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Quality Assessment of Vegetable Oils Used in Traditional Potato Chips Production in Mosul City Using Gas Chromatography–Mass Spectrometry (GC–MS)

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Abstract: This study aimed to evaluate the quality of vegetable oil used in the traditional production of unpackaged potato chips marketed in Mosul City, Iraq. Potato chips were prepared using palm oil at 170–180 °C for 3–5 min from potato slices (2–3 mm thick) after soaking in water for 30 min. Random samples were collected during 2025, and oil quality was evaluated weekly over a period of 10 weeks. Oil quality was assessed by determining peroxide value (PV), free fatty acids (FFA), oil absorption, p-anisidine value (p-AV), and volatile compounds using gas chromatography–mass spectrometry (GC–MS). The results showed considerable variation among the collected samples, indicating inadequate control of frying conditions and oil management practices. Peroxide values ranged from 32.6 to 41.1 meq O_2/kg oil, while free fatty acid values and oil absorption ranged from 1.28–3.33% and 31–41%, respectively. The addition of garlic powder, salt, or hot pepper after frying had no significant effect ($P > 0.05$) on oil absorption, peroxide value, free fatty acid content, or p-anisidine value. GC–MS analysis identified several volatile compounds associated with lipid oxidation and thermal degradation, including 2-hexylfuran, (E,E)-2,4-decadienal, (E,E)-2,4-nonadienal, hexyl formate, 3-methyltetrahydrofuran, methylcyclopentane, and 3-methyl-1-penten-4-yn-3-ol, with relative abundances ranging from 0.56% to 0.80%. The detection of these compounds confirms the formation of primary and secondary lipid oxidation products during repeated frying and supports the conventional physicochemical indices used to assess frying oil deterioration. These findings demonstrate that GC–MS is a valuable complementary analytical tool for monitoring chemical changes in frying oils and improving the quality assessment of traditionally produced potato chips.

Key words: palm oil, potato chips, free fatty acid, peroxide value, GC–MS

1. Introduction

Potato chips are widely consumed in Iraq and other countries worldwide. Especially by young people due to their taste fullness, crispy texture and rich mouthfeel. Iraqi Consumed preference for imported Potato chips was about (78%) because they were widely distributed in large quantities and lower price from that locally produced chip. While the ratio people who prefer the local product about 21% (**Jassim et al., 2020**). Potato chips are among the most popular fried snack foods worldwide characterized by salt and other taste added like garlic, hot pepper or season powder. In Mosul city most Potato chips are processed in traditionally processing methods from locally grown potatoes. Despite of easy it is production Iraq imported a large quantity from abroad, it is indicating the great demand for it most time of the year and there is no sign of declining in popularity among young peoples. Locally produced chips sold without packaging exposed to direct heat, light, moisture and ambient air which inevitably leads to self-oxidation by the presence of thin oil layer on surface of slice **(Bonacina and Decker, 2021)**.

Vegetable oils are a staple in the modern diet, widely used in cooking, particularly deep frying, which is one of the most common food preparation methods. With urbanization and a faster pace of life, reliance on fast and fried foods has increased, leading to a significant rise in oil consumption. These oils are often reused multiple times at high temperatures, without regard for hygiene standards or adequate oversight, contributing to the deterioration of their physical and chemical properties and the formation of compounds harmful to health **(López et al., 2024)**.

Frying oil acts as a heat transfer medium and simultaneously affects the texture, flavor, and overall sensory characteristics of fried foods. Recent scientific literature confirms that the deterioration of frying oils is a dynamic process that accelerates with repeated frying cycles, especially when there are breaks between cycles during which the oil is left exposed to oxygen at room temperature, increasing the rate of auto-oxidation before reheating **(Selvi Moorthy et al., 2024)**. Repeated heating of oils, especially those rich in unsaturated fatty acids such as corn oil and sunflower oil, leads to oxidation and thermal decomposition reactions that produce toxic compounds such as aldehydes, ketones, and epoxides, as well as the formation of free radicals. These compounds have a high capacity to induce oxidative stress within the body, causing damage to cell membranes, proteins, and DNA. The liver is one of the organs most susceptible to these effects due to its central role in lipid metabolism and detoxification **(Saha et al., 2025)**. One of the most important problems of chips industry which not given much attention in developing Countries like Iraq is production of carcinogenic acrylamide. The study of **Al-Janabi (2013)** on local potato chips indicated to acrylamide content were in the range 339-1024 mg/kg which is presence in all brands of potato chips collected from Iraqi grocery stores and all samples exhibited a crylamide content exceeding the recommended average dosage. To maintain public health, It was necessary to shed light on some specification of local potato chips manufactured in traditional methods and sold without package exposed to oxygen light and moisture, namely the value of Peroxide, fatty acid and absorption of chips which was the aim of this study.

2. Materials and Methods

The samples of potato chips were randomly collected weekly for the months March, April and May to which three flavoring substances were added: salt, garlic and chili powder. The samples were dried in vacuum oven at 50-55 ℃ for 4 hours until weigh stable before estimating the percentage of oil absorbed.

Percentage of oil absorbed

The total oil content absorbed by the potato chips was determined via continuous solvent extraction using a Soxhlet apparatus. Dried and crushed chip samples were extracted with petroleum ether (boiling range: 40-60 ℃) for 4 h. Following extraction, the solvent was evaporated to obtain the crude oil, and the total oil percentage was calculated gravimetrically. The extracted oil was subsequently utilized for the determination of chemical quality indices, including the peroxide value, according to the methodology described by **Yaseen (2020)**.

Peroxide value of extracted oil

It was determined according to AOCS Method Cd 18-90. The oil sample (5±0.01 g) was dissolved in 30 mL acetic acid-chloroform (3:2) solution. Then saturated KI solution and distilled water were added and shake the flask vigorously to liberate iodine from chloroform layer. The mixture was titrated with 0.01 N sodium thiosulphate using starch solution as an indicator.

$$PV = \frac{[\text{volume for the sample (mL)} - \text{volume for the blank (mL)}] \times \text{Normality} \times 1000}{\text{weight of oil sample (g)}}$$

Free fatty acid

It was determined according to AOCS method 5a-40. oil sample size, volume of alcohol (ethyl alcohol), and NaOH strength are 3.53 to 56.4 g, 50 to 100 mL, and 0.1 to 1.0 N, respectively, FFA concentration in fats and oils is calculated as percentage oleic acid.

$$\%FFA \text{ as oleic acid} = \frac{\text{alkali volume (mL)} \times \text{alkali normality } 28.2}{\text{sample weight (g)}}$$

Determination of P-anisidine value (P-AV)

The p-anisidine value was determined using a spectrophotometer (UV 1700, Shimadzu Corporation), followed by AOCS method Cd 18-90 **(AOCS, 1989)**. According to AOCS, a standard procedure was used to assess the carbonyl content of oils. The aldehydes carbonyl bond on the p-anisidine amine group, which forms a Schiff's base and absorbs at 350 nm, is measured for its reactivity. 2g of oil was dissolved in 25 ml isooctane and absorbance A_1 was measured at 350nm against a blank isooctane. An aliquot (5ml) of this solution was transferred to each of two test tubes of 10ml and 1ml anisidine solution (0.25% g/v glacial acetic acid) was added to each. After 10 minute the absorbance A_2 (blank) was measured at 350 nm against isooctane containing p-anisidine. The P-AV is determined as;

P-AV = 25 x 1.2 x (A2-A1) / W.

P-AV: P-anisidine value.

A1: First reading of absorbance.

A2: Second reading of absorbance.

W: Sample weight**.**

Estimation of the active compounds present in the oil

The active degradation compounds present in the extracted oil samples were estimated according to the method indicated by **Abdulsalam and Akdo (2023)** using gas chromatography-mass Spectrometry (GC-MC) technique. The volatile fractions were separated and identified utilizing a GC-MS system equipped with a fused silica capillary column, employing Helium (99.99% purity) as the carrier gas at a constant flow rate of 1.0 mL/min, with the oven temperature programmed from 50 ºC to a final hold at 280 ºC to optimal peak resolution.

Statistical analysis

The Social Application Statistics System (SPSS) program was used to carry out the statistical analysis in accordance with the analysis of variance (ANOVA). The Duncan's Multiple Test was used to compare the arithmetic means and identify any discrepancies between the groups **(Duncan ،1955).**

3. Results and Discussion

Typical chemically test used for shelf life of potato chips involve extraction of oil absorbed which indicate the degree of acceptance chips because the change take place in trying oil provide a good correlation to the shelf life. The peroxide value and free fatty acids are measure of the Primary oxidation products which oxidized to secondary products and polar lipids and other sub products which lead to produce off flavor and that have health risks **(Duguma and Abebaw, 2020).** Potato chips especially producing in traditional methods (batch process) and marketing without Packaging exposed to heat, light and ambient moisture that in one of the most problem in traditional food processing especially the health supervision of food processing and potato chips production with high oil uptake which lead to fat gain and increased obesity chance and health problems for consumers mostly in children category who eat this kind of foods **(Arslan et al., 2018),** the higher fat content of chips mainly owing to many factors frying temperature, potato moisture, kind of frying oil and their use thin cut (1-2mm) or crinkle cut ship result in a proportionally large absorption of fat **(Goñi et al., 1997).** Because the large interaction that cause increase oil absorption, a number of attempts have been made on potato fruit before slicing including: blanching or Partial drying decrease frying temperature and in our current study, the fruit were soaked with water for half hour.

Blanching potato slice generates an external crust during frying, thus increase resistance to oil absorption **(Zhan and Wang, 2016).** Temperature of frying 180c had uptake of fat more than 160c and the best temperature were 160c for ten minutes for production low fat potato chips and oil uptake were between 28% to 23% from weight **(Mirzaei et al., 2015).** From the table (1) obvious the percentage of oil uptake is too high and various with different days for all month's studies. The range between 31 to 41 % and the average (37%) making tham use palm oil as a frying oil which consist of a fatty layer on the surface of slices .in general oil uptake it high compared with many research **(Mirzaei et al., 2015; Cruz et al., 2018, Alkaltham et al., 2020)** while other indicate that the percentage of oil content were 35% at 180c, the and most of oil locale on surface of chips **(Saravanan and Bharathi 2012; Pedreschi 2016)** other researcher they found 40% and more from the weight chips **(Ouchon and Pyle, 2006; Pedreschi and Moyano, 2008)**.

Table (1). Characteristics of oil extracted from potato chips

Salt				Garlic				Hot pepper			
Time	**%oil**	**Pv**	**Free Fatty acid %**	**Time**	**%oil**	**Pv**	**Free Fatty acid %**	**Time**	**%oil**	**Pv**	**Free Fatty acid %**
1 week	41.68	15.5	1.63	**1 week**	37.89	15.5	3.32	**1 week**	39.16	12.34	3.2
2 week	40.44	11.8	2.79	**2 week**	31.57	18.60	3.12	**2 week**	38.04	11.40	3.33
3 week	41.79	8.1	2.09	**3 week**	32.19	15.5	3.14	**3 week**	36.16	10.2	2.99
4 week	40.71	11.2	2.03	**4 week**	34.21	16.60	1.08	**4 week**	40.41	11.12	1.35
5 week	41.65	8.3	2.58	**5 week**	31.72	20.04	1.09	**5 week**	40.81	7.51	1.82
6 week	40.71	16.60	3.59	**6 week**	30.05	17.11	1.54	**6 week**	32.6	13.80	1.28
7 week	40.51	17.18	2.53	**7 week**	30.83	40.4	1.98	**7 week**	41.01	11.16	1.29
8 week	40.10	11.8	2.3	**8 week**	31.83	17.30	2.3	**8 week**	40.4	11.18	2.22
9 week	41.52	11.05	1.23	**9 week**	31.39	18.6	2.36	**9 week**	38.16	10.3	3.26
10 week	40.44	11.09	1.27	**10 week**	31.17	15.6	3.35	**10 week**	39.26	10.6	3.18

From the some table the peroxide value was too high throughout all the days of the months in which the samples were taken that is mean the oil used for frying may be repeated several times and the high temperature used 180 ºC an oxidation happen specially on thin fat layer at surface of slice as well directly contact with oxygen and exposed to light accelerate of oxidation and that is mean there is no effect for natural antioxidant of palm oil is low as it highly saturated fatty acid, some countries forbad using oil for frying if the free fatty acid 1% or above **(INSO, 2016)** and other like USDA and European country allow to limit between 1-2.5% **(Sebastian et al., 2014 and Alani et al., 2026)**.

From table (2) there is no statistically significant difference between the three groups studied (salt, garlic, hot pepper) as regarded with free fatty acid, while there is a difference in oil percentage of oil absorption on Peroxide value for two groups, salt, garlic and garlic, hot pepper.

Table (2). Characteristics studied of oil after adding salt, garlic and hot pepper

Addition	Mean Number Standards Deviation			
	%oil absorption	Peroxide value meq O_2/kgm oil	Free fatty acid %	P. AV
Salt	40.95 ± 0.32a	12.20 ± 0.58b	2.10 ± 0.05a	15.45 ± 0.74a
Garlic	33.90 ± 0.54b	17.30 ± 0.82a	2.37 ± 0.07a	14.60 ± 0.69a
Hot peper	38.60 ± 0.48a	10.90 ± 0.63a	2.51 ± 0.06a	7.92 ± 0.51a

Anisidine value reflected secondary oxidation product (aldehydes) produce from the decomposition of hydroperoxides, anisidine number for fresh oils ranged from 4-4.7 indicate acceptance quality **(Tabee et al., 2009).** Use for frying two kinds of olive oil and palm oil at 180 ºC for 5 hrs starting of frying anisidine number increase in both oil used and reach 32.8 and 53.4 alternatively in chips industry the anisidine value different depending on the length of frying period and time taken samples.in this study the values different according the time which taken the sample and all number is not too high.

The volatile profile illustrated in Table (3) identifies a diverse group of chemical compounds generated during the deep-fat frying of traditionally processed potato chips. The continuous thermal abuse of palm oil at high temperatures 170-180 ºC combined with the moisture and chemical components evaporating from the potato slices, triggers complex degradation pathways. Most notably, the data reveals that a significant portion of the identified volatile fraction consists of cyclic derivatives, which can be categorized as oxygenated heterocycles and structural indicators of extensive lipid-protein interactions.

These compounds primarily originate from the synergistic interaction between the free amino acids present in the potato tissues (such as asparagine) and the lipid peroxidation cleavage products via thermal rearrangement and advanced Maillard reaction sub-pathways. For instance, unsaturated aldehydes including (E, E)-2,4-decadienal (Peak #6) and (E, E)-2,4-nonadienal (Peak #7) were both detected at a high relative abundance of 0.80%. These conjugated dienals are well-known markers of linoleic acid degradation. Due to their exceptionally low odor thresholds, they are directly responsible for the development of undesirable, rancid, and stale off-flavors in the non-packaged chips.

Furthermore, severe thermal alteration led to the cyclization and dehydration of primary decomposition products, explaining the accumulation of oxygenated heterocyclic rings such as 2-hexylfuran (Peak #5) at 0.80% and 3-methyltetrahydrofuran (Peak #2) at 0.56%. Simultaneously, aliphatic and cyclic hydrocarbons were identified, including methyl cyclopentane (Peak #3) at an area percentage of 0.56%, which reflects the advanced structural pyrolytic cleavage of the fatty acid backbone.

The presence of shorter-chain cleavage fragments at earlier retention times (2.033 min), such as hexyl formate (Peak #1, 0.56%) and the highly unsaturated alcohol 3-methyl-1-penten-4-yn-3-ol (Peak #4, 0.80%), further confirms continuous radical recombination between volatile alcohols and fatty acid scission products. The co-presence of these complex cyclic, ester, and aldehyde derivatives underscores the extreme state of frying oil abuse under local processing conditions in Mosul City. These experimental findings strongly concur with the structural thermal degradation trends and volatile accumulation patterns documented by **Abdulsalaam and Akdo (2023)**, **Du et al. (2022)**, and **Merlo et al. (2021)**.

Table (3). GC–MS Analysis of Volatile Compounds and Thermal Degradation Products

PK#	Retention Time (min)	Compound Name	Molecular Formula	The percentage of compound in the sample (Area %)	MolWeight
1	2.033	Formic acid, hexyl ester n-Hexyl formate Hexyl formate n-Hexyl methanoate Hexyl formiate	$C_7H_{14}O_2$	0.56	130
2	2.033	Furan, tetrahydro-3-methyl- Tetrahydro-3-methylfuran 3-Methyltetrahydrofuran	$C_5H_{10}O$	0.56	86
3	2.033	Cyclopentane, methyl- Methyl cyclopentane	C_6H_{12}	0.56	84
4	7.067	3-Methyl-1-penten-4-yn-3-ol 1-Penten-4-yn-3-ol, 3-methyl- 3-Methyl-pent-4-en-1-yn-3-ol- 3-Methyl pent-4-en-l-yn-3-ol	C_6H_8O	0.80	96
5	12.108	Furan, 2-hexyl- 2-Hexylfuran 2-n-Hexylfuran	$C_{10}H_{16}O$	0.80	152
6	12.483	2,4-Decadienal, (E, E)-	$C_{10}H_{16}O$	0.80	152
7	12.483	2,4-Nonadienal, (E, E)- 2,4-trans, trans-Nonadienal 2,4-Nonadien-1-al (2E,4E)-2,4-Nonadienal 2,4-(E, E)-Nonadienal (2E,4)	$C_9H_{14}O$	0.80	138

4. Conclusions and Recommendations

We can conclude from this survey study on random samples from potato chips manufacturing factories by traditional methods and assessment the oil used as follow:

1. There is large difference between one samples and others is due to the lake of precise control of time and temperature of the frying oil and moisture content of slices before frying.
2. The characteristics are affected by the length of the oil use of the oil and number of repeated it.
3. Soaking potatoes for half an hour in water before frying led to a high percentage of moisture content and sequent the evaporation of the water was increased and formation of vacuum gaps which was filled with oil when frying and the moment removed from the oil.
4. It is necessary to use new oils that are not stored in hot weather of Mosul city specially in spring and summer season because the high initial peroxide value will accelerate oxidation in the

presence of heat and oxygen. Then the product marketing with high peroxide value which does allow it is use in nutrition.

5. It is very necessary to fill the product in a vacuum packages that are not permeable to light.
6. It is necessary to use antioxidant from the kind that resist high temperature used in trying oil.

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Conflict of Interest

Authors declare that they have no conflict of interest.

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تقييم جودة الزيوت النباتية في صناعة رقائق البطاطس المحلية في مدينة الموصل باستخدام تقنية كروماتوغرافي الغاز المرتبط مطياف الكتلة (GC-MS)

الخلاصة

دفت هذه الدراسة إلى تقييم جودة الزيت النباتي المستخدم في الإنتاج التقليدي لرقائق البطاطس غير المغلفة والمُسوّقة في مدينة الموصل، العراق. تم تحضير رقائق البطاطس باستخدام زيت النخيل عند درجة حرارة 170-180 درجة مئوية لمدة 3-5 دقائق من شرائح البطاطس (بسماكة 2-3 مم) بعد نقعها في الماء لمدة 30 دقيقة. جُمعت عينات عشوائية خلال عام 2025، وقُيّمت جودة الزيت أسبوعيًا على مدار 10 أسابيع. وتم تقييم جودة الزيت من خلال تقدير رقم البيروكسيد (PV)، والأحماض الدهنية الحرة (FFA)، والمحتوى الكلي للزيت، وقيمة p-anisidine (p-AV)، إضافةً إلى تحديد المركبات المتطايرة باستخدام تقنية كروماتوغرافيا الغاز المقترنة بمطياف الكتلة (GC-MS). أظهرت النتائج وجود تباين ملحوظ بين العينات المجمعة، مما يشير إلى عدم كفاية التحكم في ظروف القلي وممارسات إدارة الزيت، وتراوحت قيم رقم البيروكسيد بين 32.6 و41.1 ملي مكافئ أوكسجين/كغم زيت، في حين تراوحت قيم الأحماض الدهنية الحرة بين 1.28–3.33%، وتراوح المحتوى الكلي للزيت بين 31–41%. كما بينت النتائج أن إضافة مسحوق الثوم أو الملح أو الفلفل الحار بعد عملية القلي لم يكن لها تأثير معنوي ($P > 0.05$) في الخصائص النوعية للزيت المستخلص**.** وكشف تحليل GC–MS عن وجود عدد من المركبات المتطايرة المرتبطة بأكسدة الدهون والتحلل الحراري، من بينها 2-hexylfuran،‏ (E,E)-2,4-decadienal, (E, E)-2,4-nonadienal, hexyl formate, 3-methyltetrahydrofuran, methylcyclopentane, و3-methyl-1-penten-4-yn-3-ol ، إذ تراوحت الوفرة النسبية لكل مركب بين 0.56% و0.80%. ويؤكد وجود هذه المركبات تكوّن نواتج الأكسدة الأولية والثانوية نتيجة تكرار استخدام الزيت في القلي، كما يدعم مؤشرات الجودة الفيزيائية والكيميائية التقليدية المستخدمة لتقييم تدهور زيوت القلي. وتشير هذه النتائج إلى أن تقنية GC–MS تمثل أداة تحليلية مكملة وفعّالة لرصد التغيرات الكيميائية التي تطرأ على زيوت القلي، وتعزيز تقييم جودة رقائق البطاطس المنتجة بالطرق التقليدية.