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Morphological Characteristics and Abundance of Bacteria in Fried Snack Foods from the Pujasera Canteen, Universitas Pattimura, and Fungi in Spoiled Fruits from Mardika Market, Ambon

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ABSTRACT

This study investigated the morphological characteristics and abundance of bacteria and fungi isolated from fried snack foods and spoiled fruits. Bacterial isolates were obtained from bakwan, batagor, and stuffed tofu, while fungal isolates were recovered from spoiled mango, banana, and papaya. Culture-based methods were employed to characterize macroscopic colony morphology and to quantify microbial abundance using the Total Plate Count (TPC) method. The results revealed distinct dominance patterns across different food types. In fried snacks, isolates BKK3, BTK2, and STK5 exhibited the highest TPC values, reaching up to 10^7 CFU/g, indicating substantial post-processing bacterial contamination. In contrast, spoiled fruits were predominantly colonized by fungal isolates MGK3, BNK3, and PPK4, with TPC values also reaching 10^7 CFU/g. These fungal isolates displayed typical filamentous mold characteristics, including white-to-green mycelia, granular to rugose textures, and radial and concentric growth patterns. This comparative analysis within a unified study framework demonstrates that difference in food type and intrinsic characteristics-namely ready-to-eat processed products with high environmental exposure versus fresh fruit tissues rich in nutrients and simple sugars-shape contrasting microbial dominance patterns. Fried snacks were primarily dominated by post-processing bacterial contaminants, whereas spoiled fruits were characterized by saprophytic fungal predominance. These findings highlight the critical role of physicochemical properties and handling conditions in determining microbial community dynamics and provide a conceptual basis for microbiological risk assessment in street-vended and fresh food systems. Practically, the results underscore the importance of hygiene control and post-processing management to mitigate microbial hazards and potential mycotoxin risks.

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INTRODUCTION

Food is a basic human necessity that must meet the criteria of availability, quality, and safety to be suitable for consumption. Food safety has become a critical concern, as foods contaminated with pathogenic or spoilage microorganisms may cause adverse health effects, ranging from gastrointestinal disorders to foodborne intoxication. Microorganisms, particularly bacteria and fungi, are among the primary agents responsible for the deterioration of food quality and safety, especially in ready-to-eat foods and highly perishable fresh products (Jay et al., 2005; Frazier & Westhoff, 2008). Fried snack foods represent a popular category of ready-to-eat foods due to their affordability and widespread availability. However, their processing and serving practices are often conducted under inadequate hygienic and sanitary conditions, increasing the likelihood of microbial contamination. Exposure to open environments, repeated use of frying oil, and direct contact with vendors' hands and utensils may significantly elevate the risk of bacterial contamination in fried snacks (Buckle et al., 2007; Ray & Bhunia, 2014). Consequently, the assessment of bacterial contamination in street-vended foods is essential as part of food safety evaluation efforts. In addition to ready-to-eat foods, fresh fruits are also highly susceptible to quality deterioration caused by microbial activity, particularly by fungi. Fungi play a crucial role in fruit spoilage due to their ability to degrade structural components and nutrients through the production of extracellular enzymes. Fruits that have undergone tissue damage provide favorable conditions for the growth of saprophytic fungi, such as *Aspergillus*, *Penicillium*, and *Rhizopus*, which can be identified based on their distinctive colony morphology (Pitt & Hocking, 2009; Harrigan, 1998).

The identification of foodborne microorganisms can be carried out through the observation of colony morphological characteristics and the enumeration of microbial populations using culture-based methods expressed as Colony Forming Units (CFU). This approach remains widely applied in food microbiology studies because it is simple, cost-effective, and capable of providing preliminary information regarding the diversity and abundance of microorganisms in food samples (Cappuccino & Welsh, 2017; Prescott et al., 2014). Data on colony morphology and microbial load are essential for subsequent analyses related to food quality and safety. From a regulatory perspective, microbiological food safety in Indonesia is governed by the Indonesian National Standard SNI 7388:2009, which specifies the maximum allowable limits of microbial contamination in various food products, including ready-to-eat foods, to protect consumer health (National Standardization Agency of Indonesia, 2009). Therefore, the results of microbial contamination analyses in snack foods should be interpreted in relation to these standards to determine their safety status.

Based on this background, the present study aimed to identify the morphological characteristics and abundance of bacteria isolated from fried snack foods and fungi isolated from spoiled fruits, as well as to evaluate their implications for food safety in accordance with applicable standards. Unlike previous studies that typically focus on a single food category, this research provides a comparative analysis of microbial dominance patterns between ready-to-eat fried snacks and spoiled fresh fruits within the same geographical context. Furthermore, this study offers baseline microbiological data from street-vended foods and traditional market commodities in Ambon, Indonesia, a region where limited published data on foodborne microbial contamination are available. By integrating colony morphology characterization, Total Plate Count (TPC) analysis, and evaluation against the Indonesian National Standard (SNI 7388:2009) issued by Badan Standardisasi Nasional, this study contributes a contextualized assessment of microbial contamination risks in both processed and fresh food matrices. This matrix-based comparative approach highlights how substrate composition and post-processing handling influence microbial ecological dominance in different food systems. The findings are expected to provide scientific insight into potential microbial contamination in street foods and fresh commodities and to serve as a basis for improving food safety practices and public awareness regarding safe food consumption (Atlas, 2010; Fardiaz, 1992).

MATERIALS AND METHOD

Samples consisted of fried snack foods and spoiled fruits obtained from different locations in Ambon, Indonesia. Fried snack samples were collected from the food court (Pujasera Canteen) of Universitas Pattimura, while spoiled fruit samples were obtained from Mardika Traditional Market, Ambon. The fried snack samples included bakwan, batagor, and Indonesian deep-fried stuffed tofu (*Stuffed tofu*), whereas the spoiled fruit samples comprised mango, banana, and papaya. Sampling was conducted using a purposive sampling approach, taking into account environmental exposure, handling practices, and the physical condition of the food materials. Each sample was aseptically placed in a sterile, labeled container according to sample type and collection site. Samples were transported to the laboratory under closed and cooled conditions to maintain their microbiological integrity and minimize changes in microbial composition prior to analysis. Laboratory analyses, including the identification of morphological characteristics and enumeration of bacterial and fungal abundance, were conducted at the Biology Education Laboratory, Faculty of Teacher Training and Education, Universitas Pattimura, from January-Pebruari 2024. In the laboratory, each sample (10 g) was weighed, finely chopped, and homogenized in sterile 0.85% physiological saline (NaCl) solution to obtain a uniform suspension. Homogenization ensured even distribution of microorganisms, allowing isolation and enumeration results to accurately represent the entire sample.

The resulting suspension served as the stock solution for serial dilution and microbial isolation. Bacterial and fungal isolation was performed through serial dilutions up to 10^{-3}, 10^{-5}, and 10^{-7}. An aliquot of 0.1 mL from each dilution was aseptically inoculated onto the surface of Nutrient Agar (NA) for bacterial isolation and Potato Dextrose Agar (PDA) for fungal isolation using spread plate and streak plate techniques. NA plates were incubated at 37°C for 24–48 h, while PDA plates were incubated at 25–28°C for 2–3 days.Macroscopic observations were conducted on microbial colonies grown on NA and PDA, including colony color, shape, margin, elevation, and surface characteristics for bacteria, and colony color, texture, topography, and the presence of exudate droplets for fungi. Microscopic examination of bacterial isolates was performed using Gram staining to determine cell morphology and Gram reaction. Fungal isolates were examined microscopically by observing hyphal structures, mycelia, conidia, and reproductive structures under a light microscope. Microbial abundance was determined using the Total Plate Count (TPC) method. Only plates containing 30–300 colonies were included in the calculation. Microbial counts were expressed as colony forming units per gram (CFU/g) of sample.

RESULTS AND DISCUSSION

The results of this study present data on the morphological characteristics and abundance of bacteria and fungi isolated from two different sample sources. The observations are summarized in two tables. Table 1 presents the morphological characteristics and abundance of bacterial isolates obtained from fried snack foods, while Table 2 shows the morphological characteristics and abundance of fungal isolates isolated from spoiled fruits. Isolation and observation were conducted using culture-based methods on appropriate media, allowing optimal microbial growth and macroscopic examination of colony features.

Observations of bacterial isolates from fried snack foods presented in **Table 1** included colony morphological characteristics such as color, texture, surface topography, and growth patterns, which were used as preliminary indicators of bacterial diversity in the food samples. In addition, the number of colonies was quantified and expressed as colony forming units (CFU) to describe the level of bacterial abundance in each fried snack sample. These data provide an overview of the potential extent of microbial contamination in snack foods consumed by students and highlight variations in bacterial load among different types of fried snacks.

Table 1. Morphological Characteristics and Total Plate Count (TPC) of Bacteria Isolated from Fried Snack Foods

Sample	Isolate Code	Color	Colony Shape	Margin	Elevation	Colony Count (CFU/g)	Total Count per Sample (CFU/g)
Bakwan	BKK1	Yellow	Concentric	Smooth	Flat	$9{,}0 \times 10^3$	$3{,}2 \times 10^5$
	BKK2	Yellow	Irregular, spreading	Irregular	Raised, uneven	$1{,}2 \times 10^4$	
	BKK3	Yellow	Circular	Smooth	Convex	$1{,}2 \times 10^5$	
	BKK4	Yellow	L-shaped	Smooth	Flat	$1{,}0 \times 10^4$	
	BKK5	White	Wrinkled	Curly	Flat	$2{,}5 \times 10^3$	
	BKK6	White	Circular with raised margin	Smooth	Flat	$2{,}3 \times 10^4$	

	BKK7	White	Concentric	Undulate	Raised	1,4 x 10^5	
Batagor	BTK1	Yellow	Circular	Irregular	Convex	9,0 x 10^5	5,7 x 10^7
	BTK2	Yellow	Circular	Undulate	Raised	8,7 x 10^7	
	BTK3	Yellow	Circular	Smooth	Convex	2,2 x 10^7	
	BTK4	Yellow	Circular	Smooth	Convex	3,4 x 10^7	
Stuffed tofu	STK1	Yellow	Irregular	Lobate	Raised, uneven	2,0 x 10^3	8,8 x 10^7
	STK2	Yellow	Circular	Lobate	Flat	2,0 x 10^3	
	STK3	Yellow	Filamentous	Wool-like	Raised	4,0 x 10^5	
	STK4	Yellow	Wrinkled	Undulate	Raised	1,0 x 10^5	
	STK5	Putih	Circular with spreading margin	Branched	Flat	7,0 x 10^5	
	STK6	White	Circular with raised margin	Smooth	Convex	1,0 x 10^5	
	STK7	White	Circular	Smooth	Convex	1,0 x 10^5	

Observations of fungal isolates from spoiled fruits presented in **Table 2** revealed considerable diversity in colony morphological characteristics, including colony color, texture, surface topography, and the presence of exudate droplets. These features reflect differences in growth patterns and metabolic activity of fungi on fruit substrates that have undergone spoilage. In addition to morphological traits, fungal abundance data expressed in colony forming units (CFU) were used to describe the dominance of fungi in the spoiled fruit samples analyzed.

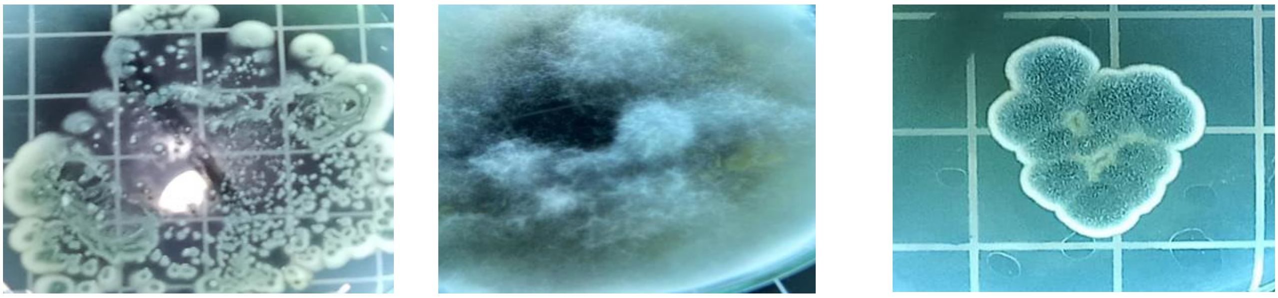
(a) (b) (c)

Figure 1. Macroscopic characteristics of the dominant bacterial isolates obtained from fried snack foods.
(a) isolate from Bakwan; (b) isolate Batagor ; (c) isolate Stuffed tofu.

Table 2. Morphological Characteristics and Total Plate Count (TPC) of Fungi Isolated from Spoiled Fruits

Sample	Isolate Code	Color	Colony Texture	Topographi	Eksudate Droplets	Radial Lines	Concentric Rings	Colony Count (CFU/g)	Total Count per Sample (CFU/g)
Mango	MGK1	White	Granular	Verugosel	√	√	√	1,4 × 10^4	1,83 x 10^5
	MGK2	Green	Absent	Umbunate	√	√	√	1,0 × 10^3	
	MGK3	Gray	Powdery	Ruogose	-	-	√	7,3 × 10^4	
	MGK4	White	Cattony	Rugoze	-	-	√	1,8 x 10^4	
	MGK5	Green	Absent	Rugose	-	-	√	2,0 x 10^4	
	MGK6	White	Velvety	Umbonate	-	√	√	7,0 x 10^4	
Banana	BNK1	White	Glabrous dan Waxy	Verrugosel	-	-	√	3,0 x 10^3	3,2 X 10^7
	BNK2	Green	Downy	Rugose	-	√	√	2,0 x 10^3	
	BNK3	White	Cattony	Rugose	√	-	-	3,1 x 10^7	
	BNK4	Green	Velvety	Umbonate	-	-	√	3,0 x 10^5	

	BNK5	White	Downy	Umbonate	-	-	-	$6,0 \times 10^{5}$	
	BNK6	Green	Velvety	Umbunate	-	√	-	$2,0 \times 10^{5}$	
Papaya	PPK1	White	Granular	Verugosel	√	√	√	$1,2 \times 10^{3}$	$3,12 \times 10^{7}$
	PPK2	Green	Absent	Rugose	√	√	-	$7,5 \times 10^{-3}$	
	PPK3	White	Cattony	Rugoze	√	√	-	$4,09 \times 10^{5}$	
	PPK4	Green	Velvety	Umbunate	√	-	√	$6,04 \times 10^{5}$	
	PPK5	Yellow	Cattony	Rugoze	√	-	√	$3,0 \times 10^{3}$	
	PPK6	Green	Cattony	Rugoze	√	-	√	$2,0 \times 10^{3}$	
	PPK7	White	Velvety	umbunate	√	-	√	$1,6 \times 10^{5}$	
	PKK8	White	downi	Umbunate	-	-	√	$3,0 \times 10^{7}$	



(a) (b) (c)

Figure 2. Macroscopic characteristics of dominant fungal isolates obtained from spoiled fruits
Note: (a) isolate from mango; (b) isolate from banana ; (c) isolate from papaya.

Based on the observations presented in **Table 1**, bacterial isolates from fried snack foods exhibited a high diversity of colony morphological characteristics, including variations in color (yellow and white), colony shape, margin, and surface elevation. This morphological diversity reflects the presence of more than one bacterial group commonly associated with ready-to-eat foods. According to Prescott et al. (2014) and Cappuccino and Welsh (2017), colony morphology serves as an important preliminary indicator for differentiating bacterial groups prior to further biochemical or molecular identification. Based on the results shown in Table 1 and the macroscopic observations illustrated in **Figure 1**, several bacterial isolates were identified as dominant in fried snack samples. Dominance was determined based on higher colony counts (CFU/g) and more consistent growth compared to other isolates within the same sample. In *bakwan*, isolate BKK3 exhibited the highest colony count among the observed isolates, indicating a greater ability to adapt and proliferate within the fried food matrix. The circular colony shape with smooth margins and convex elevation suggests a bacterial type capable of rapid surface colonization under nutrient-rich conditions.

In *batagor*, isolate BTK2 showed the highest abundance, reaching the order of 10^{7} CFU/g. The dominance of this isolate may be associated with its tolerance to environmental exposure during post-frying handling, including contact with air, utensils, and repeated human handling. Fried foods such as batagor are often displayed at ambient temperature, creating favorable conditions for the growth of mesophilic bacteria that can rapidly multiply after cooking (Ray & Bhunia, 2014). Similarly, in *stuffed tofu*, isolate STK5 was identified as the dominant bacterial isolate. The high moisture content and protein-rich composition of tofu provide an optimal environment for bacterial growth. According to Buckle et al. (2007), foods with high water activity and protein content are highly susceptible to bacterial contamination and subsequent proliferation when stored at room temperature. The spreading margin observed in isolate STK5 further indicates strong surface colonization ability, which may contribute to its dominance over other bacterial isolates.

Overall, the dominance of specific bacterial isolates in fried snack foods reflects the combined influence of substrate composition, environmental exposure, and handling practices. These findings highlight the importance of proper hygiene and temperature control in reducing bacterial contamination in ready-to-eat fried foods.

Quantitatively, the Total Plate Count (TPC) values of bacteria in fried snack foods showed a relatively high range, with several samples reaching the order of 10^{7} CFU/g. These values indicate a high level of microbial contamination in street foods. A study by Tambekar et al. (2009) in the *Journal of Applied Sciences* *in Environmental Sanitation* reported that street-vended foods often exhibit high TPC values due to inadequate hygiene practices during processing and serving, which is consistent with the findings of this study. High bacterial abundance in fried snacks may also be influenced by repeated use of frying oil, exposure to open air, and direct contact with utensils and vendors' hands. Buckle et al. (2007) as well as Ray and Bhunia (2014) stated that fried foods held at room temperature for extended periods are highly susceptible to contamination by mesophilic bacteria, particularly Gram-positive and Gram-negative bacteria that are tolerant of such environmental conditions. From a food safety perspective, several fried snack samples in this study showed TPC values exceeding the maximum permissible limits for ready-to-eat foods as stipulated in SNI 7388:2009 (National Standardization Agency of Indonesia, 2009). This condition indicates that fried snacks may pose potential public health risks, particularly foodborne diseases. A study by Rane (2011) in the *International Journal of Food Microbiology* emphasized that high bacterial contamination in street foods correlates with an increased risk of gastrointestinal disorders and intestinal infections. Observations of fungal isolates in **Table 2** showed diversity in colony morphology, including variations in color, texture (cottony, velvety, granular), colony topography, and the presence of exudate droplets. These characteristics indicate the presence of saprophytic fungi involved in fruit spoilage processes. Pitt and Hocking (2009) and Harrigan (1998) explained that fungi from the genera *Aspergillus*, *Penicillium*, and *Rhizopus* are dominant groups on spoiled fruits and can be recognized based on their macroscopic colony characteristics.

Observations of fungal isolates from spoiled fruits, as summarized in **Table 2** and illustrated in **Figure 2**, showed different dominant isolates for each fruit type. In spoiled *mango*, isolate MGK3 exhibited higher colony counts compared to other fungal isolates. The powdery colony texture and rough surface are characteristic of filamentous fungi capable of producing abundant spores, allowing rapid colonization of fruit substrates rich in sugars and organic acids (Pitt & Hocking, 2009). In spoiled *banana*, isolate BNK3 was identified as the dominant fungal isolate, with colony counts reaching the order of 10^7 CFU/g. Spoiling bananas undergo extensive tissue softening and increased availability of fermentable sugars, which strongly support fungal growth. Filtenborg et al. (1996) reported that bananas are highly susceptible to colonization by fast-growing fungi due to their high water content and easily degradable cell walls. In spoiled *papaya*, isolate PPK4 showed dominance among the observed fungal isolates. Papaya provides an ideal substrate for fungal growth due to its high water content and rapid enzymatic degradation during ripening and spoilage. Dominant fungi on papaya are often characterized by velvety colony textures and umbonate topography, indicating active mycelial growth and high metabolic activity (Samson et al., 2010). The presence of dominant fungal isolates on spoiled fruits reflects the ecological advantage of filamentous fungi in utilizing complex carbohydrates and penetrating fruit tissues through the production of extracellular enzymes. These traits allow fungi to outcompete other microorganisms and become the primary agents of fruit spoilage.

The presence of exudate droplets and radial growth patterns in several fungal isolates indicates high metabolic activity during colony development. Fungal exudates are commonly associated with the production of hydrolytic enzymes and secondary metabolites involved in fruit tissue degradation. According to Samson et al. (2010) in *Studies in Mycology*, secondary metabolite production is a characteristic feature of spoilage fungi growing on substrates rich in sugars and moisture, such as ripe and spoiled fruits. In terms of abundance, fungal TPC values in spoiled bananas and papayas reached the order of 10^7 CFU/g, indicating fungal dominance in advanced stages of fruit spoilage. Jay et al. (2005) and Fardiaz (1992) stated that spoiled fruits provide optimal conditions for fungal growth due to nutrient availability, high moisture, and suitable pH. These findings are consistent with those reported by Filtenborg et al. (1996) in the *International Journal of Food Microbiology*, which documented high fungal populations in postharvest-damaged fruits. Although spoiled fruits are generally not consumed, the presence of fungi in high numbers still has food safety implications, particularly because some fungi are capable of producing mycotoxins. Pitt and Hocking (2009) and Bennett and Klich (2003) in *Clinical Microbiology Reviews* emphasized that certain foodborne fungi can produce mycotoxins that are harmful to human health upon chronic exposure.

Overall, the results of this study demonstrate that food substrate type strongly influences microbial dominance and abundance. Fried snack foods were predominantly contaminated by bacteria, with several samples exceeding the safety limits according to SNI 7388:2009, whereas spoiled fruits were mainly dominated by spoilage fungi. Atlas (2010) and Frazier and Westhoff (2008) emphasized that food safety control must be implemented comprehensively, from raw material selection and processing to handling and serving, to minimize the risk of microbial contamination.

CONCLUSION

This study demonstrates that fried snack foods contain bacteria with high diversity of colony morphology and relatively high abundance, with several samples exhibiting Total Plate Count (TPC) values exceeding the maximum permissible limits based on SNI 7388:2009. The dominant bacterial isolates identified in each fried snack sample were BKK3 in bakwan, BTK2 in batagor, and STK5 in stuffed tofu, indicating greater adaptability and growth capacity compared to other isolates. Spoiled fruits were dominated by fungi with high morphological diversity and TPC values reaching the order of 10^7 CFU/g, reflecting the role of fungi in fruit spoilage processes. The dominant fungal isolates identified in each spoiled fruit sample were MGK3 in mango, BNK3 in banana, and PPK4 in papaya, which exhibited higher growth due to nutrient availability, high moisture content, and favorable environmental conditions for fungal development. These findings emphasize the importance of hygiene and sanitation control in street foods as well as careful selection of consumable food materials to ensure food safety and protect public health.

AUTHORS CONTRIBUTION

A. Pelamonia, M. Pattipeilohy and F. Mahulette designed and conducted the study, analyzed and interpreted the data, and wrote a draft of the manuscript. Interpreted the data and reviewed the draft manuscript, and supervised the entire process.

CONFLICT OF INTEREST

The authors declare no conflicts of interest, and will take full responsibility for the content of the article, including implications of AI-generated art.

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