil density varies depending on the nature of the fatty acids that makes it up. Unsaturated oils have higher densities than saturated oils (Abd El-Khair et al 2019). Though palm oil contains equal amount of saturated and unsaturated fatty acids it is mainly considered unsaturated and sunflower oil is highly unsaturated due to which the valued obtained in data are high as unsaturated fatty acids are denser than saturated ones

(Almeida E.et, al 2021).The p value calculated for the density of oil samples was 0.04 which is ≤ 0.05 (alpha) and F calculated > F critical is (6.8>6.5) which shows that there is significant difference in the values of samples, this change shows that repeated heating/frying of oils have significant effect on the density of oil samples (Baig et al ,2022).

3.2.Boiling and smoking point

The data obtained in Table 1 shows the boiling points of samples ranges from 230 – 224º C the values recorded for the samples are home (sunflower oil) is highest 230 º C, followed by restaurant (palm oil) 229 º C, local street shop (palm oil) 228 º C and lowest Dhaba (sunflower oil) 224 º C respectively. There is no standard value for boiling point of oil as it depends on various conditions like material used, food cooked, oil used etc, but the normal boiling point of oils must not exceed the smoking point. If the boiling points of the used oils higher than their smoke point values, it indicates that these oils can still be heated to temperatures at or below their boiling points without reaching the temperature at which visible smoke is produced. However, it's important to note that even if the boiling point is higher than the smoke point for used oils, the decrease in the smoke point suggests that the oil is more prone to smoking and degradation at lower temperatures compared to fresh oils. This can result in the release of harmful compounds, unpleasant Flavors, and potential health risks (Elalami, S. H.,2019).

The smoke point recorded for the oil's ranges from 203 - 221 º C the highest smoke point was notices in local street shop (palm oil) 221 º C followed by restaurant (palm oil) 215 º C, home (sunflower oil) 209 and lowest Dhaba (sunflower oil). The standard smoke point for oils according to WHO is 230-232 º C (Codex Alimentarius standard ,2022). The recorded values of smoke points are seen high in palm oil samples when compared to sunflower oil samples. Smoke point is an indicator of thermal stability and it is the beginning of both flavour and nutritional degradation. It is the temperature at which the sample begins to smoke underspecified conditions. Heating produces free fatty acid from oils and as the time of heating increases, free fatty acids will be released, thereby decreases the smoke point of the oil. Therefore, the recorded values of smoke points are less than the standard value as they have under gone heating process during frying so fatty acids are released and smoke points are decreased (Mengistie T. et al, 2018).The p value calculated for the boiling point and smoke point of oil samples are 0.02 and 0.01 which is ≤ 0.05 (alpha) and F calculated > F critical are (5.4>4) and (14.2>6.5) which shows that there is significant difference in the values of samples, this change shows that repeated heating /frying of oils have significant effect on the boiling and smoke points of oil samples (Baig et al ,2022).

3.3. pH

The pH of the samples represented in Table 1 are obtained which ranges from (6.2-5.5) which was recorded as highest in local street shop (palm oil) 6.2 followed by pH of 5.9 in home (sunflower oil), pH of 5.7 in Dhaba (sunflower oil) and lowest 5.5 pH in restaurant (palm oil). Fresh vegetable oils are weak basic liquids with pH values more than 7 which decline, upon heating, into an acidic form because of the hydrolysis of the triglycerides. The slight decrease in pH value recorded for the samples was due to heating of oil at high temperature as a procedure of frying the oil pH decreases to acidic condition due to hydrolysis due to which it becomes acidic even though the pH values are acidic it totally doesn't depend on oil as the oil samples are used for various food frying so the pH can be affected by this also. The thermal process begins the hydrolysis of oil triglycerides, changing them into FFAs and glycerol, which influences' the pH-parameter. Presumably, the formation of FFAs on thermal treatment are important dynamics of

vegetable oils that may be related to pH reduction. The p value calculated for the pH of oil samples is 0.01 which is ≤ 0.05 (alpha) and F calculated > F critical is (5.9>4) which shows that there is significant difference in the values of samples, this change shows that frying of oils have significant effect on the pH of oil samples (Baig et al ,2022).

3.4. Oil absorptivity and Colour

The oil absorption percentage was recorded by simple gravimetric method and the values obtained ranges from 74-57% respectively highest recorded in local street shop (palm oil) sample of about 74 % followed by 67 % in home (sunflower oil) sample, 62 % in restaurant (palm oil) sample and lowest in Dhaba (sunflower oil) as of 57 %. The oil absorptivity of the samples is shown in the (Table 1). The absorption of oil totally depends on various factors including the type of food, cooking temperature, time and characteristic of oils. So, the oils samples cannot be compared to any standard values of oil absorption. From the data above it is observed that the oil absorption in palm oil was higher than the percentage of sunflower oils (Momoh et al, 2017).The colours of oil samples when compared to normal oils are as follow the colour of oil sample of restaurant (palm oil) collected was black colour, local street (palm oil) sample was yellow colour (normal refined palm oil has bright orange red colour), change in colour was due to repeated heating and food fried in it and oxidation process during heating. whereas the samples of sunflower oil collected are Dhaba and home sample having colours orange and yellow. (Normal sunflower oil has typically pale-yellow colour) the colour was nearly similar to normal oil as the samples where less used in frying process compared to palm oil samples. It's important to note that colour alone is not a definitive indicator of the quality or purity of the oil, as other factors such as storage conditions and age can also affect the colour over time. The p value calculated for the oil absorptivity of oil samples is 0.004which is ≤ 0.05 (alpha) and F calculated > F critical is (26.2>6.5) which shows that there is significant difference in the values obtained of samples, this change shows that frying process of oils have significant effect on the oil absorptivity of oil samples (Baig et al ,2022).

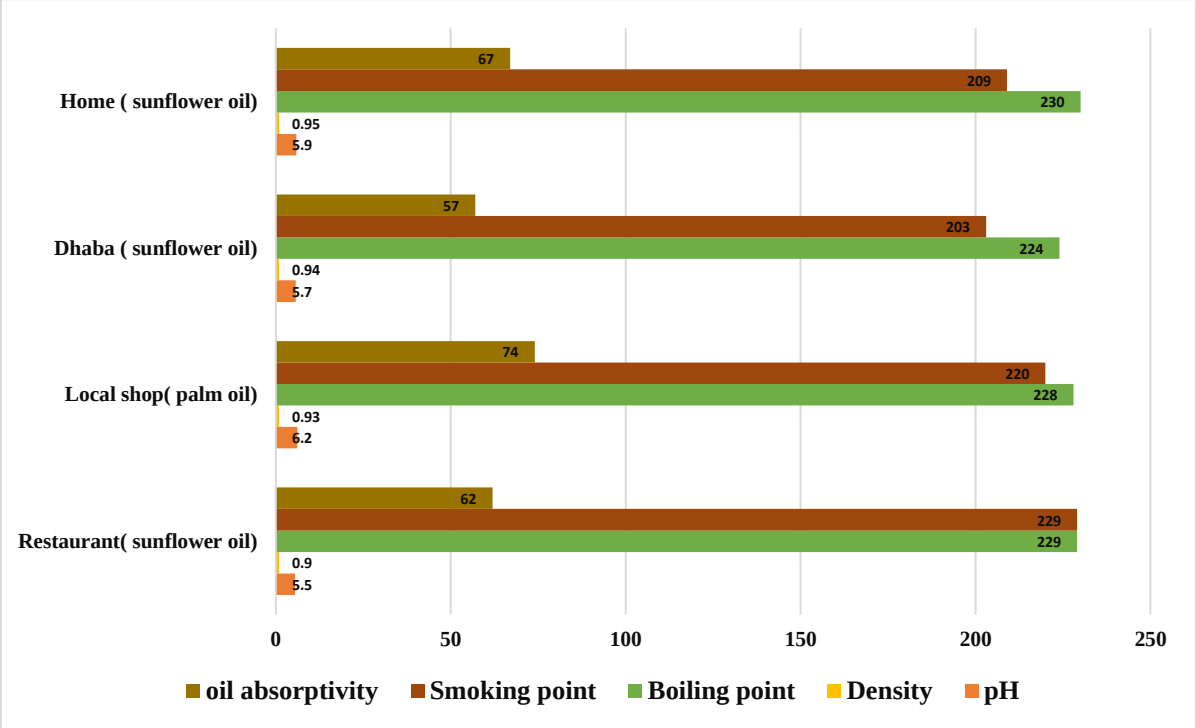
Table -1: Physical analysis of oil samples

SAMPLES	PH	DENSITY(g/ml)	BOILING POINT (°c)	SMOKE POINT (°c)	OIL ABSORPTIVITY (%)
Standard values	Above 7	(0.88-0.89g/ml) for palm oil & (0.91-0.92 g/ml) for sunflower oil	-	230-232°c	-
Restaurant (palm oil)	5.5±0.3B	0.9±0.01A	229±1A	229±3A	62±2.5B
Local street shop (palm oil)	6.2±0.2A	0.93±0.02A	228±1.5A	220±3.6A	74±4A
Dhaba (sunflower oil)	5.7±0.1B	0.94±0.01A	224±3.6A	203±3.2A	57±2.6C

Home (sunflower oil)	5.9±0.1B	0.95±0.01A	230±1.15A	209±1A	67±2.5B

Values in each column are presented as mean ± SD (i.e., n = 3). Means in the same column in each parameter with a different superscript (A, B, C) are significantly different ($p < 0.05$).

Figure 1: Graphical comparison of the physical analysis of all four oil samples



3.5. Peroxide value

The peroxide values obtained are shown in Table 2 for each sample, where the highest peroxide value was seen in local street shop (palm oil) sample as 23meq/kg followed by Dhaba (sunflower oil) as 22.8 meq/kg, restaurant (palm oil) as 18.8 meq/kg and lowest home (sunflower oil) sample as 17.6 meq/kg, whereas the standard value of peroxide in normal oil is 10 milliequivalent/ kg and for rancid oils 20-40 milliequivalent / kg (FSSAI ,2021).The peroxide value of palm oil samples is more than that of sunflower oil samples which shows that there is more oxidation in palm oil samples (restaurant & local street) than sunflower oil samples (home and Dhaba) leading to rancidity. Peroxide value is used as a measure of the extent to which rancidity reactions have occurred during storage and it is used as a good criterion for the prediction of the quality and stability of oils. High peroxide value could be resulted from high degree of unsaturation and found to increase with the storage time, temperature, light and contact with atmospheric oxygen (Mengistie et al, 2018). According to the Food Safety and Standards Authority of India the rancid oils are 20 – 40 meq/kg so the value recorded for local street shop 23 meq/kg and Dhaba 22.8 meq/kg shows that they are rancid due to high oxidation during frying process because high temperatures can cause the oil to break down, resulting in the formation of free radicals and the degradation of the oil's chemical structure, and chemical reactions occurs one of which is oxidation reaction of oxygen with air, whereas the samples of home and Dhaba recorded 17 and 18 meq/kg are higher than the normal peroxide value of oil i.e. 10meq/kg but are near to border line of rancidity this means that oxidation has occurred in them but not till extent of rancidity . The oxidative process is influenced by factors such as the type of oil

used, frying temperature, duration of frying, presence of oxygen, and the presence of food components. Antioxidants, such as natural or synthetic compounds, can be added to the oil to inhibit oxidation and prolong the frying life of the oil. The p value obtained for the peroxide value of oil is obtained as 0.0001 which is ≤ 0.05 (alpha) which indicates that there is significant difference in the values obtained means the effect of frying process on the oil samples causes change in the peroxide values of oil samples showing that oxidation has occurred (Baig et al ,2022).

3.6. Acid value and free fatty acid content

Table 2 shows the acid values of oil obtained during chemical analysis of oil samples which are recorded as highest 16.4mg KOH/g in local street shop (palm oil sample) followed by restaurant (palm oil) sample 15.6 mgKOH/ g , and lowest in Dhaba and home (sunflower oil samples) as 14.1 mgKOH/g each .The standard value for acid value of normal palm oil and sunflower oil must not exceed more than 10 mgKOH/g and 6mgKOH/g according to Food Safety and Standards Authority of India (FSSAI,2021).It is observed that the acid values of all oil samples are more than the standard value which indicates the presence of high free fatty acid in oil samples. It's found that compared to sunflower oil samples the acid value of palm oil samples is high. The p value obtained for Acid values of oil samples is 0.002 which is ≤0.05 (alpha) which indicates that there is significant difference in the values obtained stating that the frying process of oil causes changes in the acid values of oil showing amount of free fatty acids in it. Acid values indicate the number of FFAs and the suitability of the oil for degradation and the level of oxidative deterioration. FAs are usually found in the form of triglycerides, but they disrupt into FFAs during processing at high temperatures. This may be due to an increase in the activity of hydrolytic and lipolysis, which decomposes the glycerides in the oil as the operating temperature increases. An increasing AV is a sign of oil deterioration, which, in turn, is caused by the degradation of the chemical bonds in oil at high temperatures (Baig et al ,2022). The acid and free fatty acid (FFA) values are used to indicate the level of rancidity and edibility of oils. Acid value represents the mg KOH required to neutralize the free fatty acid in 1 g of oil while free fatty acid is the percentage by weight of a specified fatty acid such as percent oleic acid in oil. Therefore, acid value is a good indicator of oil degradation caused by hydrolysis or enzymes. Table 2 also represents the free fatty acid content in oil samples which is obtained as in restaurant (palm oil) sample are as follows palmitic acid 7.3%,oleic acid 7.6%,linoleic acid 7.5% and steric acid 7.9% the FFA of local shop (palm oil) sample are palmitic acid 7.5%, oleic caid 7.6% ,linoleic acid 7% and steric acid 8.3% FFA of Dhaba (sunflower oil) sample are palmitic acid 8%,oleic acid 77.%,linoleic acid 7.1% and steric acid 7.8% and FFA content of home (sunflower oil) sample are palmitic acid 7..7%,oleic acid 7.5%,linoleic acid 7.1% and steric acid 7.3% respectively. The acid value and the free fatty acid content have a direct relationship. This means that a greater acid value will result in more free fatty acids, lowering the oil quality (Nwosu et al.,2022). These values are obtained from acid value experiment using FSSAI manual formula (FSSAI, 2021). The p value obtained for FFA content is 0.04 which is ≤0.05 (alpha) which indicates that there is significant difference in the values obtained showing that frying of oil causes changes in the FFA content of oil samples collected (Baig et al ,2022).

3.7. Iodine value

The iodine values of oil samples are represented in Table 2, the highest 75gI2/100g in restaurant (palm oil) sample, home (sunflower oil) sample 70gI2/100g, 69 gI2/100g in local shop (palm oil sample) and lowest in 61 gI2/100g in Dhaba (sunflower oil sample). The standard values of palm oil and sunflower

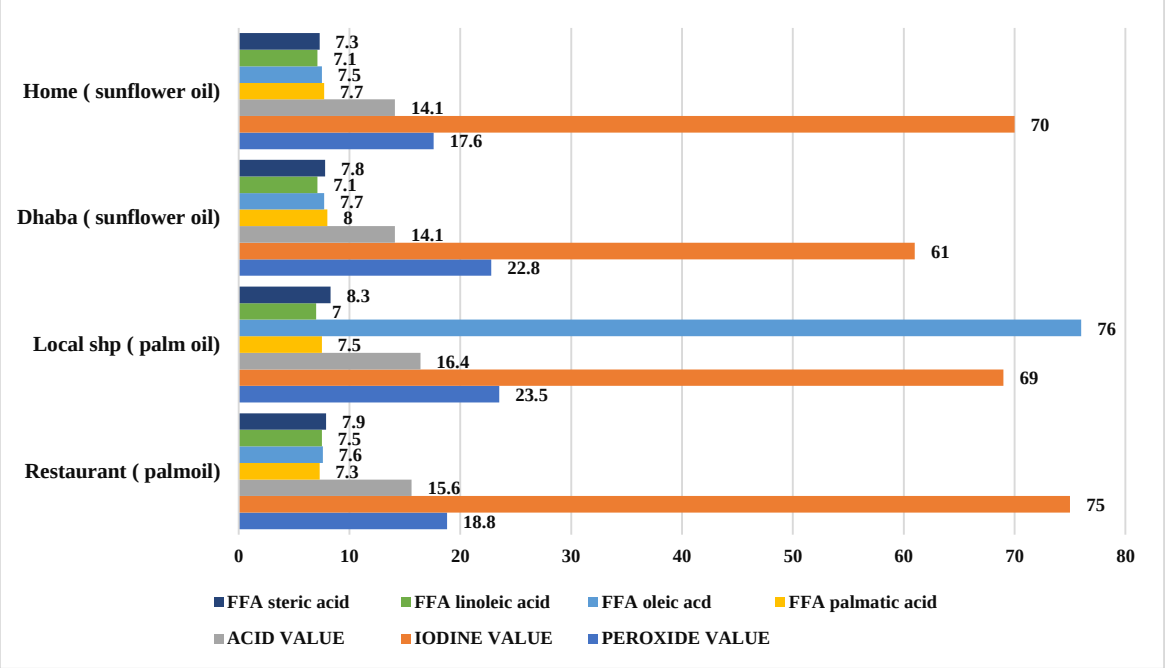
oil are 45-55 gI2/100g and 100-150 gI2/100g(FSSAI,2021). Iodine value (IV) measures the degree of unsaturation in a factor vegetable oil. It determines the stability of oils to oxidation and allows the overall unsaturation of the fat to be determined qualitatively (Hasan et al,2016).The iodine values of palm oil samples are more than the sunflower oil samples, whereas the values of palm oil samples are more than the standard values because the unsaturation of oils decrease as oil temperature increases, but here it is high due to the stability of oils some oils can with stand high temperatures so the peroxide values are high in palm oil samples. The values of sunflower oil samples are less than the standard values because the unsaturation decreases as temperature increases leading to breakdown the unsaturated fatty acids to saturated ones this result in the decreases of overall unsaturation of oil so the peroxide value obtained was less ,and the extent of this decrease depends on various factors, including the type of oil used, the temperature of frying, the duration of frying, and the presence of other compounds such as antioxidants(Avendano et al, 2021).The p value obtained for the iodine values is 0.002 which is ≤ 0.05 (alpha) which indicates that there is significant difference in the iodine value of oil samples and the frying process of oil samples has led to changes in the iodine value of oil (Baig et al ,2022).

Table 2: Chemical analysis of oil samples

SAMPLES	Iodine values(gI2/100g)	Acid value (mgKOH/g)	Peroxide value(meq/kg)	FFA palmitic acid %	FFA Oleic acid %	FFA linoleic acid %	FFA steric acid %
Restaurant (palm oil)	75±0.5A	15.6±0.9B	18.8±0.2B	7.3±0.4B	7.6±0.4A	7.5±0.1A	7.9±0.1B
Local shop (palm oil)	69±1B	16.4±0.3A	23.5±0.5A	7.5±0.5B	7.6±0.4A	7±0.1A	8.3±0.1A
Dhaba (sunflower oil)	61±1.8B	14.1±0.2B	22.8±0.2A	8±0.4A	7.7±0.5A	7.1±0.1A	7.8±0.1B
Home (sunflower oil)	70±0.4A	14.1±0.2B	17.6±0.2C	7.7±0.4B	7.5±0.4A	7.1±0.1A	7.3±0.1B

Values in each column are presented as mean ± SD (i.e., n = 3). Means in the same column in each parameter with a different superscript (A, B, C) are significantly different ($p < 0.05$).

Fig 2: Graphical comparison of the chemical analysis of oil samples



3.8. STATISTICAL ANALYSIS

In the study we conducted the results obtained by one way ANOVA for the physiochemical properties of 4 oil samples (a) restaurant(palm oil), (b) local shop (palm oil),(c) Dhaba (sunflower oil) ,(d) home(sunflower oil) are respectively observed on the basis of p value (taken as α 0.05)the p values of physical properties for all samples a,b,c,d are density (0.04), pH (0.01),boiling point(0.01),smoke point (0.01) respectively and the p values for chemical properties are as iodine value (0.002), peroxide value (0.001) , acid value (0.002) and FFA (0.04).All values are represented in Table 3 below with ANOVA results. The results indicate variations in physiochemical characteristics among the oil samples. The standard statistical analysis shows If the calculated p-value is below a predetermined threshold ($\alpha \leq 0.05$), it is considered statistically significant. This means that the observed data is unlikely to occur by chance alone under the null hypothesis. In this case, we reject the null hypothesis in Favor of the alternative hypothesis, if the calculated p-value is greater than the threshold, it is not considered statistically significant. This suggests that the observed data is likely to occur by chance under the null hypothesis. The values obtained for the physiochemical properties are all below standard significance level or alpha level ($\alpha \leq 0.05$), so it shows that there is significant difference and we reject null hypothesis(H_0) in favour of alternate hypothesis(H_1), and this indicates that there is significant difference in the values of physiochemical properties and the effect of frying has an effect on the physiochemical properties of oil and the p values and F values are in detail shown under each analysis and the mean ± standard deviation for each analysis is shown in Table1 and 2. The purpose of this analysis was to determine if there are significant variations in a specific characteristic or variable among 4 oil samples (the independent variable was heat of oil samples and dependent variable are physiochemical properties) (Baig et al ,2022).

Table 3: Statistical Analysis of Physiochemical Properties of the Oil Samples Collected

CHARACTERISTICS	MEAN RANGES	SD RANGES	df	F-Cal	p-value	F crit
pH	6.2-5.5	0.3-0.1	3	5.9	0.01	4
Density(g/ml)	0.95-0.9	0.02-0.01		6.8	0.04	6.5
Boiling point °c	230-224	3.6-1		5.4	0.02	4
Smoke point °c	229-203	3.6-1		14.2	0.01	6.5
Peroxide value(meq/kg)	23.5-17.6	0.5-0.2		171.1	0.001	6.5
Iodine value (gI2/100g)	75-61	1.8-0.4		32.7	0.002	6.5
Acid value (mgKOH/g)	16.4-14.1	0.9-0.2		33.3	0.002	6.5
Free fatty acid %						
Palmitic acid	8-7.3	0.4-0.5	3	4	0.04	4.6
Oleic acid	7.7-7.5	0.5-0.4				
Linoleic acid	7.5-7	0.1-01				
Steric acid	8.3-7.3	1-1				

F> Fcrit or P-value<0.05: significant and F< Fcrit or P-value>0.05: non-significant

3.9. SENSORY ANALYSIS

According to the study the sensory analysis was evaluated for the four samples A- restaurant (palm oil), B- local shop (palm oil), C- Dhaba (sunflower oil), D – home (sunflower oil), by frying a papad in the oil samples collected, descriptive sensory analysis was done by 20 members to evaluate the aroma, taste, texture, appearance attributes, using 5-point hedonic scaling (5-1).The results obtained in score card is shown as means of all the attributes of sensory analysis done represented in Table 4 below;

Table 4 Sensory Analysis of Oil Samples

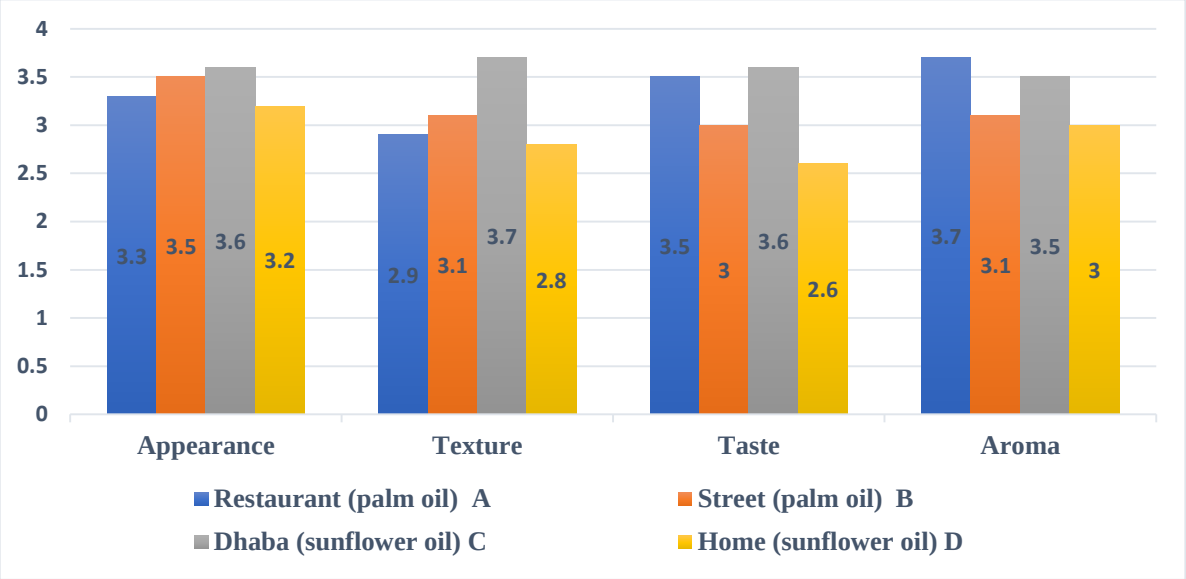
Attributes	Restaurant (palm oil) (A)	Street (palm oil) (B)	Dhaba (sunflower oil) (C)	Home (sunflower oil) (D)
Appearance	3.3±1.2a	3.5±1a	3.6±1a	3.2±1.3a
Texture	2.9±1.1b	3.1±1.2a	3.7±1a	2.8±1.2b
Taste	3.5±0.9a	3±1.1a	3.6±1a	2.6±1.3b
Aroma	3.7±1a	3.1±0.9a	3.5±1a	3±1.3a

Values in each column are presented as mean ± SD (i.e., n = 20). Means in the same column in each parameter with a different superscript (a, b, c) are significantly different ($p < 0.05$).

According to the above data the appearance was rated highest based on hedonic scaling in sample C (3.6) followed by other samples B (3.5), A (3.3) and lowest D (3.2) this indicates that sample C is more visually appealing than other samples, but according to 5-point hedonic scale used 3.6 comes between 3-4 rating i.e., the appearance is neutral to appealing. In relation to texture as papad is course texture the highest rated sample for crispiness was sample C (3.7) followed by sample B (3.1), A (2.9) and lowest D (2.8) but in the means obtained the value is rated according to5- point hedonic scale between 3-4 i.e., neutral to good. In terms of taste the sample C (3.6) was rated highest according to hedonic scaling

followed by samples A (3.5), B (3) and lowest D (2.6) resulting that sample C has superior taste quality compared to other samples but still comes under slightly bad to neutral -good taste according to5-point hedonic scale used the values are between 2-4 scaling. For aroma the highest rating was given to sample A (3.7) indicating a more pronounced and desirable aroma profile followed by other samples C (3.5), B (3.1) and lowest D (3) compared according to the 5-point hedonic scale used the valued comes between points 3-4 i.e., neutral-good. Form the comparison it is stated that sample C has better appearance, taste and texture compared to all other samples but the aroma of sample A was better compared to other samples but according to the hedonic scaling they all come under neutral to good scale (Cara Vaca G et al ,2020).

Figure 4: Graphical representation of sensory analysis



CONCLUSION

The present study conducted shows a comprehensive assessment of the effect of repeated heating of frying process on the quality and stability of oils. The physicochemical analysis revealed significant changes in various parameters, indicating oil degradation, oxidation, presence of free fatty acids FFA, degree of unsaturation, rancidity etc in the four oil samples collected, it is also observed that the palm oil samples were more effected by heating compared to the sunflower oil samples and this may be due to the composition and chemical properties of it. The statistical analysis identified variances and difference among the parameters, and determining the significance of the values obtained as it rejects null hypothesis (H_0) in favour of alternate hypothesis(H1). Sensory evaluation provided valuable insights into the oils acceptability and helped determine the point at which their sensory quality became undesirable. This study also emphasizes the importance of proper frying oil management practices and highlights the need for informed decision-making to enhance fried food quality, so that effect of heating on the physiochemical analysis can be reduced which prevent from harmful chemical reactions and health effects as fried foods are consumed by many people.

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