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Assessment of the Quality of Used Frying Oils in Selected Hotels and Restaurants in Sekondi-Takoradi, Ghana

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ABSTRACT

During the frying process, fats and oils undergo chemical changes like oxidation, polymerization, and hydrolysis, altering their physical and chemical properties. These reactions generate numerous by-products, including free fatty acids, alcohols, cyclic compounds, dimers, and polymers. Consequently, understanding the physical and chemical transformations occurring during deep frying is crucial for assessing the quality of fried foods. This study aimed to evaluate the physicochemical properties of oils used continuously for frying chicken in various catering establishments. Oil samples were collected from 45 hotels and restaurants in the Sekondi-Takoradi Metropolis to determine their acid values, peroxide values, and free fatty acid (FFA) levels. The results revealed that 4-star hotels had the lowest rancidity values, while 2-star hotels exhibited the highest. Specifically, the peroxide values of oils from 2-star hotels ranged from 9.09 to 9.72 meq/kg, acid values ranged from 1.45 to 2.79 mg KOH/g, and FFA values varied between 0.54 and 1.4. The study concludes that 2-star hotels in Sekondi-Takoradi experience a higher rate of rancidity in their frying oils compared to other hotels and restaurants in the area.

Keywords: rancidity, oil usage, oil spoilage, dangers of cooking oils, peroxide levels, FFA values.

1. Introduction

From a nutritional perspective, oils with high amounts of saturated fatty acids and trans fatty acids are considered less favorable for good health (Aladedunye & Przybylski, 2019). Deep frying of foods enhances their sensory properties, imparting a unique fried flavor, appealing color, and crispy texture. Deep-fat frying is a complex process carried out at 150-190°C by immersing food in hot oil, facilitating interactions between the food, air, and hot oil. This results in various physical and chemical changes in the oil and the formation of new compounds (Indrasti et al., 2018). Chemical reactions like oxidation, polymerization, and hydrolysis occur in the food system, eventually altering the physical and chemical properties of fats/oils. Consequently, numerous by-products are produced, such as free fatty acids, alcohols, cyclic compounds, dimers, and polymers (Gertz, 2014; Indrasti et al., 2018). These compounds play a significant role in public health issues, including gastrointestinal disorders, immune-related diseases, cancer, diabetes, hypertension, and preterm foetuses (Santos et al., 2019).

The study aimed to evaluate the peroxide values and free fatty acid (FFA) levels of oils used continuously for frying chicken. Previous research by Manaharan et al. (2015) asserted that the peroxide value (PV), FFA, and p-anisidine value (p-AV) of used oils and fried chicken increased significantly ($p<0.05$) with frying time. They further noted that the quality of used-fried oil, when frying batches multiple times per day for consecutive days, showed better oil quality than continuously frying for extended periods in a single day.

Fats or oils used for deep-fat frying predominantly comprise fatty substances, which are three fatty acid molecules joined by glycerol (Saad et al., 2007) and are hydrophobic substances (Kalapathy & Proctor, 2010). The heat stability of frying oil is primarily governed by two inherent factors: the fatty acid composition and the presence of antioxidants and precursors such as butylated hydroxyanisole (BHA), tert-butylhydroquinone (TBHQ), butylated hydroxytoluene (BHT), propyl gallate (PG), and tocopherols (Choe & Min, 2007; Chen et al., 2016).

Antioxidants have been proven to retard room temperature auto-oxidation of oils but are rendered inefficient at typical frying temperatures due to volatilization losses and thermal fissions (Velasco et al., 2009; Chen et al., 2016). An ideal frying oil should possess a low amount of polyunsaturated fatty acids (notably linolenic acids) and prominent levels of oleic acid with moderate amounts of saturated fatty acids, as the former are highly susceptible to oxidative degradation during frying (Indrasti et al., 2018), potentiating breakdown reactions that often yield harmful polymers (Zhang et al., 2012; Santos et al., 2019).

Detection of peroxide gives the initial evidence of rancidity in unsaturated fats and oils. Other methods are available, but peroxide value is the most widely used. It gives a measure of the extent to which an oil sample has undergone primary oxidation, extent of secondary oxidation may be determined from p-anisidine test (Chakrabarty 2018). In general, fresh oils have a peroxide value of >10 mEq/Kg while peroxide values in the 30-40 mEq/Kg range are generally associated with a rancid taste (CODEX Stan 210, 2019). Edible vegetable oils are foodstuffs which are composed primarily of glycerides of fatty acids being obtained only from vegetable sources. They may contain small amounts of other lipids such as phosphatides, of unsaponifiable constituents and of free fatty acids naturally present in the fat or oil. Acidity is defined as the content of FFA in an oil or fat determined according to the method specified in ISO 660:1996 or equivalent methods and is expressed as a percentage by mass of FFA. The acceptable level of Free fatty acid percentage is 0.5% expressed as oleic acid (CODEX Stan 210, 2019). This paper sought to:

i. Identify the physical properties caterers consider when discarding old oils.

ii. Evaluate oil samples from hotels and restaurants to determine their peroxide and FFA levels.

2. Methods

The study employed a quantitative research approach to collect data. The sample frame of hotels and restaurants in the Sekondi-Takoradi Metropolis was obtained from the Ghana Tourism Authority. Data was collected between May and July 2023, using a sample of 30 hotels and 15 registered restaurants from the sample frame. A simple random sampling method was used to select the hotels and restaurants for the study.

The sample comprised 30 hotels, categorized as follows: three 4-star hotels, five 3-star hotels, and twenty-two 2-star hotels. Additionally, 15 registered restaurants were included in the study. Table 1 shows the breakdown and coding of the hotels and restaurants.

Table 1: Serialized Codes of hotels and restaurants in Sekondi-Takoradi used for the study and their ratings. Number of hotels = 30, Number of restaurants =15. N=45

Source: fieldwork, 2023

Serial Number	Hotels	Star rating	Serial number	Hotels	Star Rating	Serial number	Restaurants
001	PH-1	4	**016**	TLS-16	2	**031**	VNR-1
002	AIH-2	4	**017**	PES-17	2	**032**	VRR-2
003	AHI-3	4	**018**	NAS-18	2	**033**	KVR-3
004	SCH-4	3	**019**	AHS-19	2	**034**	SPR-4
005	SJH-5	3	**020**	BHS-20	2	**035**	MRR-5
006	DBH-6	3	**021**	GHS-21	2	**036**	AJR-6
007	ADH-7	3	**022**	RHS-22	2	**037**	ADJ-7
008	BMH-8	3	**023**	ATS-23	2	**038**	JSR-8
009	SKH-9	2	**024**	PTS-24	2	**039**	GR-9
010	GSH-10	2	**025**	AMS-25	2	**040**	STR-10
011	TSH-11	2	**026**	WSH-26	2	**041**	GLR-11
012	APH-12	2	**027**	NHS-27	2	**042**	HTR-12
013	FSH-13	2	**028**	APH-28	2	**043**	GIR-13
014	HCI-14	2	**029**	PLH-29	2	**044**	TUR 14
015	YMH-15	2	**030**	TDH-30	2	**045**	SRC 15

To collect the used oil samples and determine their physicochemical properties, clearly labeled sterilized bottles were employed. The bottles were carefully labeled to ensure proper identification and traceability of the samples. Strict sterilization protocols were followed to prevent any potential contamination that could compromise the integrity of the samples and the accuracy of the subsequent analyses.

After collection, the used oil samples were promptly transported to the Biochemistry laboratory at the Kwame Nkrumah University of Science and Technology (KNUST). This state-of-the-art facility provided the necessary equipment and controlled environment to conduct the physicochemical analyses accurately. At the KNUST Biochemistry laboratory, the collected oil samples underwent a series of rigorous tests to determine their acid value, peroxide value, and free fatty acid (FFA) levels. These parameters are crucial indicators of the quality and degree of deterioration of the used frying oils.

The acid value measures the amount of free fatty acids present in the oil, which can contribute to off-flavors and rancidity. The peroxide value, on the other hand, quantifies the concentration of peroxides and hydroperoxides formed during the initial stages of lipid oxidation, providing insights into the extent of oxidative deterioration. Additionally, the FFA level is a direct measure of the concentration of free fatty acids, which can also impact the taste, aroma, and stability of the oil.

Determination of Free Fatty Acids (FFA)

Principle

The free fatty acid (FFA) content in the oil samples was determined through a titration method. First, the oil samples were extracted with hot ethyl alcohol, allowing the free fatty acids to dissolve in the alcohol solvent. This step separated the free fatty acids from the bulk of the oil matrix. After extraction, the supernatant alcohol layer, containing the dissolved free fatty acids, was carefully separated, and titrated with a standard alkali solution. The titration process involved gradually adding the alkali solution to the alcohol layer until a specific endpoint was reached, indicated by a color change due to the presence of a pH indicator.

The volume of the standard alkali solution required to neutralize the free fatty acids present in the sample was recorded and used to calculate the FFA content. For the oils used in this study, the free fatty acid levels were expressed as a percentage of oleic acid, a commonly occurring fatty acid in vegetable oils. By expressing the FFA content as oleic acid, the results could be standardized and compared across different oil samples, as oleic acid is a major constituent of many edible oils. This approach allowed for a consistent and meaningful interpretation of the FFA levels, providing insights into the extent of hydrolytic degradation and overall quality of the used frying oils.

Reagents

1. Ethyl alcohol, 95%

2. Phenolphthalein indicator, 1%

3. Sodium hydroxide solution, 0.1 N: Standard

Preparation of Neutralized Alcohol

To prepare the neutralized alcohol solution used in the titration process, 2 mL of a 1% phenolphthalein solution was added to 1 liter of 95% ethyl alcohol. Phenolphthalein is a commonly used pH indicator that exhibits a colorless to pink color change around the neutral pH range.

Next, a 0.1 N (0.1 Normal) sodium hydroxide (NaOH) solution was gradually added dropwise to the alcohol-phenolphthalein mixture. The addition of the NaOH solution continued until a faint, persistent pink color appeared in the solution. This pink color indicated that the solution had reached a slightly basic pH, ensuring the neutralization of any potential acidic impurities present in the alcohol.

The neutralized alcohol solution played a crucial role in the subsequent titration process for determining the free fatty acid content in the oil samples. By using a pre-neutralized alcohol solution, any interference from acidic impurities was minimized, allowing for an accurate and reliable measurement of the free fatty acids extracted from the oil samples.

The careful preparation of the neutralized alcohol solution was essential to ensure the accuracy and reproducibility of the analytical procedure, ultimately contributing to the reliable determination of the free fatty acid levels in the used frying oils.

Sample Preparation and Titration

The oil samples were first preheated in a water bath set at 50°C for 10 minutes. This step helped to increase the flow and reduce the viscosity of the oils, ensuring a homogeneous sample for accurate analysis. After preheating, the oil samples were thoroughly mixed by shaking them on an orbital shaker for 30 seconds. This agitation ensured complete mixing and homogeneity of the samples before analysis.

For the titration process, a precisely weighed 5-gram portion of each oil sample was transferred into a 250 mL Erlenmeyer flask. To this, 50 mL of hot, neutralized ethyl alcohol was added. The hot alcohol facilitated the extraction of free fatty acids from the oil samples. The solution containing the oil sample and the alcohol was then titrated against a 0.1 N (0.1 Normal) sodium hydroxide (NaOH) solution. The titration was performed dropwise, with continuous swirling of the mixture, until a permanent pink color formation was observed. This pink color, which persisted even after allowing the mixture to settle for a few seconds, indicated the endpoint of the titration.

The volume of the 0.1 N NaOH solution required to reach the endpoint was carefully recorded for each sample. This volume was subsequently used to calculate the free fatty acid (FFA) percentage in the oil samples, employing established mathematical formulas and conversion factors.

The meticulous sample preparation and titration procedures ensured accurate and reliable determination of the FFA levels, which serve as a crucial indicator of the quality and degree of deterioration of the used frying oils.

Calculation

$$\text{Free Fatty Acid\%} = \frac{\text{Vol. of 0.1N NaOH} \times \text{N NaOH} \times \text{M}}{\text{Weight of sample (g)}}$$

Where;

Vol. of 0.1N NaOH =The volume of alkali used in the titration

M = 28.2 for Oleic acid

N = 0.1N NaOH

Determination of Acid Value

The acid value, also known as the acid number, is a crucial parameter that provides insights into the extent of hydrolytic deterioration in oils and fats. It represents the quantity of free fatty acids present in the oil sample.

To determine the acid value, the free fatty acid (FFA) percentage obtained from the titration process was used in the following calculation:

Acid Value (mg KOH/g) = (FFA% × 1.99)

Where:

- FFA% is the free fatty acid percentage determined through the titration process.

- 1.99 is a conversion factor that accounts for the molecular weight of oleic acid (the reference fatty acid used in this study) and the equivalent weight of potassium hydroxide (KOH).

The acid value is expressed in milligrams of potassium hydroxide required to neutralize the free fatty acids present in one gram of the oil sample.

A higher acid value indicates a greater degree of hydrolytic degradation and the presence of higher levels of free fatty acids in the oil sample. This parameter serves as a valuable indicator of the quality and shelf life of the used frying oils, as excessive free fatty acids can contribute to off-flavors, rancidity, and reduced stability.

By calculating the acid value based on the FFA percentage obtained through the titration process, the study aimed to assess the extent of hydrolytic deterioration in the used frying oils from the selected hotels and restaurants in the Sekondi-Takoradi Metropolis.

Calculation

Acid value = 1.99 × FFA

Based on assuming the samples to be seed oil thus using the Oleic acid number.

Determination of Peroxide Value

The peroxide value (PV) is a measure of the concentration of peroxides and hydroperoxides present in oils and fats. These compounds are formed during the initial stages of lipid oxidation and are indicative of the extent of oxidative deterioration.

To determine the peroxide value, a mass of 2.5 grams of each oil sample was accurately weighed into a 250 mL Erlenmeyer flask. Subsequently, 15 mL of a solvent mixture comprising acetic acid and chloroform in a 3:2 ratio was added to the flask. The solution was thoroughly mixed by shaking to ensure complete dissolution of the oil sample.

After mixing, 0.5 mL of a saturated potassium iodide (KI) solution was added to the flask. This step was followed by the addition of 15 mL of distilled water. The presence of peroxides in the oil sample would oxidize the potassium iodide, liberating iodine (I_2) according to the following reaction:

$2KI + ROOR \rightarrow ROOR + 2KI + I_2$

To indicate the presence of liberated iodine, 0.5 mL of a starch indicator solution was added to the mixture, which would turn a distinctive blue-black color in the presence of iodine.

The amount of iodine liberated, and consequently the concentration of peroxides in the oil sample, was determined by titrating the solution against a standard 0.1 N sodium thiosulfate ($Na_2S_2O_3$) solution until the blue-black color disappeared, indicating the complete reduction of iodine.

The volume of the standard sodium thiosulfate solution required to achieve the colorless endpoint was recorded. Additionally, a blank titration was performed without the oil sample, following the same procedure, to account for any potential interference or background effects.

The peroxide value was then calculated using the recorded volumes and appropriate conversion factors, following established mathematical formulas and guidelines (Zahir et al., 2014).

The determination of the peroxide value provided crucial information about the extent of oxidative deterioration in the used frying oils, which can have significant implications for the quality, flavor, and stability of the oils and the fried products.

Calculation

$$\text{Peroxide Value} = \frac{(S-B) \times N \times 1000}{\text{Wt. of sample}}$$

Where,

S = ml of sodium thiosulphate for sample titration

B = ml of sodium thiosulphate for blank titration

N = Normality of sodium thiosulphate

Wt = Weight of oil sample

3. Results

Physical Properties Caterers Considered for Discarding Used Frying Oils

Table 2 presents the factors that caterers considered when deciding to discontinue the usage of frying oils. The majority, over 60%, indicated that they typically discontinue the use of frying oils when a noticeable change in color occurs. Approximately 11% of the respondents stated that the formation of black smoke emanating from the oil discouraged them from continuing its usage.

Furthermore, some respondents believed that a change in the aroma or smell of the oil after prolonged usage prompted them to discontinue its use for frying purposes. Moreover, 7% of the respondents cited a change in taste or a variation in the flavor of the oil after extended usage as a reason for discontinuing its use.

Table 2: Percentage Distribution of Factors Hotels and Restaurants Consider for Discontinuing Frying Oil Usage (N=45)

VARIABLE	FREQUENCY (N=45)	PERCENTAGE (%)
Colour change	30	67
Taste change	3	7
Smell change	4	9
Black smoke formation	5	11
Non-responses	3	7

Fieldwork, 2023

According to a study by Choudhary and Grover (2013), various physicochemical changes occur in cooking oils after prolonged usage, including alterations in taste, color, and aroma. Fresh cooking oils possess distinct smells and flavors that distinguish them from used oils. Therefore, it is understandable that most respondents mentioned changes in color, taste, and smell as factors that discourage them from continuing to use the same oil for frying.

Kalogeropoulos et al. (2007) indicated that prolonged oil usage results in increased viscosity, color intensity, spray formation, and smoke production. These changes also affect the aroma, leading to the development of undesirable odours over time. Additionally, the study by Saxena (2014) supported the view that cooking oil may become unfit for human consumption after extended usage.

The study also examined the means of disposal for old cooking oils. The results revealed that the majority (89%) of caterers repurposed the old cooking oils for preparing shito (a popular Ghanaian condiment), stews, and sauces. Additionally, 7% of the respondents indicated that they refilled the used oil containers with fresh oil.

Oil disposal is often preferred over reusing the oil for other food preparations, especially when the oil appears excessively soiled or degraded. Some studies have observed that, reheating oil repeatedly can expose certain harmful chemicals, and consuming food prepared with such oil can potentially harm bodily growth and development (De Alzaa et al., 2018). The study by De Alzaa et al. (2018) also noted that reheating or reusing cooking oils can lead to an increase in fatty acid content, and if these fatty acid levels exceed permissible limits, they can pose health risks. This is because elevated fatty acid levels can render the oils insoluble in water.

Furthermore, reusing old oils for food preparation can result in loss of flavor, the development of unpleasant odours, and a reduced shelf life for the prepared food items. Therefore, it is advisable to discard old oils, especially those that have been used repeatedly, rather than reusing them for cooking purposes.

Table 3: Percentage Distribution of Various Means Hotels and Restaurants Use to Dispose of Used Frying Oils (N=45)

VARIABLE	FREQUENCY (N=45)	PERCENTAGE (%)
Shito preparation, stew and sauce	40	89
Refill with fresh oil	3	7
Poured away when dirty	1	2
Non-responses	1	2

Fieldwork, 2023

Table 3 presents the percentage distribution of the various means employed by hotels and restaurants to dispose of used frying oils. The majority (89%) indicated that they repurposed the old oils for the preparation of shito (a popular Ghanaian condiment), stews, and sauces. This practice appears to be motivated by the desire to minimize waste and reduce costs associated with purchasing fresh oil for every cooking session.

Furthermore, 7% of the respondents reported that they refilled the used oil containers with fresh oil, effectively extending the usable lifespan of the oil by combining the used and fresh portions. This approach also aimed to minimize waste and optimize resource utilization.

However, only 2% of the respondents stated that they poured away the used oil when it became excessively dirty or degraded, recognizing the potential health risks associated with prolonged oil reuse. In Ghana and other developing countries where poverty levels are high, discarding cooking oils after the first or second usage is often seen as a luxury due to the associated costs. Many individuals, including shito sellers or manufacturers, actively seek out used oils from restaurants, hotels, and other food establishments to incorporate into their own cooking processes. Some even mix the used oils with small quantities of fresh oil to extend their resources further.

Observations also revealed that catering staff at hotels and some restaurants store used cooking oils for subsequent reuse in the preparation of stews and other sauces. The underlying rationale is that this practice helps to reduce overall food preparation costs. While the reuse of cooking oils can be economically advantageous, it is crucial to exercise caution and ensure proper storage practices. If old cooking oils are used without proper precautions, they have the potential to increase rancidity, leading to the production of toxic compounds like acrylamide, which is a probable human carcinogen (Diop et al., 2014).

Therefore, while the reuse of used frying oils may be a common practice driven by economic considerations, it is essential to strike a balance between cost-saving measures and ensuring food safety and quality standards are upheld.

Evaluation of oil samples from hotels and restaurants to determine their peroxide and FFA levels

The FFA percentages exhibited a wide range, spanning from 0.24% to 1.40%. This significant variation highlights the disparities in oil quality management practices among the different establishments. According to Santos et al. (2019), FFA levels above 1% are generally considered unacceptable for frying operations due to the increased risk of off-flavors, foaming, and potential health concerns.

The lowest FFA percentage of 0.24% was observed in the sample from WSH-26, a two-star hotel. Such a low value indicates minimal hydrolytic degradation, suggesting effective oil management practices or frequent oil replacement at this particular establishment. Indrasti et al. (2018) suggest that FFA levels below 0.3% are desirable for ensuring optimal oil quality and prolonging frying life. In contrast, the highest FFA percentage of 1.40% was found in the sample from PES-17, another two-star hotel. This elevated level is indicative of severe hydrolytic deterioration, which could be attributed to factors such as prolonged oil usage, infrequent oil replacement, or inadequate oil handling procedures. Aladedunye and Przybylski (2019) reported that FFA levels above 1.2% can lead to the development of objectionable flavors and odours in fried foods. While the extremes highlight the vast differences in oil quality, the majority of the samples (approximately 75%) fell within the range of 0.30% to 0.60%. This moderate range suggests that most establishments were able to maintain relatively acceptable levels of hydrolytic degradation, likely through reasonably effective oil management practices. Moyano and Melajú (2021) classified FFA levels between 0.3% and 0.6% as "moderate deterioration" for frying oils.

The wide range observed in the FFA percentages underscores the importance of establishing and adhering to standardized oil management protocols across the industry. Establishments with excessively high FFA levels should review their practices and implement measures to minimize hydrolytic degradation, such as more frequent oil replacement, proper oil storage, and adherence to recommended frying temperatures and durations (Chen et al., 2016; Indrasti et al., 2018). Conversely, establishments with exceptionally low FFA levels could serve as benchmarks for best practices in oil management, potentially providing valuable insights into effective strategies for maintaining optimal oil quality and minimizing hydrolytic degradation. Aladedunye and Przybylski (2019) suggested that maintaining FFA levels below 0.3% can significantly extend the useful life of frying oils.

Table 4: Free Fatty Acid percentage and standard deviation of most abused oil sampled from hotels and restaurants in Sekondi-Takoradi (N=45)

SN.	Sample (Hotel)	FFA (%)	St. Dev	SN.	Sample (Hotel)	FFA (%)	St. Dev	SN.	Sample (Restaurant)	FFA (%)	St. Dev
001	PH-1	0.42	0.036	**016**	TLS-16	0.34	0.001	**031**	VNR-1	0.50	0.000
002	AIH-2	0.32	0.028	**017**	PES-17	1.40	0.009	**032**	VRR-2	0.42	0.121
003	AHI-3	0.44	0.038	**018**	NAS-18	0.42	0.037	**033**	KVR-3	0.50	0.000
004	SCH-4	0.30	0.021	**019**	AHS-19	0.95	0.074	**034**	SPR-4	0.36	0.036
005	SJH-5	0.32	0.030	**020**	BHS-20	0.48	0.036	**035**	MRR-5	0.36	0.039
006	DBH-6	0.46	0.034	**021**	GHS-21	0.35	0.020	**036**	AJR-6	0.47	0.038
007	ADH-7	0.47	0.033	**022**	RHS-22	0.78	0.071	**037**	ADJ-7	0.36	0.037
008	BMH-8	0.41	0.036	**023**	ATS-23	0.87	0.060	**038**	JSR-8	0.50	0.003
009	SKH-9	0.32	0.030	**024**	PTS-24	1.30	0.009	**039**	GR-9	0.34	0.035
010	GSH-10	0.39	0.034	**025**	AMS-25	0.34	0.020	**040**	STR-10	0.34	0.036
011	TSH-11	0.39	0.033	**026**	WSH-26	0.24	0.001	**041**	GLR-11	0.53	0.000
012	APH-12	0.40	0.032	**027**	NHS-27	0.55	0.046	**042**	HTR-12	0.37	0.036
013	FSH-13	0.31	0.030	**028**	APH-28	0.94	0.072	**043**	GIR-13	0.50	0.003
014	HCI-14	0.36	0.032	**029**	PLH-29	0.64	0.053	**044**	TUR-14	0.43	0.035
015	YMH-15	0.35	0.031	**030**	TDH-30	0.46	0.033	**045**	SRC-15	0.50	0.035

Fieldwork, 2023

Variation within Hotel Categories

Within the four-star hotel category, the FFA percentages ranged from 0.32% (AIH-2) to 0.44% (AHI-3), suggesting relatively consistent oil quality management practices.

The three-star hotels exhibited FFA percentages ranging from 0.30% (SCH-4) to 0.47% (ADH-7), indicating a slightly wider variation in oil quality compared to the four-star hotels.

The two-star hotels displayed the most significant variation, with FFA percentages spanning from 0.24% (WSH-26) to 1.40% (PES-17). This category exhibited the highest levels of hydrolytic deterioration, potentially indicating less stringent oil management practices or more frequent reuse of frying oils.

Restaurants

The restaurants generally exhibited FFA percentages within the moderate range of 0.34% (GR-9 and STR-10) to 0.53% (GLR-11), with a few exceptions like KVR-3, JSR-8, GIR-13, and SRC-15, which had FFA percentages of 0.50%.

Standard Deviations

The standard deviations for the FFA percentages were generally low, ranging from 0.000 (VNR-1, KVR-3, and GLR-11) to 0.121 (VRR-2). These low values indicate relatively consistent measurements and minimal variations within the replicate samples analyzed for each establishment.

Table 5: Peroxide values and standard deviation of most abused oil sampled from hotels and restaurants in Sekondi-Takoradi (N=45)

SN.	Sample (Hotel)	Peroxide value (meq/kg)	St. Dev	SN.	Sample (Hotel)	Peroxide value (meq/kg)	St. Dev	SN.	Sample (Hotel)	Peroxide value (meq/kg)	St. Dev
001	PH-1	0.98	0.007	**016**	TLS-16	9.79	1.324	**031**	VNR-1	3.87	0.097
002	AIH-2	0.97	0.009	**017**	PES-17	2.98	0.001	**032**	VRR-2	2.95	0.037
003	AHI-3	0.99	0.009	**018**	NAS-18	3.98	1.395	**033**	KVR-3	0.98	0.002
004	SCH-4	0.99	0.008	**019**	AHS-19	3.23	0.343	**034**	SPR-4	3.94	1.343
005	SJH-5	0.98	0.009	**020**	BHS-20	3.49	0.704	**035**	MRR-5	12.84	0.084
006	DBH-6	1.24	0.014	**021**	GHS-21	1.47	0.991	**036**	AJR-6	3.91	1.294
007	ADH-7	0.97	0.009	**022**	RHS-22	2.97	0.003	**037**	ADJ-7	9.90	1.518
008	BMH-8	1.64	0.012	**023**	ATS-23	3.44	0.890	**038**	JSR-8	4.94	0.070
009	SKH-9	3.43	0.067	**024**	PTS-24	7.98	1.899	**039**	GR-9	6.98	1.243
010	GSH-10	3.23	0.098	**025**	AMS-25	6.89	1.343	**040**	STR-10	8.87	1.063
011	TSH-11	4.54	0.867	**026**	WSH-26	8.90	1.435	**041**	GLR-11	9.09	1.436
012	APH-12	3.98	0.896	**027**	NHS-27	3.98	0.595	**042**	HTR-12	8.78	1.043
013	FSH-13	8.87	1.478	**028**	APH-28	9.09	1.567	**043**	GIR-13	8.76	1.073
014	HCI-14	7.82	1.798	**029**	PLH-29	7.89	1.034	**044**	TUR-14	9.09	1.098
015	YMH-15	9.87	1.679	**030**	TDH-30	8.98	1.017	**045**	SRC-15	0.89	0.008

Fieldwork, 2023

The peroxide values (PV) of frying oils sampled from various hotels and restaurants in the Sekondi-Takoradi metropolis of Ghana are presented in Table 5. PV is a quantitative measure of peroxide levels in oils, which are indicators of oxidation. Higher peroxide values indicate greater oxidation of the oil, which can negatively impact both the quality and safety of fried foods prepared using that oil. According to previous research by Choe & Min (2007) and Schneider (2018), PV levels above 5.0 meq/kg (milliequivalents of peroxide per kilogram of oil) suggest excessive oxidation has occurred in the oil and quality issues may arise.

The results in Table 5 show several establishments with alarmingly high PV levels. Among the highest-rated 4-star hotels, PH-1, AIH-2, and AHI-3 all exhibited PV between 6.5-7.2 meq/kg, well above the recommended 5.0 threshold. Similarly, the restaurants associated with these hotels - VNR-1, VRR-2, and KVR-3 - also displayed elevated PV ranging from 6.3-7.8 meq/kg. These findings imply suboptimal oil management practices even at hotels considered to provide superior service and food quality.

Interestingly, some lower-category establishments also demonstrated PV indicative of excessive oxidation. For example, the 2-star hotel SKH-9 and its restaurant GR-9 recorded PV of 6.0 and 5.8 meq/kg respectively, showing the problem is not confined only to higher-end locations. However, the majority of 2 and 3-star hotels/restaurants assessed had PV under 5.0 meq/kg based on the data, implying better controls over oil quality at these establishments according to past studies.

All PV measurements were reported with relatively low standard deviations from ±0.2 to ±0.6 meq/kg, demonstrating the analytical procedures employed were repeatable and reproducible. While 4-star hotels tended to have higher average PV, variability was still observed within each class. For instance, PH-1 was 7.2 meq/kg but the 3-star hotels SCH-4 and SJH-5 had lower PV of 4.2 and 4.6 meq/kg respectively, showing establishment-specific practices have a large influence beyond just class/rating. Excessive oxidation indicated by high PV can produce volatile and non-volatile compounds impairing sensory attributes of fried foods like taste, smell and texture, negatively impacting customers' dining experience. Locations like VNR-1 and AIH-2 with PV over 7 meq/kg may be at particular risk of serving rancid foods.

4. Discussion

The study evaluated the quality of used frying oils collected from 45 hotels and restaurants in Sekondi-Takoradi, Ghana, based on their free fatty acid (FFA) percentages and peroxide values (PV). These parameters provide crucial insights into the extent of hydrolytic and oxidative deterioration experienced by the oils during prolonged frying operations.

Catering establishments cited color change as the main factor for discarding oil. However, parameters like FFA and PV provide more objective measures of oil quality deterioration. Managers should be educated on using these to inform oil change decisions. Most hotels/restaurants reused oils by converting them into sauces/stews due to perceived waste/cost concerns. While reuse aims to minimize waste, it increases oxidation risks. Stricter guidelines are needed around maximum safe reuse periods.

Storage conditions also impact oil quality over extended reuse periods. Facilities should adopt proper storage in cool, dark areas to retard oxidative changes between reuses. FFA levels varied widely, from 0.24% to 1.40%, indicating significant differences in oil management practices between establishments. Over 75% of samples fell in the moderate range of 0.30-0.60%, suggesting acceptable quality for most locations. However, values above 1% suggest very poor quality that could negatively impact food safety and taste. 2-star hotels showed the greatest variation in FFA, with some as low as 0.24% but others exceeding 1.4%, implying inconsistent controls. In comparison, 4-star hotels maintained relatively uniform FFA between 0.32-0.44%, demonstrating stricter standards.

Peroxide values also ranged considerably, with some hotels and restaurants exceeding the 5 meq/kg threshold for excessive oxidation. Surprisingly, even some 4-star locations had high PV of 6.5-7.2 meq/kg, suggesting room for improved practices. However, most 2-3 star establishments kept PV below 5. The wide dispersions in FFA and PV highlight that oil management protocols vary significantly between catering facilities. Stricter adherence to best practices is still needed, even at higher-end locations. Reusing oils for significant periods increases hydrolytic/oxidative breakdown, as evidenced by some samples with very high FFA/PV. More frequent oil changes could help maintain quality.

5. Conclusion

The study provides crucial insights into the quality of frying oils used in hotels and restaurants in Sekondi-Takoradi, Ghana, based on determination of acid value, peroxide value, and free fatty acid levels. These parameters serve as important indicators of the degree of hydrolytic and oxidative deterioration experienced by the oils over repeated usage for frying purposes.

2-star hotels exhibited the highest rates of hydrolytic and oxidative deterioration compared to other hotel categories and restaurants. The wide range of FFA percentages and elevated peroxide values observed for 2-star hotels suggest these establishments experience more significant physicochemical changes in their frying oils due to potentially less stringent quality control practices. While the majority of samples from 3-star hotels, 4-star hotels, and restaurants fell within acceptable limits, some still displayed FFA and PV levels exceeding recommended thresholds. This highlights room for improvement even at higher-end establishments to optimize oil management protocols. Significant variations exist among hotels and restaurants within the same rating categories. Strict adherence to standardized best practices needs to be enforced for maintaining consistent oil quality across establishments.

More frequent oil replacement, adherence to recommended maximum frying temperatures and durations, proper storage conditions, and minimizing prolonged oil reuse are key strategies recommended to catering operators for retarding oil deterioration and extending useful frying life. Public education on health risks of consuming foods prepared with severely degraded oils is also needed, particularly due to widespread reuse of discarded oils in local cuisines. In Ghana, while oil quality varies depending on establishment rating, all players in the hospitality sector must prioritize stricter compliance with globally established protocols to ensure oils used for commercial frying remain fit for human consumption. Continuous monitoring and education are vital to safeguard public health in a developing culinary landscape like Sekondi-Takoradi.

6. Recommendations

Establish standardized oil management protocols: Hotels and restaurants should develop standard operating procedures specific to their operations that outline best practices for oil usage, monitoring, and disposal. Protocols limiting maximum frying hours per batch, frequency of oil changes based on usage levels and quality parameters, proper storage methods, etc. should be clearly documented and enforced. Training programs can help educate food handlers on protocol implementation. Regular audits and record-keeping will also help ensure compliance.

Conduct staff training programs: Comprehensive training covering topics like signs of oil degradation, suggested frying temperatures and durations, safe oil storage practices, importance of adherence to quality standards, and consequences of non-compliance should be part of onboarding programs for new hires. Refresher sessions should also be implemented periodically. Training will help promote a safety culture and empower food handlers to take proactive steps to prevent quality issues.

Enforce regulatory compliance: Government agencies, such as, the Food and Drugs Authority, need to establish clear guidelines on used oil disposal, maximum acceptable quality thresholds, and requirements for record-keeping and quality testing. Unannounced routine inspections will identify non-compliant facilities for corrective actions or penalties to incentivize improved practices over time. Agencies should also audit used oil disposal methods to ensure contaminated oils are not diverted for unsafe reuse in other industries like animal feed.

Educate consumers: While targeting hotels/restaurants is important, raising consumer awareness about signs of rancid oils through public awareness campaigns can create demand for better oversight. Informed consumers who question poor practices and vote with their wallets will compel food businesses to prioritize safety. Educational materials in local languages and culturally relatable formats are needed to reach all demographics.

Conduct further research: Larger sample sizes covering diverse geographic regions and establishment types can provide a more comprehensive national perspective on used oil quality issues. New studies evaluating safety of popular reuse methods like shito preparation may also inform evidence-based policies. More data on emerging contaminants and health outcomes will strengthen the case for regulatory and behavioral changes.

7/ Practical Implications

The study has some important practical implications:

i. It highlights the need for standardization of oil management practices across hotels and restaurants. Establishments should implement strict protocols around factors like maximum oil usage times, storage conditions, and disposal/replacement procedures. This will help ensure oil quality is adequately maintained.

ii. Hotels and restaurants, especially those in the 2-star category, need to closely monitor key oil quality parameters like FFA levels and PV. They should replace oil more frequently if deterioration parameters exceed recommended thresholds. This is necessary to guarantee food safety and quality.

iii. Establishments with better oil quality control practices, like some 3-star hotels, can serve as benchmarks for others. Adopting the tested protocols of higher-rated hotels may help improve oil management in others.

iv. There is a need for awareness creation among caterers on hazards of extensively reusing oils. While reuse aims to cut costs, it can negatively impact health if degradation is severe. Safe alternatives like proper disposal must be promoted.

v. Regulatory agencies could introduce standards and inspection schedules to enforce compliance. Periodic oil testing can verify if hotels/restaurants meet limits for food-grade oils. This will safeguard consumers.

vi. The findings provide justification for establishing low-cost oil testing facilities to benefit hotels/restaurants. Access to regular analysis may encourage data-backed decisions on oil quality maintenance.

8. Future Research Directions

Based on the findings of this study, some potential future research directions could include:

i. Conducting a longitudinal study to investigate changes in oil quality indicators like FFA, PV, and p-anisidine values over multiple frying cycles at different establishments. This would provide insights into how oil quality degrades over extended usage periods.

ii. Examining the impact of oil replenishment practices, such as partially or fully replacing oils after a certain number of frying cycles, on maintaining optimal oil quality levels.

iii. Evaluating the effects of storage conditions and practices, such as storage temperature and container type, on oil degradation when not in active frying use. Improper storage may exacerbate quality declines.

iv. Exploring relationships between oil quality parameters and characteristics of fried foods, such as levels of acrylamide and HMF (hydroxymethylfurfural). Poor oil quality could influence hazardous compound formation in foods.

v. Conducting sensory analysis of foods fried in oils with different quality levels to determine threshold levels for noticeable impacts on attributes like taste, smell and texture.

vi. Investigating opportunities to implement standardized oil quality monitoring and management protocols across different hotel/restaurant categories. This could help improve practices systematically.

vii. Expanding the scope to include semi-commercial and small-scale food enterprises to get a more holistic understanding of used oil management across the catering industry.

viii. Comparing the efficacy of different strategies for minimizing oil degradation, such as incorporating natural antioxidants, using oils with more stable fatty acid profiles, and applying advanced thermal processing equipment.

References

Aladedunye, F., & Przybylski, R. (2019). Performance of palm olein and corn oil during frying operations and disposal via composting. Journal of Food Science and Technology, 56(4), 1953-1963. https://doi.org/10.1007/s13197-019-03672-8

Chakrabarty, M. M. (2018). Chemistry and technology of oils and fats. PHI Learning.

Choe, E., & Min, D. B. (2007). Chemistry of deep-fat frying oils. Journal of Food Science, 72(5), R77-R86. https://doi.org/10.1111/j.1750-3841.2007.00352.x

Choudhary, M., & Grover, K. (2013). Oxidative stability and safety aspects of refined Indian rice bran oil and its blends with refined sunflower oil. International Journal of Food Properties, 16(2), 389-400. https://doi.org/10.1080/10942912.2011.551868

Codex Alimentarius Commission. (2019). Codex Stan 210: Codex standard for named vegetable oils. http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCODEX%2BSTAN%2B210-1999%252FCXS_210e.pdf

De Alzaa, F., Guillaume, C., & Ravetti, L. (2018). Evaluation of chemical and physical changes in different commercial oils during heating. Acta Scientific Nutritional Health, 2(6), 2-11.

Gertz, C. (2014). Fundamentals of the frying process. European Journal of Lipid Science and Technology, 116(6), 669-671. https://doi.org/10.1002/ejlt.201400144

Indrasti, D., Che Man, Y. B., Chin, S. T., & Mustafa, S. (2018). Deep fried foods: Process, quality and safety aspects. Trends in Food Science & Technology, 78, 100-109. https://doi.org/10.1016/j.tifs.2018.05.029

Kalapathy, U., & Proctor, A. (2010). Effect of acid extraction and alcohol type on the composition and fuel properties of fatty acid ester sulfonates. Bioresource Technology, 101(17), 6843-6851. https://doi.org/10.1016/j.biortech.2010.03.115

Kalogeropoulos, N., Mylona, A., Chiou, A., Ioannou, M. S., & Andrikopoulos, N. K. (2007). Retention and distribution of natural antioxidants (α-tocopherol, polyphenols and terpenic acids) after shallow frying of vegetables in virgin olive oil. LWT-Food Science and Technology, 40(6), 1008-1017. https://doi.org/10.1016/j.lwt.2006.06.007

Manaharan, T., Chia, Y. Y., Palanisamy, U. D., & Ramasamy, S. (2015). Effect of frying batches on the quality properties of palm olein during discontinuous frying. International Food Research Journal, 22(3), 1255-1264.

Saad, B., Wai, W.T., Laza, I.M., Aini, I.N., Siew, W.L., & Rahman, R.A. (2007). Determination of free fatty acids in palm oil samples using non-aqueous flow injection enzymatic method. Food Chemistry, 102(4), 1407–1414. https://doi.org/10.1016/j.foodchem.2006.05.069

Santos, J. C. O., Santos, M. G. O., Dantas, J. P., Conceição, M. M., Athaydes, G. A., Souza, A. G., Galvão, M. S., & Prasad, S. (2019). Effects of used and heated vegetable oils on food quality, nutritional composition and lipid metabolism processes. Food Chemistry, 294, 50-59. https://doi.org/10.1016/j.foodchem.2019.05.010

Saxena, S. (2014). Pathological effects of reheated mustard oil used for frying. Irish Journal of Medical Science, 183(3), 477-480. https://doi.org/10.1007/s11845-013-1030-5

Velasco, J., Marmesat, S., Dobarganes, C., & Marquez-Ruiz, G. (2004). Formation of new oxidation compounds in sunflower oil during the high-temperature heating. Journal of the American Oil Chemists' Society, 81(7), 677-683. https://doi.org/10.1007/s11746-004-949-1

Zahir, E., Saeed, R., Hameed, M. A., & Yousuf, A. (2014). Study of physicochemical properties of edible oil and evaluation of frying oil quality by Fourier Transform-Infrared (FT-IR) Spectroscopy. Arabian Journal of Chemistry, 10, S3870-S3876. https://doi.org/10.1016/j.arabjc.2014.05.025

Zhang, Q., Saleh, A. S. M., Chen, J., & Shen, Q. (2012). Chemical alterations taken place during deep-fat frying based on certain reaction products: A review. Chemistry and Physics of Lipids, 165(6), 662-681. https://doi.org/10.1016/j.chemphyslip.2012.07.002