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A Systematic Review and Meta-analysis of the Microbiological Quality of Fruit Juices across Africa

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ABSTRACT

Background: Across Africa, where diverse fruits thrive in abundance, fruit juices constitute a part of daily life, offering refreshment and nourishment. However, the microbiological quality of fruit juices stands as a pivotal issue affecting public health.

Purpose: This systematic review and meta-analysis aimed to investigate the microbiological quality of fruit juices across Africa.

Methods: Three databases; Scopus, PubMed, and Embase were systematically searched from inception to November 4th, 2023 for African studies which have reported assessing the microbiological quality of fruit juices. Twenty studies were included in this review having met the eligibility criteria. The selection and inclusion process followed the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines.

Results: A total of 1531 fruits juices were sampled and assessed for microbial contamination in 20 studies across eight countries and we observed a pooled prevalence of bacterial contamination of 86.96%,(95% CI [81.25 - 90.93], I^2= 86.96% (95%CI [81.25 - 90.93]) across the studies. We observed that *Staphylococcus, Escherichia coli, Bacillus,* and *Salmonella* are common isolates across studies. Other bacteria are *Micrococcus, Pseudomonas, Streptococcus, Lactobacillus, Acetobacter, Corynebacteria, Enterobacter, Serratia, Aeromonas, Shigella, Listeria, Yersinia, Proteus, Klebsiella, and Enterococcus*.

Conclusion: Our study indicated a higher prevalence of bacterial contamination with both commensals and pathogenic bacteria indicating juices and potential sources of foodborne illness. We observed that the majority of African countries had no published research on fruit juices. The potential pathogens observed in our study are *Salmonella*, *Shigella*, *Staphylococcus*, and *Bacillus*. Proper personal hygiene, washing of fresh fruits, and good handling during the preparation of juices are mandatory for the prevention of bacterial contamination.

ARTICLE DETAILS

KEYWORDS: Fruit Juice, Microbiological, Bacteria, Juice Contamination, Fresh Juice Contamination.

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INTRODUCTION

The consumption of fruit juices is a common practice worldwide, largely for their nutritional value, refreshing taste, and quick source of energy after heavy work. In Africa where fruits are readily available throughout the year, the preparation of fruit juices holds a significant part of African traditions serving as both a staple beverage and, a source of essential vitamins and minerals

(Braide, 2012). However, the microbiological safety of fruit juices remains a subject of public health concern due to the risks associated with microbial contamination. Fruit juices are susceptible to contamination by a range of microorganisms, including bacteria, which can pose serious health threats to consumers (Aneja et al., 2014).

Microflora found in juices are originally present on the surfaces or within the fruits that are used for juice preparation. These sources can also be traced to harvest and postharvest processing including transport, storage, and processing (Kaddumukasa et al., 2016). The presence of microflora does not rule out the potential of having pathogenic microorganisms in the fruit juices although some juices may not be favorable for the growth of other bacteria, some bacteria have an acid-tolerant status such that these organisms use the acids as a substrate for their survival and growth (Batra et al., 2018). Common acid-tolerant bacteria isolated from fresh fruit juices include lactic and acetic acid bacteria (Centre for Food Safety, 2014).

The presence of *E. coli*, *Salmonella*, and *S. aureus* in fruit juices is primarily a concern because these pathogens were implicated in several outbreaks associated with fruit juices (Kabwama et al., 2017). Fruit juices sold for consumption in public places need extra precaution to make it safer for the consumers however, due to poor preparation and handling, contamination has been observed from fruit juices sold in restaurants, cafes, and roadside vendors which is unacceptable for human consumption and this has become a significant public health concern among the population of consumers (Mortuza, 2016).

Amidst high consumption patterns of fruit juices and several studies highlighting the microbiological quality of these juices across Africa, no study has systematically analyzed the African situation wholistically to inform public health decisions on the bacteria profile of fruit juice.

Fruit Juice Consumption and Outbreaks

Outbreaks are rare occurrences in the community and can happen spontaneously due to contamination with potential pathogens from the environment (Braide, 2012).

There is growing concern about the safety of ready-to-eat food sold in various restaurants across Africa despite the need for food safety by consumers (Tafere & Desaleegn, 2017). Many studies have documented poor handling of food, poor hygiene practices, and the use of unclean utensils as sources of high-risk bacteria contaminating foods. The most common outbreaks-related pathogens documented are *Salmonella*, *Vibrio cholera*, *Bacillus*, *Staphylococcus*, and *Clostridium* (Mengistu et al., 2021).

METHODS

Search Strategy

We searched PubMed, Scopus, and Embase on the 4th of November, 2023, to identify studies on the microbiological quality of fruit juices across Africa. The search was run using the algorithm "microbiological Quality" OR "Microbial Load" OR " Bacterial Load" OR "Microbial contamination") AND ("Fruit Juices") AND ("Algeria" OR "Angola" OR "Benin" OR "Botswana" OR "Burkina Faso" OR "Burundi" OR "Cabo Verde" OR "Cameroon" OR "Central African Republic" OR "Chad" OR "Comoros" OR "Democratic Republic of the Congo" OR "Republic of the Congo" OR "Djibouti" OR "Egypt" OR "Equatorial Guinea" OR "Eritrea" OR "Eswatini" OR "Ethiopia" OR "Gabon" OR "Gambia" OR "Ghana" OR "Guinea" OR "Guinea-Bissau" OR "Ivory Coast" OR "Kenya" OR "Lesotho" OR "Liberia" OR "Libya" OR "Madagascar" OR "Malawi" OR "Mali" OR "Mauritania" OR "Mauritius" OR "Morocco" OR "Mozambique" OR "Namibia" OR "Niger" OR "Nigeria" OR "Rwanda" OR "Sao Tome and Principe" OR "Senegal" OR "Seychelles" OR "Sierra Leone" OR "Somalia" OR "South Africa" OR "South Sudan" OR "Sudan" OR "Tanzania" OR "Togo" OR "Tunisia" OR "Uganda" OR "Zambia" OR "Zimbabwe") with no restriction to study type or year of publication. No protocol was registered prior to the commencement of this study.

Study Selection Criteria

The search yielded 198 bibliographies cumulatively from Scopus, PubMed, and Embase. We removed Ninety-eight (98) duplicates were removed, and one hundred titles and abstracts were screened down to forty-nine (49) articles sought for retrieval and further screened for eligibility. We included only studies conducted in Africa that reported isolating bacteria from fruit juices among the respondents. Two authors, TP and DM, carried out independent and overlapping screening of titles and abstracts to establish eligibility. After the screening process, twenty-one (20) studies met the inclusion criteria and were included in the review (**Figure 1)**.

Data Extraction

From the included studies, we extracted and classified the following information: author name, year of publication, country of study, study design, sample size, type of fruit juice, type bacteria isolated, number of isolates per sample, and total bacterial count.

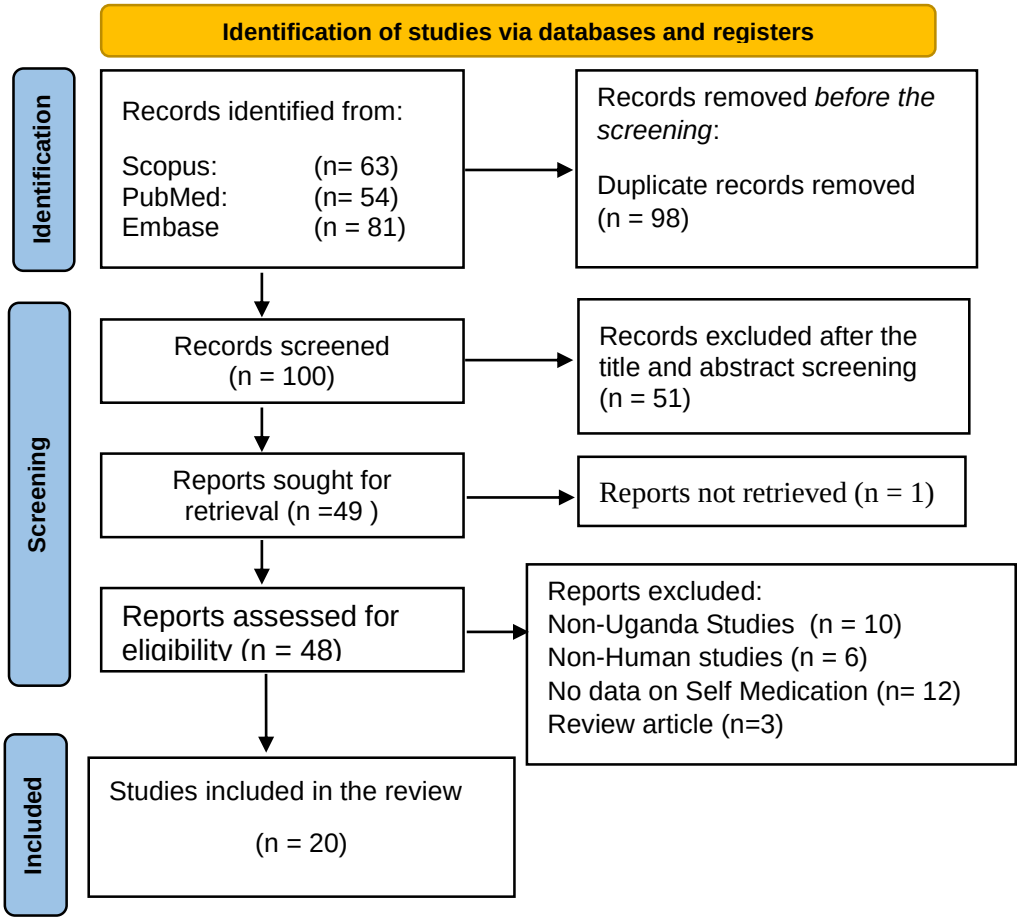

Figure 1: Search Query

Statistical Analysis

Data analysis was descriptive; study characteristics were summarized as frequencies and percentages using Microsoft Excel, (2019). Equally, the pooled prevalence of the isolates was estimated using MedCalc® Statistical Software version 22.006.

RESULTS

Study Selection and Characteristics

A total of 1531 fruit juices were sampled and assessed for microbial contamination in 20 cross-sectional studies across eight countries. The majority of the studies (n=9) were conducted in West Africa (Ghana & Nigeria) and closely followed by East African studies (Ethiopia & Uganda) (n=8). The remaining studies were from Egypt and Libya, all in Northern Africa. Moreover, 50% of the studies (n=10) were published between 2015 and 2019.

Common Fruits Used for Fruit Juices in Africa

Several fruits are used to make fruit juices globally. Across the included twenty studies mangoes, pineapples, paw paw, gnamakoudjii, watermelon, citrus, avocado, guava, passion fruits, and grapes are the most juiced fruits. These fruits are often processed into juices singly or in combination (Bhagra et al., 2017).

Prevalence of bacterial contamination of fruit juices in Africa

Our meta-analysis observed an 11.6 % (95% CI [7.24-16.89]; I^2 = 99.59 % [99.54-99.64]) bacterial contamination of fruit juices. [Table 2] below presents the burden of bacterial contamination of fruit juices across the continent.

Microbial Profile of fresh fruit juices sold across Africa

Our reviews observed that fruit juices across Africa were contaminated by bacteria. Nineteen bacterial species have been isolated with the majority (N= 10) identified as Gram-negative bacteria (*Klebsiella spp, Salmonella spp, E. coli, Aeromonas, P. aeruginosa, Yersinia, Proteus, Shigella, Serratia, and Enterobacter)* and the remaining (n=9) Gram positives (*S. aureus, Micrococcus, Streptococcus, Lactobacillus, Listeria, Bacillus, Enterococcus, Corynebacterium, Acetobacter*)

The dominant species were Staphylococcus aureus (n = 18), Escherichia coli (n= 13), Salmonella spp (n=9), and Bacillus (n= 10). **Figure 4** presents the meta-analytic distribution of bacterial contaminants in fruit juices across Africa.

Table 1: Pooled Prevalence of Bacteria in Fruit Juices across Africa

Studies	Sample size	Proportion (%)	95% CI	I^2 (95% CI)	P - value
Kaddumukasa et al	86	3.49	0.73 - 9.86		
Ogodo et al	40	12.50	4.19 - 26.80		
Adesetan et al	75	12.00	5.64 - 21.56		
Alemayehu et al	120	3.33	0.92 - 8.32		
Braide et al	14	42.86	17.66 - 71.14		
Christine et al	10	40.00	12.16 -73.76		
Chuku et al	3	100.00	29.24 -100.00		
El-Shenawy et al	43	13.95	5.29 - 27.93	86.96%	P < 0.0001
Geta et al	36	5.56	0.68 - 18.66	(81.25 - 90.93)	
Ghenghesh et al	146	8.22	4.32 - 13.92		
Jimma et al	28	42.86	24.46 - 62.82		
Kebede et al	80	3.75	0.78 -10.57		
Mahgoub et al	360	0.83	0.17- 2.42		
Mengistu et al	78	3.85	0.80 - 10.83		
Oladipo et al	7	57.14	18.40 - 90.10		
Olorunjuwon et al	120	7.50	3.49 - 13.76		
Onuoha et al	21	23.81	8.22 - 47.17		
Tafere et al	90	1.11	0.02 - 6.04		
Tchamba et al	150	1.33	0.16 - 4.73		
Worku et al	24	12.50	2.66 - 32.36		

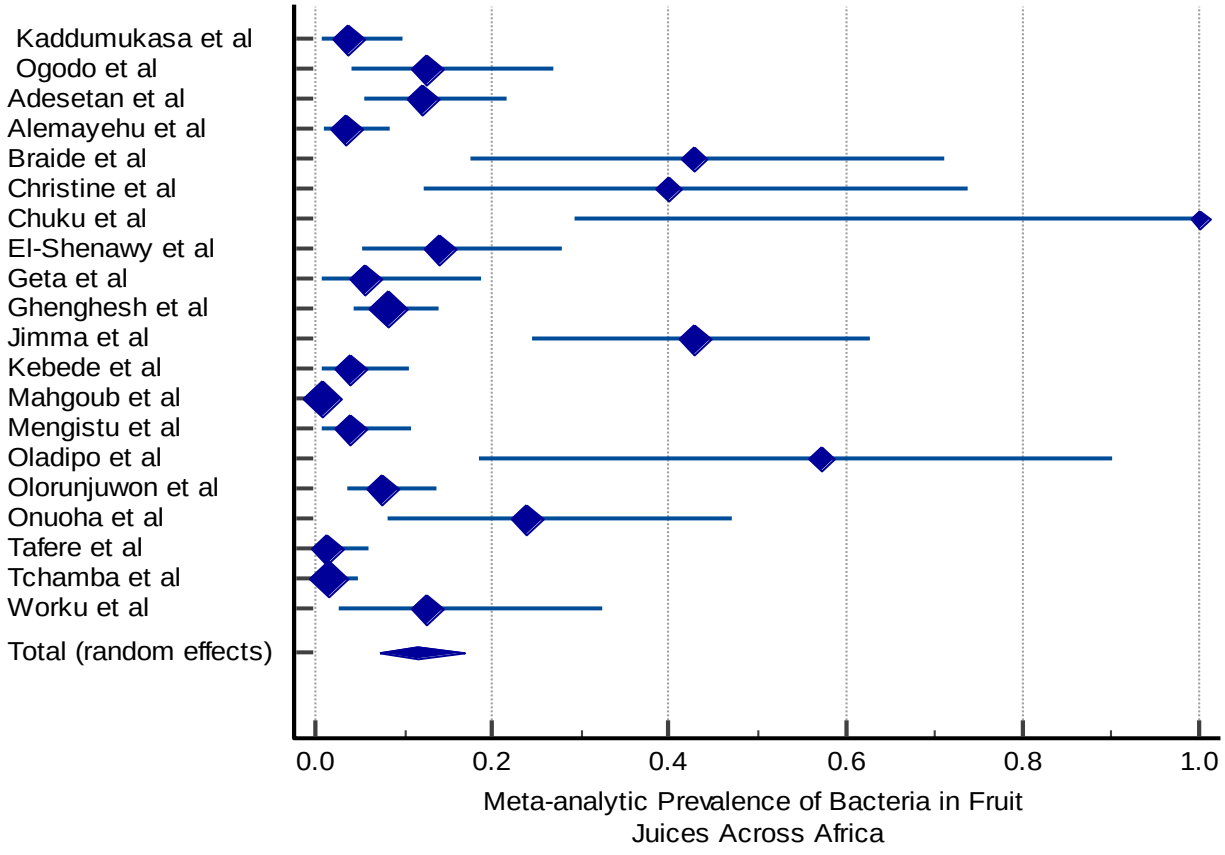

Figure 2: Meta-analytic distribution of bacterial contaminants of fruit juices Africa

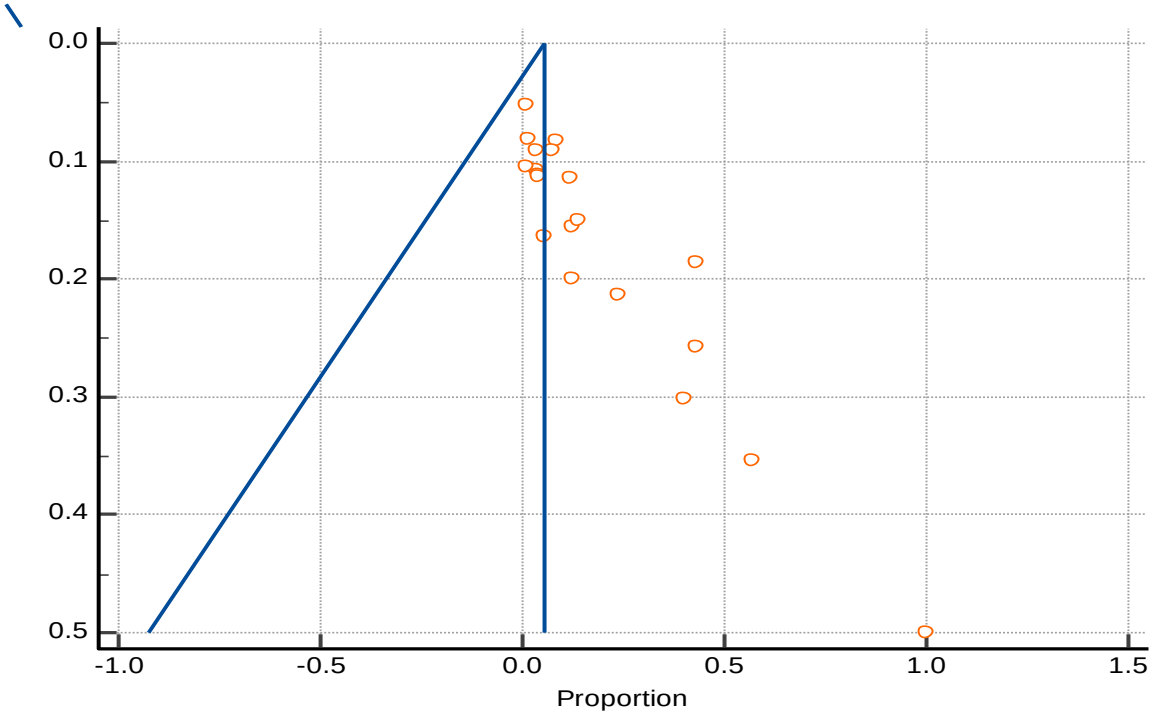

Figure 3: Funnel Plot of the Meta-analytic Prevalence of Bacteria in Fruit Juices Across Africa

Table 2: Sub-group meta-analytic prevalence of bacterial contamination of fruit juices across Africa

Characteristics	Sample size	Proportion (%)	95% CI	I^2 (95% CI)	P - value
Country					
Burkinafaso	150	1.33	0.16- 4.73		
Egypt	403	2.23	1.03- 4.19		
Ethiopia	428	3.74	2.15- 6.00		
Ghana	28	42.86	24.46-62.82	92.55% (87.68- 95.50)	P < 0.0001
Libya	146	8.22	4.32- 13.92		
Nigeria	282	15.96	11.88-20.76		
Rwanda	10	40.00	12.16-73.76		
Uganda	86	3.49	0.73-9.86		
Region					
East Africa	524	4.39	2.80- 6.51		
North Africa	549	3.83	2.38-5.79	94.10% (86.15- 97.49)	P < 0.0001
West Africa	460	12.83	9.90-16.23		
Period of Study					
2005-2009	146	8.22	4.32-13.92		
2010-2014	269	14.13	10.19-18.87	93.35% (86.17-96.80)	P < 0.0001
2015-2019	988	3.54	2.48-4.89		
2020-2024	130	13.85	8.42-20.99		

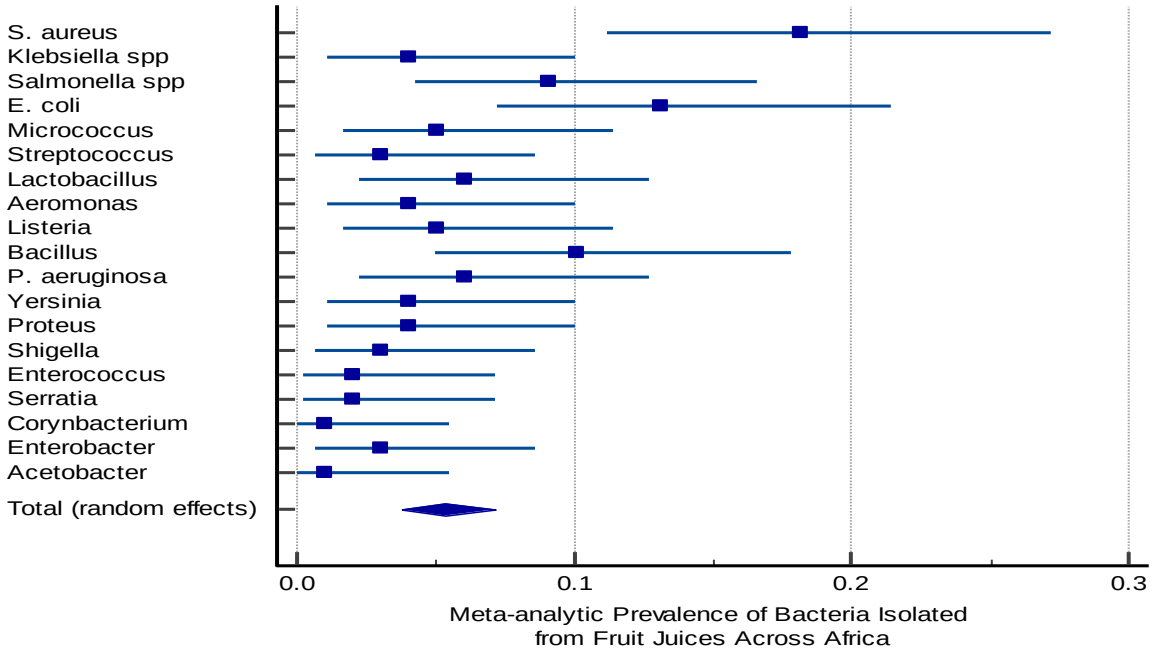

Figure 4: Meta-analytic distribution of bacterial isolates of fruit juices in Africa

DISCUSSIONS

In this study, we searched and made use of twenty (20) articles that met the criteria for isolating bacteria from ready-to-drink fruit juice samples sold across Africa. The pooled prevalence of bacteria isolated at 86.96% was significantly present in all studies with a p-value of 0.0001 and confidence interval (CI) [81.25-90.93] indicating an even distribution of bacterial profile across the studies done. We observed in this study that despite the differences in fruit juices across the study areas and in different countries, bacteria were found in all juices [Table 1]. However, the prevalence cannot be used for all African countries because, out of about 55 countries in the continent of Africa, only a few countries have published research on the microbiological quality of fruit juices.

Our study observed that studies with a higher prevalence of bacteria isolated from fruit juice had fewer sample sizes, unlike studies with larger sample sizes (Oladipo et al., 2010); (Braide, 2012); Chukwu) [Figure 2]. This showed a higher random effect of bacterial contaminants in fruit juices among studies with fewer sample sizes than those studies that considered larger sample sizes therefore, we cannot assume that bacteria contamination is more prevalent in those studies with fewer sample sizes.

Our study observed variability in bacteria distribution across the studies done in Africa on bacteria contamination of fruit juices as indicated on the forest plot [Figure 3]. Also, the bacteria isolated were not prevalent only one-sided but, all studies done had bacteria contaminating fruit juices samples which is a threat to consumers of the fruit juices.

We observed that there is no difference in bacteria contaminant of fruit juices over the years across all eight (8) countries in Africa, years of study, and across regions with most studies done from 2005 to 2024 showing significant p-values of <0.005 respectively, [Table 2]. this shows that most food-borne illnesses are not only transmitted through ready-to-eat food or vegetables but also through fruit juices since, there was no reduction of bacterial contamination of fruit juices observed over the years despite the research done in this area (Iqbal et al., 2016).

We observed in this study that *Staphylococcus aureus* has been the most isolated bacteria contaminating fruit juices among the studies across Africa, followed by *Escherichia coli*, *Salmonella*, *Bacillus*, and *Pseudomonas aureginosa*. These isolated bacteria are potential pathogens that are common causes of illness ranging from enteric fever, diarrhea, and food poisoning with delayed wound healing (Akter et al., 2013). Among the most prevalent bacteria isolated from fruit juices in studies done in Africa, only *Lactobacillus* is not a potential pathogen. The isolation of these bacteria from fruit juices calls for concern and indicates poor sanitation, personal hygiene, and poor handling during juice processing. Fruit juices are largely consumed by the public due to their availability in street vendors, restaurants, and cafes therefore, the a need to give proper attention for their safety to the public. The least bacteria isolated were *Acetobacter* and *Corynbacteria* which are mostly normal flora of the body with less potential of causing outbreaks [Figure 4]. However, the bacteria isolates are mostly contaminants due to poor hygiene practices from fruit juice producers and poor handling. Also, *Acetobacter* bacteria are acetic acid bacteria that can survive in an acidic medium which most juices provide; also, *Acetobacter* has been reported to be isolated from Drosophila which is a common fruit fly. *Corynebacteria* on the other hand are found everywhere in nature including water, soil, plants, animals, humans, and food products; these bacteria are important disease-causing

organisms and, are used in industries for acid production and this indicates their presence in ready-to-take fruit juices since they can survive in acidic environment.

CONCLUSIONS

Our study indicated a higher prevalence of bacterial contamination with both commensals and pathogenic bacteria indicating juices and potential sources of foodborne illness. We observed that the majority of African countries had no published research on fruit juices. The potential pathogens observed in our study are Salmonella, Shigella, Staphylococcus, and Bacillus. Proper personal hygiene, washing of fresh fruits, and good handling during the preparation of juices are mandatory for the prevention of bacterial contamination.

List of Abbreviations

Declarations

Ethics approval and consent to participate

Ethics approval is not required for this study

Consent for publication

Not required for this study

Availability of data and materials

Extracted and synthesized studies are cited in this manuscript and available on request through the corresponding author.

Competing interests

All the authors declare that they have no competing interests whatsoever

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There was no financial aid for this study

Authors' contributions

All authors contributed equally to this work and approved the final version for submission

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