

RESEARCH ARTICLE

Quality and Microbial Assessment of Cooking Oils and Serving Plates Used by Street Food Vendors in District Sialkot, Pakistan

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Abstract

Introduction: Street-vended foods are essential for low- and middle-income populations in developing countries, but public health risks arise from unhygienic practices, including the continual reuse of cooking oil. This study aimed to evaluate the physicochemical quality of cooking oils and the microbial contamination of serving plates used by street food vendors in Sialkot District, Pakistan. **Materials and Methods:** One hundred and fifty composite samples of frying oils and serving plates were collected from vendors across six zones: urban, educational, *kachebri* (government offices), *bazar* (market), fast-food, and rural areas. Oil quality was assessed by analyzing moisture content, free fatty acids (FFA), acid value (AV), peroxide value (PV), and total polar compounds (TPC). Microbial load on serving plates was evaluated using total plate count (TPC) and *Escherichia coli* enumeration. **Results:** The highest mean values indicating severe oil degradation were found in samples from rural vendors: FFA (1.82%), AV (3.62 mg KOH/g), PV (13.8 meq/kg), and TPC (28.4%). The *bazar* area exhibited the poorest hygiene, with the highest mean total plate count (3.7×10^4 CFU/cm²) and the presence of *E. coli* on multiple serving plates. **Discussion:** The results demonstrate significant deterioration of cooking oils, particularly in rural settings, and substantial microbial contamination on serving utensils, especially in market areas. This indicates widespread unsafe practices, including excessive oil reuse and poor hygiene, which pose serious cross-contamination risks to consumers. **Conclusion:** The findings underscore an urgent need for periodic monitoring of street food operations, strict enforcement of national food safety standards, and targeted awareness programs for vendors and consumers to promote safer food practices in Pakistan.

Keywords: Street food, Cooking oil quality, Microbial contamination, Food safety, Public health

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1. Introduction

Street foods have become an integral component of the urban and rural food supply chain in developing countries, providing affordable, convenient, and culturally appealing meals to millions of consumers daily. In Pakistan, as in many low- and middle-income people, street vending serves as both a livelihood opportunity and a primary source of ready-to-eat foods for the working class, students, and travelers. Despite their economic and social importance, street foods are frequently prepared and served under unhygienic conditions, making them potential vehicles for foodborne diseases (1,2).

One of the most critical health concerns associated with street food is the repeated use of cooking oil for deep-frying. Prolonged and repeated heating accelerates lipid oxidation, hydrolysis, and polymerization reactions, leading to the formation of free fatty acids, aldehydes, and polar compounds that compromise oil quality and consumer health (3,4). Consumption of such deteriorated oils has been linked to oxidative stress, cardiovascular disease, obesity, and other metabolic disorders (5). In Pakistan, vendors often reuse oil multiple times to reduce operating costs, largely due to limited regulatory oversight and low public awareness regarding the toxicological risks associated with degraded oils. Equally concerning is the microbial contamination of serving utensils, particularly plates and cutlery, which are seldom washed properly between uses. Vendors typically use stored or contaminated water for cleaning, often without detergents or sanitizers, facilitating the growth and transmission of pathogenic microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* spp. (6,7). These practices contribute to the spread of gastrointestinal infections and foodborne outbreaks in densely populated areas.

Previous studies conducted in various regions of Pakistan have documented the chemical and microbiological hazards associated with street foods (8). However, there is limited empirical data on the quality of cooking oils and hygiene of serving utensils used by street food vendors in secondary urban centers such as Sialkot. This district represents a diverse mix of socio-economic zones, from rural settlements to industrial and educational areas, making it an ideal case study for assessing the variation in street food safety practices.

Therefore, the present study was designed to:

- (1) assess the physicochemical quality of cooking oils used by street food vendors in different localities of Sialkot, and
- (2) evaluate the microbial contamination of serving plates employed by these vendors.

The findings aim to provide evidence-based recommendations for improving food safety practices among street food vendors and to support the implementation of regulatory measures by local authorities and public health departments.

2. Literature Review

Street food represents an essential and growing segment of the informal food sector in low- and middle-income countries because it provides low-cost, convenient meals and livelihoods for many urban and peri-urban residents. However, the informal nature of this sector often results in limited regulatory oversight, suboptimal infrastructure

(water, waste disposal), and widely variable hygiene practices that together increase the risk of chemical and microbiological hazards in ready-to-eat foods (2). Repeated heating and prolonged use of frying oils cause a cascade of physico-chemical changes hydrolysis, oxidation and thermal polymerization producing free fatty acids, peroxides, carbonyl compounds and high-molecular-weight polar fractions. These compounds reduce oil quality, alter sensory attributes of fried food, and may generate biologically active toxicants associated with oxidative stress and other chronic health effects (3,9). Several field studies have reported that street vendors commonly reuse frying oil well beyond recommended turnover intervals, producing oils with elevated FFA, peroxide value and total polar compounds (10,11). Regional evidence confirms these global findings. In Brazil and India, surveys of vendors and small restaurants found frequent reuse of oils and chemical markers (TPC, FFA, PV) that exceed safe thresholds; similar observations were recorded in Pakistani market surveys of packaged and used oils that revealed deviations from PSQCA (national) standards (12,13). These studies highlight that both industrial and small-scale frying practices can yield oils that pose a health risk if not properly managed. Serving plates, cutlery and other food contact surfaces act as critical control points for cross-contamination. Poor washing practices (use of stored or contaminated water, inadequate detergents or drying), hand hygiene failures, and environmental exposure lead to high bacterial loads and fecal indicator organisms (e.g., *E. coli*) on utensils in many street-food settings (6). Field studies across South Asia and Africa repeatedly report unacceptable total plate counts and frequent detection of *E. coli*, *Staphylococcus aureus* and non-typhoidal *Salmonella* on plates and spoons, reflecting fecal contamination and poor sanitation infrastructure (2,4,7). In Pakistan, several cross-sectional studies have documented high microbial loads in popular street foods and implicated utensils, water used for washing, and vendor practices as major contributory factors. Microbiological surveys from Karachi and other cities reported significant bacterial contamination of commonly vended items and implicated water quality and handling practices as major drivers of contamination (14). These national studies corroborate the need for localized assessments (city/district level) because food safety risks and vendor behaviors vary substantially across urban, peri-urban and rural settings. Bangladesh offers additional evidence of widespread contamination in handmade condiments and street foods; studies have reported high prevalence of *Salmonella* and other enteropathogenesis in sauces and ready-to-eat items, largely attributed to manual preparation, inadequate reheating and storage, and poor vendor hygiene (15). The Bangladesh data further emphasize that small, perishable accompaniments (sauces, chutneys) can be frequent sources of foodborne pathogens when prepared under unhygienic conditions.

Intervention studies and randomized field trials in India have tested vendor training and information interventions. While knowledge and awareness often improve after short trainings, behavioral change is more challenging and sometimes limited by economic constraints (e.g., cost of replacing oil, lack of access to potable water) underscoring that training must be paired with structural support and enforcement to be effective (16). This body of evidence

suggests multi-pronged interventions (training + infrastructure + monitoring) are more likely to produce sustainable improvements in street-food safety. WHO and FAO guidance documents and risk-analysis frameworks emphasize the need for context-appropriate food safety measures in the informal sector, recommending simplified Good Hygiene Practices (GHP), access to clean water, risk-based inspection, and community education. The FAO/WHO approach also promotes adaptation of HACCP principles to small-scale operations through simplified checklists and capacity building of local health authorities (WHO; FAO resources). These international instruments provide a practical roadmap for designing interventions and surveillance strategies tailored to street-food contexts. Although numerous studies document either frying-oil degradation or utensil contamination, far fewer have combined both chemical (oil quality) and microbiological (serving plate) assessments from the same vendors and across diverse localities. There is also a paucity of district-level studies in Pakistan that map spatial variability (urban vs. educational vs. market vs. rural) in both oil and utensil safety. The present study addresses these gaps by concurrently analyzing physicochemical markers of oil deterioration (FFA, AV, PV, TPC) and microbiological contamination of serving plates across six representative zones of Sialkot, providing integrated evidence for targeted policy and interventions.

3. Materials and Methods

3.1 Study Area and Design

This cross-sectional study was conducted in District Sialkot, Punjab, Pakistan — an industrial and commercial hub known for its dense network of street food vendors. Six representative localities were selected based on population density and food vending activity: Urban (U), Educational (E), Kachehri/Government (K), Bazar/Market (B), Fast-food fryer (F), and Rural (R) areas. The sampling design aimed to capture spatial variability in food handling and hygiene practices across the district.

3.2 Sample Collection

A total of 150 composite samples were collected, comprising 75 used cooking oil samples and 75 surface swabs from serving plates. From each zone, fifteen oil samples were collected from active frying operations, and fifteen swab samples were taken from serving plates immediately after use. All samples were collected aseptically in sterilized glass bottles and sterile swab kits, labeled appropriately, and transported in insulated containers at 4°C to the Food Analysis and Microbiology Laboratory, Department of Food Sciences, Government College University, Faisalabad.

3.3 Physicochemical Analysis of Cooking Oil

The quality of cooking oils was evaluated using standard analytical methods (AOAC). The parameters included:

3.3.1 Moisture Content (%): Water content of oil was checked oven drying method (17). I took a cleaned porcelain cup and heated it in hot air oven at 105°C for 30 minutes. Then cool it in a desiccator. The weight of the empty dry porcelain cup was calculated using weighing balance. Then 2 grams of oil sample was taken on the dry porcelain cup

and put in a hot air oven for 4 hours at 105°C. After a given time the weight of the dried oil porcelain cup was calculated. Weight loss is the amount of water (moisture content) in the oil.

3.3.2 Free Fatty Acids (FFA %): Oil sample neutralized with ethanol was titrated with NaOH taken in the burette, by protocol described in AOCS (2006) manual. 20 ml pure ethanol was taken in 250 ml Erlenmeyer flask. 10 g of oil sample was poured in it. Stirrer the flask with magnetic stirrer. 3 drops of phenolphthalein indicator were added with pipette in the flask. Titrated using 0.1 N NaOH until a color change from colorless to pink.

3.2.3 Acid Value (AV, mg KOH/g): The acid number is the number milligrams of Potassium Hydroxide needed to neutralize 1 gram of sample. Procedure was done according to AOCS Ca 5a-40. 20 ml pure ethanol was taken in a conical flask. Add 3 drops of Phenolphthalein Indicator. Titrate it against 0.1 N Potassium Hydroxide until a faint pink color appears. 5 g oil sample was added in it, shaken and heated the solution in a hot plate magnetic stirrer until the mixture mixed. Titration was done against 0.1 N Potassium Hydroxide solution until faint pink color appeared. Note the initial and final reading of 0.1 N KOH used.

3.2.4 Peroxide Value (PV, meq O₂/kg): It is determined as by AOAC 965.33. I took a 5 g sample of oil in 250 ml Erlenmeyer flask. Add 30 ml of Acetic Acid Chloroform mixture with 3:2 v/v (12 ml of chloroform and 18 ml of glacial acetic acid) were added to the flask. The solution was shaken until the ingredients were mixed. After all the ingredients were mixed, 0.5 ml of saturated KI solution was added and mixed it for 1 minute. Add 30 ml of distilled water in a flask and mixed. Then 0.5 ml of 1% starch was added mixed, dark color appears. Immediately titrated the mixture with 0.1000 N Na₂S₂O₃ until the solution changed color from dark blue to blue began to disappear. The determination was done with all samples. The peroxide number is expressed in mg-peroxide equivalent in every 100 g of sample.

3.2.4 Total Polar Compounds (TPC, %): The total polar compounds (TPC) were determined according to the procedure described by (Ghobadi et al., 2018). For the measurement Testo 270 instrument (Germany) is used. Testo sensor was put into the oil sample and the value was recorded after 20 seconds. After each sample testing the sensor was cleaned with hot water and

neutralized and dried for next measurement. All analyses were performed in triplicate to ensure accuracy. Results were compared with the permissible limits set by the Pakistan Standards and Quality Control Authority (PSQCA) and the Codex Alimentarius Commission (2019).

3.4 Microbiological Assessment of Serving Plates

Swab samples from serving plates were analyzed for total bacterial load and *Escherichia coli* contamination using standard microbiological techniques (FDA BAM, 2020).

3.4.1 Total Plate Count (TPC): Swabs were serially diluted in sterile peptone water, plated on Plate Count Agar (PCA), and incubated at 37°C for 48 h. Colony-forming units (CFU) were recorded and expressed as CFU/cm².

3.4.2 Enumeration of *E. coli*: Samples were streaked on MacConkey agar and incubated at 37°C for 24 h. Typical colonies (pink to red) were confirmed using Gram staining, oxidase, and catalase tests following the procedure of (18).

3.5 Statistical Analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) under a Completely Randomized Design (CRD) to compare mean values among zones. Significance was determined at $p < 0.05$ using SPSS (version 22.0, IBM Corp., Armonk, NY, USA). Mean differences were separated by Duncan's Multiple Range Test (DMRT). Results were presented as mean \pm standard deviation (SD).

4. Results and Discussion

4.1 Physicochemical Quality of Cooking Oils

The results of physicochemical analyses of used cooking oils collected from street food vendors in different zones of Sialkot are summarized in Table 1. Variations were observed in all parameters, indicating differences in oil handling, heating frequency, and replacement practices among vendors.

Table 1: Physicochemical Quality of Cooking Oils

Zone	Moisture (%)	FFA (%)	Acid Value (mg KOH/g)	Peroxide Value (meq/kg)	Total Polar Compounds (%)
Urban	0.09 \pm 0.01	0.82 \pm 0.05	1.56 \pm 0.11	8.2 \pm 0.4	20.4 \pm 0.6
Educational	0.11 \pm 0.02	0.89 \pm 0.06	1.74 \pm 0.13	9.1 \pm 0.5	21.6 \pm 0.5
Kachehri	0.14 \pm 0.03	1.05 \pm 0.08	2.01 \pm 0.14	10.2 \pm 0.5	22.9 \pm 0.7
Bazar	0.18 \pm 0.02	1.45 \pm 0.07	2.81 \pm 0.16	12.6 \pm 0.8	26.2 \pm 0.8
Fast-food	0.08 \pm 0.01	0.72 \pm 0.04	1.41 \pm 0.09	6.2 \pm 0.3	18.4 \pm 0.5
Rural	0.22 \pm 0.03	1.82 \pm 0.09	3.62 \pm 0.18	13.8 \pm 0.6	28.4 \pm 0.9

4.1.1 Moisture Content

The moisture content of oils ranged from 0.08% to 0.22%, with the highest mean value recorded in samples from rural areas and the lowest in those from fast-food vendors. Elevated moisture content is indicative of poor oil storage and excessive reuse, leading to hydrolytic rancidity (3). According to Codex standards, moisture content in edible oils should not exceed 0.2% to ensure oxidative stability. The values in rural and bazar samples slightly surpassed this limit, suggesting improper handling and exposure to environmental humidity.

4.1.2 Free Fatty Acids (FFA)

The FFA content varied significantly ($p < 0.05$) among sampling zones, ranging from 0.72% to 1.82% (as oleic acid). The maximum FFA levels were found in rural samples, whereas the lowest were noted in fast-food vendor oils. These findings suggest more frequent reuse of oil in rural settings, consistent with the observation that small-scale vendors rarely discard used oil due to cost constraints. The increase in FFA indicates the breakdown of triglycerides during

prolonged heating and exposure to moisture (13). The Codex Alimentarius (2019) recommends an upper limit of 0.3% FFA for edible frying oils, highlighting the extent of deterioration in the samples studied.

4.1.3 Acid Value (AV)

The mean acid value of the oil samples ranged between 1.41 and 3.62 mg KOH/g, again exceeding permissible limits in rural and bazar zones. Elevated acid values signify hydrolytic degradation caused by moisture and temperature fluctuations during repetitive frying cycles. Similar results have been reported in studies conducted in Brazil and Nigeria, where street vendors commonly reuse oils multiple times before replacement (1,10). Continuous monitoring and vendor education regarding oil turnover are therefore essential to mitigate rancidity development.

4.1.4 Total Polar Compounds (TPC)

The total polar compound content ranged from 18.4% to 28.4%, with rural samples exhibiting the highest mean levels. Oils containing >25% polar compounds are considered unfit for human consumption (IUPAC, 2017). The elevated TPC levels reflect cumulative thermal degradation and polymerization of unsaturated lipids during repeated frying (8). Comparable studies by (2) reported similar trends, linking high TPC with adverse sensory and nutritional effects in fried foods.

4.1.5 Peroxide Value (PV)

The peroxide values ranged from 6.2 to 13.8 meq O₂/kg, indicating oxidative rancidity in several samples. The PSQCA standard for edible oil sets the upper limit at 10 meq/kg, suggesting that a portion of the oils analyzed were oxidatively unstable. High peroxide values are a direct result of lipid peroxidation induced by prolonged heating and oxygen exposure. Studies from India and Malaysia have reported parallel findings, associating high PV with the formation of reactive oxygen species and toxic aldehydes (4,5). Collectively, the physicochemical results demonstrate that most cooking oils used by street food vendors in Sialkot are chemically deteriorated and unsafe for repeated use. The severity was most pronounced in rural and bazar areas, reflecting inadequate awareness and lack of regulatory enforcement. Regular surveillance and training on proper oil disposal are urgently needed to safeguard consumer health.

4.2 Microbial Quality of Serving Plates

The microbial assessment of serving plates revealed significant contamination across all sampling sites (Table 2). Both Total Plate Count (TPC) and *E. coli* presence varied among areas, indicating differences in washing practices, water quality, and exposure to environmental contaminants.

Table 2: Microbial Load on Serving Plates Used by Street Food Vendors

Zone	Total Plate Count (CFU/cm ²)	<i>E. coli</i> Detection (%)
Urban	$1.8 \times 10^3 \pm 1.1 \times 10^2$	40
Educational	$2.1 \times 10^3 \pm 1.4 \times 10^2$	33

Kachehri	$2.8 \times 10^3 \pm 2.0 \times 10^2$	47
Bazar	$3.7 \times 10^4 \pm 2.5 \times 10^3$	67
Fast-food	$2.9 \times 10^4 \pm 1.9 \times 10^3$	60
Rural	$3.5 \times 10^4 \pm 3.2 \times 10^3$	53

4.2.1 Total Plate Count (TPC)

The mean TPC values ranged between 1.8×10^3 and 3.7×10^4 CFU/cm², with the highest counts in bazar and rural areas. The World Health Organization (WHO, 2015) recommends a maximum TPC of $<10^3$ CFU/cm² for food-contact surfaces, implying that all plate samples exceeded acceptable hygiene levels. The elevated plate count may be attributed to the use of stored, non-chlorinated water for washing, coupled with inadequate drying and reuse of plates without proper cleaning. Similar microbial loads were documented in Ghana and Uganda by (2,4), respectively, where unregulated street food practices contributed to foodborne illness outbreaks.

4.2.2 Escherichia coli Contamination

Out of 75 plate samples, *E. coli* was detected in 45 samples (60%), predominantly from fast-food fryer and bazar areas. The presence of *E. coli* signifies fecal contamination and poor sanitation during food handling. (14), reported *E. coli* contamination on utensils from restaurants due to improper dishwashing and cross-contact with contaminated water. Such microbial hazards pose direct risks for enteric infections including diarrhea, typhoid, and gastroenteritis, particularly among consumers with low immunity.

4.3 Correlation between Oil Quality and Microbial Hygiene

Interestingly, areas with poorer oil quality parameters (high FFA, TPC, and PV) also showed elevated microbial contamination levels. This parallel deterioration suggests a systemic lack of food safety awareness among vendors. Economic pressures and absence of inspection mechanisms likely contribute to such practices, as previously reported in similar socioeconomic contexts(19). Ensuring hygienic utensils without addressing oil reuse, or vice versa, will not sufficiently mitigate health risks; both aspects must be concurrently managed through integrated public health interventions.

Table 3. Correlation Matrix between Oil Quality Parameters and Microbial Load

Parameter	FFA	AV	PV	TPC (%)	Plate TPC	<i>E. coli</i> (%)
FFA	1	0.96**	0.88**	0.91**	0.72*	0.68*
AV	-	1	0.84**	0.87**	0.70*	0.65*
PV	-	-	1	0.78*	0.59	0.57
TPC (%)	-	-	-	1	0.75*	0.61
Plate TPC	-	-	-	-	1	0.81**
<i>E. coli</i> (%)	-	-	-	-	-	1

5. Conclusion

This study provides a comprehensive assessment of the chemical quality of cooking oils and microbial hygiene of serving plates used by street food vendors in District Sialkot, Pakistan. The findings reveal widespread deterioration of frying oils and poor sanitation practices across most sampling zones. Elevated free fatty acids (1.82%), acid values (3.62 mg KOH/g), peroxide values (13.8 meq/kg), and total polar compounds (28.4%) confirmed that a significant portion of oils had undergone extensive oxidative and hydrolytic degradation, rendering them unfit for consumption as per PSQCA and Codex standards. While microbial analyses demonstrated high total plate counts (up to 3.7×10^4 CFU/cm²) and frequent detection of *Escherichia coli* on serving plates, indicating poor washing practices and exposure to contaminated water sources. The coexistence of chemically degraded oils and microbiologically unsafe utensils underscores a systemic failure in food safety compliance among street food vendors, particularly in rural and market areas. The results highlight an urgent need for intervention at multiple levels, vendor education, regulatory enforcement, and consumer awareness to prevent chronic exposure to lipid oxidation products and foodborne pathogens. This research contributes baseline data for policymakers and public health authorities to strengthen surveillance systems for street food safety in Pakistan.

6. References

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