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Research Article

Microbial Assessment of Spices Available In Different Markets of Karachi, Pakistan: A Food Quality Index Assessment Approach

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Abstract

Spices are used in almost all types of food preparation, and their microbial contamination can lead to spoilage and pose a risk to public health. Therefore, the aim of this study was to investigate the microbiological contamination of spices available in the markets of Karachi, Pakistan. 149 samples of 12 different types of spices were collected from different markets in Karachi. The spices were examined using standard microbiological procedures (U.S. Food and Drug Administration) to analyze Aerobic Plate Count (APC) and Mold and Yeast Count (MYC). The number of colonies in salt was lower (APC 4.01 × 104), while in mixed spices sample the highest APC (5.72 × 105) was recorded. The Food Quality Index (FQI) for bacterial contamination of spices indicates the highest level of contamination (FQI; 3199.15). The Mold and Yeast Count (MYC) was higher in mixed spices (3.93 × 103), the lowest MYC was observed in the pomegranate seed sample (11.0 × 101). Mold and yeast contamination of spices also indicated a higher contamination level of FQI (743.40). The evaluation of the spices based on APC, MYC, and FQI indicates that the spice samples are of very poor quality.” Consumption of these contaminated spices may endanger human health.

Keywords: Aerobic plate count; Food quality index; Microbial assessment; Mold and yeast count; Spices

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Introduction

Spices have always been used in a variety of foods. They can be extracted from the natural parts of the plant such as roots, rhizomes, leaves, flowers, fruits, seeds, tubers and bark [1]. They can be used as colorants, flavorings, preservatives, and folk medicines throughout the [2,3]. The small needle-shaped leaves of the rosemary plant and the seeds of the anise plant are strongly aromatic and are used in cooking and cosmetics, while the oil extracted from rosemary seeds has medicinal properties, such as a relaxing effect on the smooth muscles of the digestive tract and uterus in digestive disorders and menstrual cramps [4]. Food poisoning caused by contamination with bacteria and fungi such as *Campylobacter*, *Salmonella*, *Shigella*, *E. coli*, *Aspergillus*, *Penicillium*, and *Fusarium* is very common and life-threatening for millions of people around the world. Certain plant-derived matrices have been associated with an increase in foodborne disease outbreaks in recent years. Various types of digestive tract dysfunction have been associated with microbial contamination, which can occur at various points from cultivation to consumption [5,6].

Contamination of spices with various bacterial species such as *Salmonella* spp, *Bacillus cerus*, *Staphylococcus aureus*, *C. perfringens*, and *E. coli* has been observed [7-9]. In the past, much less attention was paid to the myco-flora of foods than to the bacterial flora; fungi are considered as the natural flora of foods, but nowadays fungi are considered to be able to cause spoilage by secreting mycotoxins [10,11].There are a large number of studies reporting the prevalence of toxigenic fungi in various spices [12,13]. Food safety is one of the most important factors in maintaining public health. Almost half of the world’s population has been suffering from foodborne diseases for several years. Since spices are used in very small quantities, but due to their high consumption tend to contaminate a wide range of products, it is very difficult to identify contaminated spices that cause foodborne illness. Pakistan is a developing country with limited control over food quality. The hot climate, inadequate processing methods and improper crop storage conditions favor the spread of food contaminants. To prevent serious microbial contamination and possible food deterioration, microbial counts should be as low as possible. There are few studies on the microbiological quality of spices in Pakistan [14]. Apart from this, there is a lack of comparative studies according to national and international standards regarding aerobic plate count and yeast and mold count of spices [15]. Therefore, the aim of the current study is to determine the microbial quality of spices and compare the microbiological status of spices with the national and international standards. Food quality index is also used to evaluate the level of microbial contamination of spices available in the markets of Karachi, Pakistan.

Materials and Methods

Study area and period

The study was conducted on spices from retail (N=112) and production (N=37) sites in different regions of South, Central and West Karachi districts. All samples were analyzed consecutively from June 2020 to March 2021.

Sample size and sample collection

A total of 149 samples of 12 different types of spices were collected in sterile and sealed plastic bags from street markets (N=63), small stores/shops (N=49) and production sites (N=37).

Laboratory methods

Sample preparation

For enumeration of yeasts and molds, 50 g of each sample was collected. Samples were homogenized in 450 mL of 0.1% peptone water to prepare an initial suspension (10^{-1}) in sterile vials. As described in bacteriological manual, after shaking, the vials were not moved for 10-15 min to allow the samples to settle, and then serial dilutions were made up to 10^{-3} [16]. For aerobic plate count determination, 50 g of each sample was collected and homogenized in 450 mL of Butterfield phosphate buffer to prepare a starting suspension (10^{-1}). After homogenization, centrifugation was performed at 12000 rpm for 2 min, then serial dilutions were made up to 10^{6} (USFDA, 2001).

Molds and yeast count

For analysis of mold and yeast count (MYC) in each sample, 0.1 mL of sample was collected from a serially diluted sample (ranging from 10^{-1} to 10^{-3}) and poured onto separate solidified dichloran rose-bengal chloramphenicol (DRBC) agar plates. After pouring, the plates were incubated at 25 °C for 5 days in the dark (USFDA, 2001).

Aerobic plate count

Aerobic plate count was analyzed in each sample by pouring 1 mL of the serially diluted samples (10^{-1}-10^{-6}) onto the plate count agar. After pouring, all Petri dishes were incubated at 35°C for 48 hours. After incubation, the colony forming unit (CFU) was calculated for each sample (USFDA, 2001).

Degree of contamination assessment

The degree of contamination with bacteria, molds, and yeasts was evaluated using the food quality index.

Food quality index

Food quality was evaluated using the equation of Horton (1965). It shows the composite effect of individual contaminants on food quality. It is a rating index whose values range from zero to one and are inversely proportional to Sn (recommended standard). It indicates the level of contamination. The critical value of this index is 100. The FQI can be expressed by the following equations of Horton:

$$FQI = \frac{\sum qn\,Wn}{\sum Wn} \quad (1)$$

$$qn = \frac{Vn - Vid}{Sn - Vid} \times 100 \quad (2)$$

$$Wn = \frac{k}{Sn} \quad (3)$$

$$k = \frac{1}{\sum \frac{1}{Sn} = 1, 2,, n} \quad (4)$$

Where, Sn is a standard value, Vn is calculated value, Vid is ideal value and is zero for all contaminants (microbes), k is proportionality constant.

Results

149 spice samples were tested using standard microbiological methods to analyze aerobic plate count (APC) and Mold and Yeast Count (MYC). Table 1 shows the APC values of each sample compared to Pakistan Standard and Quality Control Authority (PSQCA) and U.S. Food and Drug Administration (USFDA) standards. The data in Table 1 show that the Aerobic Plate Count (APC) in the mixed spices sample is very high (5.72×10^{5} CFU/g). Compared to PSQCA and USFDA standards, the mixed spices are unfit for human consumption. The data also show that the number of colonies in salt is the lowest compared to the other samples (4.01×10^{4} CFU/g). Despite the lower number, salt is still microbiologically unsuitable according to USFDA and PSQCA standards. Comparing the APC values of the salt samples with the PSQCA and USFDA standards (PSQCA, 2009) (*Revised Guidelines for the Assessment of Microbiological Quality of Processed Foods*, 2013) , it can be seen that these spices have a higher microbial load than the PSQCA and USFDA standards. The Food Quality Index (FQI) value is greater than 100, indicating that the highest risk of bacterial contamination was found in the spice samples. In Food Quality Index (FQI), the last column (Wn.qn) indicates the contribution of bacterial contamination in each spice sample, while the summation gave the total FQI result (3199.15), which proves "that the spice samples are of very poor quality".

All spice samples were also analyzed for Mold and Yeast Count (MYC). Table 2 shows the data of all samples analyzed for mold and yeast count. According to the data, the yeast and mold count is higher in mixed spices (3.93×10^{3}), followed by turmeric powder (3.75×10^{3}), curry powder (3.75×10^{3}), coriander powder (2.91×10^{2}), bay leaf (2.84×10^{2}), and red chili powder (2.72×10^{2}) compared to other spice samples. In accordance with USFDA and PSQCA standards, these spice samples were shown to be unfit for human consumption. The lowest MYC value is observed in the pomegranate seed sample (11.0×10^{1}) Except for mixed spices, turmeric powder, curry powder, coriander powder, bay leaf and red chili powder, all other samples are within the satisfactory limits of USFDA and PSQCA. To evaluate the contamination level of mold and yeast in the spice samples, the food

Spices	N	APC (CFU/g)	Food Quality Index (FQI)			PSQCA Standards			USFDA Standards		
			Wn	qn	Wn.qn	s	b	u	s	b	u
Mixed Spices	28	5.72 × 105 ± 403.73	0.083333	5720	476.6648	104	104-106	>106	102	104	106
Cinnamon	9	4.72 × 104 ± 244.95	0.083333	472	39.33318						
Curry powder	6	5.02 × 105 ± 393.23	0.083333	5020	418.3317						
Turmeric powder	13	4.96 × 104 ± 230.22	0.083333	496	41.33317						
Bay leaf	9	5.13 × 105 ± 287.30	0.083333	5130	427.4983						
Black pepper powder	10	5.02 × 105 ± 264.70	0.083333	5020	418.3317						
Salt	9	4.01 × 104 ± 223.61	0.083333	401	33.41653						
Coriander powder	18	4.97 × 104 ± 279.28	0.083333	497	41.4165						
Pomegranate seeds	7	5.08 × 105 ± 415.93	0.083333	5080	423.3316						
Red Chili powder	20	5.03 × 105 ± 427.78	0.083333	5030	419.165						
Cloves	8	4.84 × 104 ± 230.22	0.083333	484	40.33317						
Cumin powder	12	5.04 × 105 ± 311.45	0.083333	5040	419.9983						
			∑Wn =0.999		∑qn.Wn = 3199.15						
			FQI = 3199.17								

Table 1: Aerobic Plate Count (APC) of spices samples compared with Pakistan Standard Quality Control Authority (PSQCA, 2009) and U.S. Food and Drug Administration (USFDA, 2013) standards. Food quality index (FQI) indicating, the degree of contamination of the spices samples by the bacteria.

Key: Data (each sample with means ± SD, n = 9). APC= aerobic plate count, N= total number of the spice sample, CFU/g = Colony forming unit in 1 gram, FQI = indicating the degree of bacterial contamination in spices, Wn = bacterial concentration as unit in one gram of the n^{th} spice sample, qn = quality rating of bacterial load in n^{th} spice sample, s = satisfactory limits, b = borderline limits, u= unsatisfactory limits

Spices	N	MYC (CFU/g)	Food Quality Index (FQI)			PSQCA Standards			USFDA Standards		
			Wn	qn	Wn.qn	s	b	u	s	b	u
Mixed Spices	28	3.93 × 103 ± 50.95	0.0833	3930	327.369	102	102-104	>104	102	102-104	>104
Cinnamon	9	17.4 ×101 ± 0.30	0.0833	17.4	1.44942						
Curry powder	6	2.92 ×102 ± 20.12	0.0833	292	24.3236						
Turmeric powder	13	3.75 ×103 ± 75.83	0.0833	3750	312.375						
Bay leaf	9	2.84 ×102 ± 19.63	0.0833	284	23.6572						
Black pepper powder	10	15.7 ×101± 0.24	0.0833	15.7	1.30781						
Salt	9	19.0 ×101 ± 0.40	0.0833	19	1.5827						
Coriander powder	18	2.91 ×102 ± 20.88	0.0833	291	24.2403						
Pomegranate seeds	7	11.0 ×101 ± 0.24	0.0833	11	0.9163						
Red Chili powder	20	2.72 ×102 ± 20.89	0.0833	272	22.6576						
Cloves	8	19.7 ×101 ± 0.27	0.0833	19.7	1.64101						
Cumin powder	12	19.0 ×101 ± 0.40	0.0833	19	1.5827						
			∑Wn =0.999		∑qn.Wn=743.10						
			FQI = 743.40								

Table 2: Mold and Yeast Count (MYC) of spices samples compared with Pakistan Standard Quality Control Authority (PSQCA, 2009) and U.S. Food and Drug Administration (USFDA, 2013) standards. Food quality index (FQI) indicating, the degree of contamination of the spices samples by the mold and yeasts.

Key: Data (each sample with means ± SD, n = 9). MYC = mold and yeast count, N= total number of the spice sample, CFU/g = Colony forming unit in 1 gram, FQI = indicating the degree of mold and yeast contamination in spices, Wn = bacterial concentration as unit in one gram of the n^{th} spice sample, qn = quality rating of mold and yeast load in n^{th} spice sample, s = satisfactory limits, b = borderline limits, u= unsatisfactory limits

quality index (FQI) was used. Wn.qn column indicates the contribution of mold and yeast contamination in each spice sample, while the summation gave the total FQI result (743.40), which in turn proves that "the spice samples are of very poor quality" so that the consumers are not able to use them.

Discussion

Spices are exposed to a variety of microbial contaminants before, during, and after processing, especially when they are sun-dried on the ground and traded in markets. Spices can contain a significant amount of microbial contaminants, such as xerophilic molds, mesophilic bacteria, and enterobacteria. Most bacterial species are pathogenic, while fungal species are potential producers of mycotoxins that have toxic and carcinogenic effects in humans and animals, e.g., aflatoxins, ochratoxins and sterigmatocystin [1-20].

The initial level of bacterial contamination depends mainly on the hygienic conditions of handling raw materials and final products, as well as on the processing conditions [21]. Therefore, for food quality, hygiene and safety are important at every stage of processing and sale. In the present study, spices were collected from different markets in Karachi, Pakistan. Microbial load of spices was determined by Aerobic Plate Count (APC) and Mold and Yeast Count (MYC) method. The microbial load values were higher than the standard limits when compared with USFDA and PSQSA standards. Production of these commodities under poor hygienic conditions and in warm and humid climates can increase the risk of contamination with total microbial loads.

According to the results, the lowest Aerobic Plate Count (APC) was observed in salt samples because salt reduces water availability by removing water from the cell through the process of osmosis [22], inhibiting bacterial growth, but some bacteria are halotolerant and can grow at high salt concentration, some predominant bacterial genera are halotolerant, including; *Halomonas*, *Bacillus*, *Streptomyces*, *Oceanobacillus*, and *Pseudomonas* [23]. Dry mixed spices are produced at various stages such as drying, harvesting, and threshing, so there is a possibility of contamination at each stage [24]. Molds and Yeasts Count (MYC) was also observed high in the spice samples, as most fungi are halotolerant and can survive in high salt concentrations [25]. Well-studied examples of halotolerant yeasts and fungi include *Debaryomyces hansenii* black, *Aureobasidium pullulans* and *Hortaea* [26-28]. They can grow even in the saturated NaCl solution. The lowest MYC is observed in the samples of pomegranate seeds. According to a previous study, pomegranate seeds have antifungal activity [29]. Food Quality Index (FQI) was used to determine the level of contamination of the spices with microbes (bacteria, fungi and yeast). It was found that the FQI values of the spices (APC; 3199.17 and MYC; 743.40) were above the critical value (100), indicating that the spices were highly contaminated with bacteria, fungi and yeast. Even most of the spices were microbiologically unsuitable according to USFDA and PSQCA standards. These contaminated spices can cause serious health problems in consumers with acute and chronic diseases [30]. Consumption of these contaminated spices can endanger people's health [31]. Therefore, spices should be processed under standardized hygienic conditions. To reduce the risk of microbiological contamination, several countries and international organizations have enacted strict food and feed legislation. The best preventive measure is to ensure proper pre- and post-harvest practices. For example, spices must be cleared of physical contaminants shortly after harvest and dried to a safe storage moisture level [32]. Drying is one of the oldest physical methods of food preservation that aims to reduce the moisture content of spices [33-38].

Conclusion

This study evaluated the microbiological quality of the most commonly consumed types of unpackaged spices sold in Karachi, Pakistan. In the local market, spices sold in bulk (in open containers) are highly susceptible to microbial contamination. Hygiene, environmental, and sanitary conditions during processing, distribution, and storage of unpackaged spices and herbs must be controlled to avoid high microbial counts. In this context, food handlers, suppliers, and consumers should be aware of appropriate handling and storage practices to reduce the risk of contamination. Our results also suggest that a food safety management system, the use of good hygiene practices and manufacturing practices, routine inspections, and testing of the final product are necessary to ensure microbial safety at all stages of safer spice production. In addition, the use of irradiation, heat or steam treatment can help inhibit pathogenic and spoilage microorganisms.

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Conflict of Interest

There is no conflict of interest among the authors

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References

1. Elmurodovich RN (2022) A Medicine with Alkaloids New Information about the Biology and Importance of Plants 5: 351-353.
2. Khanal A, Devkota HP, Kaundinnyayana S, Gyawali P, Ananda R, et al. (2021) Culinary herbs and spices in nepal: A review of their traditional uses, chemical constituents, and pharmacological activities. Ethnobotany Research and Applications 21: 1-18.
3. Kumari K, Sachan AK, Kumar S, Singh D, Anupam KR (2018) Medicinal uses of spices used in our traditional culture: Worldwide. Journal of Medicinal Plants Studies 6: 116-122.
4. Alamgir ANM (2017) Pharmacognostical Botany: Classification of Medicinal and Aromatic Plants (MAPs), Botanical Taxonomy, Morphology, and Anatomy of Drug Plants. Therapeutic Use of Medicinal Plants and Their Extracts 1: 117-293.
5. Auchtung TA, Fofanova TY, Stewart CJ, Nash AK, Wong MC, et al. (2018) Investigating Colonization of the Healthy Adult Gastrointestinal Tract by Fungi. MSphere 3: 2.
6. Salim SY, Kaplan GG, Madsen KL (2019) Air pollution effects on the gut microbiota. Gut Microbes 5: 215-219.
7. Choi YM, Hwang SI, Park GY, Kim ST, Lee HK, et al. (2021) Microbial Contamination Levels of Red Pepper Powder Purchased in Gyeonggi Province and Changes in Characteristics According to the Storage Method. Journal of Food Hygiene and Safety 36: 382-391.
8. György E, Laslo E, Antal M, Andras CD (2021) Antibiotic resistance pattern of the allochthonous bacteria isolated from commercially available spices. Food Science and Nutrition 9: 4550-4560
9. Köppel R, Tolido I, Gabriela M, Martin P (2017) Detection of DNA from Escherichia coli, Clostridium perfringens, Staphylococcus aureus and Bacillus cereus after simplified enrichment using a novel multiplex real-time PCR system. European Food Research and Technology 243: 521-530.
10. Hussein MA, El-Said AHM, Yassein AS (2020) Mycobiota associated with strawberry fruits, their mycotoxin potential and pectinase activity. Mycology 11: 158-166.
11. Temesgen A, Teshome G (2018) Major mycotoxins occurrence prevention and control approaches. Biotechnology and Molecular Biology Reviews 12: 1-11.
12. Algammal AM, Elsayed ME, Hashem H, Ramadan H, Sheraba NS, et al. (2021) Molecular and HPLC-based approaches for detection of aflatoxin B1 and ochratoxin A released from toxigenic Aspergillus species in processed meat. BMC Microbiology 21: 1-10.
13. Pickova D, Ostry V, Malir J, Toman J, Malir F (2020) A Review on Mycotoxins and Microfungi in Spices in the Light of the Last Five Years. Toxins 12: 1-33.
14. Asghar MA, Zahir E, Rantilal S, Ahmed A, Iqbal J (2016) Aflatoxins in composite spices collected from local markets of Karachi, Pakistan. Food Additives and Contaminants 9: 113-119.

15. Aqeel A, Abbas T, Mirani ZA, Naveed T, Ahmed N, et al. (2021) Seasonal variation in microbial contamination of various food items in Karachi. Pakistan Journal of Scientific and Industrial Research Series Biological Sciences 64: 75-80.

16. (2016) In Bacteriological analytical manual.

17. Awuchi CG, Ondari EN, Ogbonna CU, Upadhyay AK, Baran K, et al. (2021) and Detoxification Strategies. A Revisit 1-48.

18. Fogele B, Granta R, Valciņa O, Berzins A (2018) Occurrence and diversity of Bacillus cereus and moulds in spices and herbs. Food Control 83: 69-74.

19. Kabak B, Dobson ADW (2017) Mycotoxins in spices and herbs-An update. Critical Reviews in Food Science and Nutrition 57: 18-34.

20. Niels S (1999) International Food Safety Handbook.

21. Ehuwa O, Jaiswal AK, aiswal S (2021) Salmonella, food safety and food handling practices. Foods 10: 1-16.

22. Yan N, Marschner P, Cao W, Zuo C (2015) Influence of salinity and water content on soil microorganisms. Int Soil Water Conserv 3: 316-323.

23. Etesami H, Glick BR (2020) Halotolerant plant growth-promoting bacteria: Prospects for alleviating salinity stress in plants. Environmental and Experimental Botany 178: 104-124.

24. Bakobie N, Addae AS, Duwiejuah AB, Cobbina SJ, Miniyila S (2017) Microbial profile of common spices and spice blends used in Tamale, Ghana. Intern J of Food Contamin 4: 1.

25. Gunde-Cimerman N, Zalar P (2014) Extremely halotolerant and halophilic fungi inhabit brine in solar salterns around the globe. Food Tech and Biotech 52: 170-179.

26. Elsayis A (2022) Elucidation of Melanin Pigment Production From A Promising Locally Isolated Halotolerant Black Yeast Hortaea Werneckii AS 1: 1-17.

27. Gostinčar C, Stajich JE, Kejžar A, Sinha S, Nislow C, et al. (2021) Seven Years at High Salinity-Experimental Evolution of the Extremely Halotolerant Black Yeast Hortaea werneckii. J Fungi (Basel) 7: 723.

28. Plemenitaš A (2021) Sensing and Responding to Hypersaline Conditions and the HOG Signal Transduction Pathway in Fungi Isolated from Hypersaline Environments: Hortaea werneckii and Wallemia ichthyophaga. Wallemia Ichthyophaga. J Fungi 7: 988.

29. Skenderidis P, Leontopoulos S, Petrotos K, Mitsagga C, Giavasis I, et al. (2021) The In Vitro and In Vivo Synergistic Antimicrobial Activity Assessment of Vacuum Microwave Assisted Aqueous Extracts from Pomegranate and Avocado Fruit Peels and Avocado Seeds Based on a Mixtures Design Model. Plants (Basel) 10: 1757.

30. Tomar P, Alka G (2022) Food adulteration and its impact on health. Int J of Home Sci 8: 164-168.

31. Visciano P, Schirone M (2021) Food frauds: Global incidents and misleading situations. Trends in Food Science & Technology 114: 424-442.

32. Pandey AK (2018) Harvesting and post-harvest processing of medicinal plants: Problems and prospects Harvesting and post-harvest processing of medicinal plants: Problems and prospects. 6: 229-235.

33. Thamkaew G, Sjöholm I, Galindo FG (2020) A review of drying methods for improving the quality of dried herbs. Critical Reviews in Food Science and Nutrition 61:1763-1786.

34. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-3-aerobic-plate-count.

35. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-18-yeasts-molds-and-mycotoxins.

36. Harold LJ, Ira NG, Robert KH, Lyon WA, Earle CH, et al. (1965) Water Quality Criteria-Stream vs. Effluent Standards. Journal of Water Pollution Control Federation 37: 292-315.

37. Theresa M, Unni AS, Geevarghese A, Sebastian SK, Pareek S, et al. (2021) Foodborne Pathogens and Food-Related Microorganisms.

38. Skovgaard N (1999) International Food Safety Handbook (1st ed.).