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Assessment of Microbial Safety of Bread Production Process in Some Selected Bakeries in Lafia Metropolis, Nasarawa State, Nigeria

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***Abstract*—**Microorganisms in the ecosystem are always looking for nourishment in order to survive. Their feeding actions invariably have a negative impact on our food chain, which is harmful to human health. Food safety is critical in the quest for healthy diets and sustainable food systems because it ensures that food is wholesome for human consumption. The goal of this study was to investigate the microbiological safety of the bread making process in a few bakeries in the Lafia metropolitan region. In Lafia, a total of 20 samples were collected at random from four (4) separate bakeries. Aseptic samples were collected during the ingredient mixing, kneading, dough proofing, cooling, and packaging stages of the baking process. To make the stock solution for each sample, 10 g of each sample was weighed and suspended in 90 ml of buffered peptone water (BPW) and homogenized in a beaker. Using the pour-plating procedure, the stock solution was serially diluted, inoculated, and incubated on the appropriate agar. Colonies were established, enumerated, divided into subcultures, and identified. The result obtained showed that the mean heterophilic bacterial count range from 3.2 x 10^4 to 8.7 x 10^4 cfu/g; 6.7 x 10^4 to 1.2 x 10^5 cfu/g; 7.2 x 10^4 to 9.7 x 10^4 cfu/g; 0.3 x 104 cfu/g to 2.3 x 10^4 cfu/g during the mixing, kneading, dough rising, and cooling and packaging stages respectively. The mean coliform count during the mixing stage range from 1.2 x 10^4 to 6.7 x 10^4 cfu/g, 3.7 x 10^4 to 7.2 x10^4 cfu/g during the kneading stage, 5.9 x 10^4 to 8.7 x 10^4 cfu/g during dough rising stage and 0.9 x 10^4 cfu/g to 1.3 x 10^4 cfu/g at the cooling stage. The mean fungal count range in the different bread production processes included 0.9 x 10^4 to 1.4x 10^4 cfu/g during the mixing stage, 1.2 x 10^4 to 1.8 x 10^4 cfu/g at the kneading stage, 3.2 x 10^4 cfu/g to 6.9 x 10^4 cfu/g at the dough rising stage, while 1.3 x10^4 at the cooling and packaging stage was only seen in one bakery. *Staphylococcus aureus, Lactococcus acidophilus, Bacillus cereus, Enterococcus fecalis, Escherichia coli, Lactobacillus spp, and Saccharomyces spp., Aspergillus spp., Fusaruim spp.,* and *Mucor spp*. were among the bacterial and fungi isolates found. The various phases of bread production were contaminated with different bacteria, according to this study. During the mixing, kneading and rising of the dough, these bacteria are more prevalent. Because *Lactococcus acidophilus, Lactobacillus spp.,* and *Saccharomyces spp*. are involved in bread fermentation, their presence is normal. The existence of other microorganisms in bakeries is a sign of how clean they are. As a result, during the manufacturing and packing of bread, handlers must maintain stringent hygiene.

Keywords— *bread, bread production process, microbiological safety, bakeries,*

I. INTRODUCTION

Food has long been acknowledged as one of life's essential requirements, because of its potential to bring sustenance, health, and vitality to the consumer. Despite the importance of food, it is now well accepted that both risky food preparation and risky eating behaviour contribute to a rise in foodborne disease outbreaks [1]. Microorganisms in the ecosystem are always looking for nourishment in order to survive. Their dining habits unavoidably have a negative impact on our food system, which is bad for human health. Food safety is crucial in the quest of healthy eating and sustainable food systems because it ensures that food is safe for human consumption. Grains and grain products account for a significant component of the food consumed by many people around the world. Bread is a grain product that is consumed by people of various genders, ages, ethnicities, and faiths around the world. Due to its primitive origin, simple production technology and wide consumption, bread has attracted a significant level of food innovation in terms of recipes diversity and improvement in production technology that have led to complete

automation of production system thereby minimizing human contact leading to improvement in food safety, quality and hygiene in developed nations. However, the same cannot be said of most developing countries in which the bread production system is still largely a traditional affair dominated by traditional technology and persons with limited levels of education; lacking knowledge of food safety and hygiene practices. These have led to bread being produced in an unhygienic environment characterized with high level of hazardous food safety practices. Poor food handling techniques have been linked to food-borne disease in studies [2]. Bread is a meal that is typically consumed unprocessed, making it a potential cause of food-borne disease if handled incorrectly [3]. Open and unsealed loaves of bread are frequently exposed to hot and humid conditions, which raises the risk of new microbial contamination and the spread of previously infected organisms. As a result of the disparity between developed and developing countries in terms of advanced food processing and enhanced food safety practices, all bakery operators must be well-trained and prepared to deal with such issues. Knowledge of the chemical, physical, and biological processes involved in bakery technology flow, as well as the impact of new operations and devices on the entire production, are critical in managing the major issues. This is required because consumers desire bread that has the same flavor, look and aroma as traditional goods, but is created in a safer environment and has a longer shelf life comparable to innovative technology.

Baked foods and cereals offer enough nutrients and calories to meet daily requirements [4]. They are important food sources in our diet, supplying the majority of our dietary calories and about half of our protein requirements. Carbohydrates, proteins, fats, vitamins and minerals are all found in baked foods. They are crucial for customers, particularly those in the low and middle income stratum whose basic diets rely on street food [5]. Bread is the second most popular non-native food in Nigeria after rice [6]. Despite the fact that bread is a staple diet for the world's population, it has been shown to be hazardous to human health when contaminated with pathogenic microbes [7]. Microorganisms play a crucial function in the baking process in terms of consistency and formation of aroma, but they can also cause damage or spoilage [5].
Despite attempts by food regulators to enhance hygienic and sanitary conditions and eliminate risky food safety practices in the bread-making industry in Nigeria, the sector remains mired in poor food safety standards due to poverty, illiteracy, corruption, and tax regulation. While a few significant bakery enterprises have been able to build their bakery brands on a national scale, they remain insufficient and unavailable to the poor. As a result, the growing demand is satisfied on a smaller scale from unlawful and semi-authorized local producers that is rarely checked by current food regulatory agencies. Consequently, so many individuals are at danger of foodborne diseases and adulteration [8]. Typically, mold spores existing in the environment surrounding the loaves infect bread and other confectionary items during the post-baking process, which includes chilling, slicing, packing, and storage. *Bacillus*, *Escherichia*, *Salmonella*, *Streptococcus aureus* and other bacteria can infect baked goods while they are sliced, packed, and packaged manually [8]. As a result, the basic medium for the transmission of foodborne disease microbes, which is responsible for the rapid deterioration of the food system and the rising incidence of foodborne diseases around the world, can be traced back to poor cleaning of food machine contact surfaces, cross-contamination, and poor hand decontamination prior to and after food handling, improper storage temperature, and insufficient heat treatment [1]; [9].

Food safety is essential for healthy living and overall well-being, because a shortage of safe food leads to food insecurity, which leads to malnutrition and foodborne infections [1]. Food spoiling is a metabolic process that causes changes in sensory characteristics of food, making it unattractive or unsatisfactory for human ingestion [10]. Spoiled food is safe to eat if it does not cause sickness since it contains no germs or poisons, but it is rejected due to changes in texture, smell, taste, or appearance [10]. Freshly baked bread is almost devoid of living microorganisms on the surface, but airborne mold spores contaminate it during cooling and prior to wrapping. Microorganisms in the air, on the blades, or on the case can all cause contamination while slicing. Bacterial spores that cause bread to become ropy survive baking [11].

Furthermore, despite public awareness and attempts to guarantee that residents have access to high-quality bread, there are various ways for bread to get contaminated during the manufacturing process, particularly during packing [12]. Because improper handling and personal hygiene of food, especially during packaging, contribute to most foodborne diseases from cross-contamination and poor personal hygiene of bread traders. Bread contamination and pathogen growth change its quality and are a potential source of infection for consumers [13].

As a result of the indiscriminate use of potassium bromate, consumer concerns about bread safety have grown, while storage, handling, the state of the bread processing environment, and the health of home industry workers and street vendors are all important considerations in ensuring consumer safety [14]. In most cases, neither the manufacture of bread nor the transportation system conform to any sanitary regulations. Ingredients and equipment are handle with bare hands throughout the preparation. Because bakeries lack flowing water, equipment is cleansed simply by immersing it in one or more buckets and occasionally without soap [5]. The items are contaminated with hazardous microorganisms if they are used in unhygienic conditions. *Bacillus cereus, Clostridium botulinum, Escherichia coli, Shigella spp., Salmonella spp., Vibrio parahaemolyticus, Staphylococcus aureus, Campylobacter jejuni, Streptococcus pyogenes, E. colytogenese, and Salmonella spp.* are the most prevalent food-borne pathogenic bacteria. The presence of

pathogenic bacteria in food poses serious health risks and can result in food poisoning epidemics [15].

Though the need for safe food grows in Nigeria, the issue of food safety has not been seriously considered, particularly in the manufacturing, storage, distribution, and marketing of street food items, due to a lack of food safety monitoring and inadequate enforcement of applicable regulations [1]. Given the relevance and applications of bread in modern life, it is crucial to retain its microbiological purity. Food handlers who do not exercise good personal hygiene become carriers of infections, which they can spread through their hands, mouths, and skin [12]. This study's goal was to determine the microbiological composition of bread during the mixing, kneading, fermenting/proofing, cooling, and packing processes.

II. RELATED WORK

The contamination of bread has been investigated in several research conducted at various times and in various locations. Reference [16] discovered 2.86 x 10^4 bacterial cells per gram in local bread, 2.96 x 10^3 in baked biscuits and 2.73 x 10^3 average bacterial cells per gram in pastry. In their investigation of locally manufactured bread, pastries and baked biscuits *Bacillus spp., E. coli* and *Klebsiella spp*. were found. However, no microorganisms were found in Parle-G biscuit.

According to reference [17], 66.7 percent of kitchen equipment were infected with *S. aureus*, 14.1 percent with *B. subtilis*, 7.7 percent with *B. cereus* and 11.5 percent had no sign of bacterial development in their study of bacteria linked with appliances in bread factories. To avoid food poisoning, the authors recommended that rigorous cleanliness rules be observed when using these devices. Many commercial baked items emerge from the baking process with an essentially clean surface, but post-baking handling can quickly lead to fungal and microbiological surface contamination due to exposure to airborne pollutants as well as contact with equipment, according to [18].

Rope spoilage, according to [19], is a bread illness caused by bacterial degradation of the bread crumb. Heat-resistant bacterial spores are the spoilage organisms. *Bacillus subtilis, Bacillus licheniformis*, and *Bacillus pimilus* all withstand baking process. *Bacillus, Staphylococcus, Micrococcus, Aspergillus, Penicillium, Rhizopus,* and *Mucor* were isolated from bread, according to [20]. Reference [21] examined 30 bread samples and discovered that the deterioration was caused only by fungi such as *Rhizopus spp., Aspergillus spp., Mucor spp., Penicillium spp. and Fusarium spp*. According to [22], poor personal hygiene can make pathogenic bacteria found in the environment and on people's hands more easily transmitted to humans through food.

Reference [10] carried out a qualitative and quantitative analysis of baked goods and isolated bacteria such as *Bacillus subtilis, Bacillus megaterium, Bacillus shaericus, Bacillus polymyxa, Bacillus psychrophilus and Bacillus spp.,* as well as molds *Aspergillus luchuensis, A. flavus, A. terreus, Alternaria alternata, A. Tenuissima*. Germs that are gram-positive are more prevalent than bacteria that are gram-negative. All baked items included *Bacillus subtilis and Aspergillus luchuensis*. On a qualitative level, the most number of molds were isolated and identified from bread loaves, followed by cakes, pastries, pies and a limited number in buns and biscuits, while the most bacteria were recovered from bread, followed by cakes, biscuits, pies and a small number in pastries.

Reference [5] investigated the microbiological quality for shelf life of several bread and cake samples prepared locally in Tangail, Bangladesh, and discovered that the products' Total Viable Count (TVC) ranged from 1.0×10^2 cfu/g to 1.3×10^6 on the first day. On the first day, the Total Coliform Count (TCC) varied from 2 cfu/g to 244 cfu/g. On the first day, the Total Fungi Count (TFC) was also in the range of 6 cfu/g to 1.1×10^6 cfu/g. The microbiological characteristics of all bread and cakes sampled were beyond the allowed requirements after the third day, according to the WHO standard (maximum value 200 cfu/g for coliforms and maximum value $1x10^5$ cfu/g for bacteria and fungus). It has been suggested that because of poor production procedures, such as inadequate cleanliness and sanitation, healthy bread and cakes serve as ideal substrate for microbial development. As a result, in order to create safe food, an initial step should be done to educate the bakery owner as well as consumers about hygiene and sanitation.

Reference [3] did a descriptive cross-sectional research in an urban neighborhood to assess the safety of bread for human consumption and discovered that just a third of the bakeries tested were sanitary, while bread dealers' cleanliness was subpar. *S. aureus* was identified in 33% and 90% of bread samples from bakeries and bread vendors, respectively. Several contamination locations were discovered, as well as evidence of inadequate bread handling methods. Existing rules should be enforced, and bread vendors should be instructed on safe bread handling to limit the spread of foodborne infections, according to the authors.

Despite the fact that bread is widely consumed in Lafia as a daily meal at home, in cafeterias, and in tea shops, the microbiological safety of this delightful delicacy is still unknown. However, several consumer and producer organizations are unaware of the microbiological safety of bread, as many bakeries continue to utilize filthy practices for baking, distributing, and storing bread. With the rise in foodborne illness outbreaks throughout the world and rising consumer demand for clean food, it is more vital than ever to examine the safety and quality of street food [1]. The majority of bread studies have focused on the microbiological content and safety of equipment and

completed bread products; however, none have been undertaken in Lafia, Nigeria, to examine the microbial content and safety of the various phases of bread manufacturing. As a result, this research was created to evaluate the microbiological load and safety of the bread-making process, and it was aimed to be eye-opening for both producers and customers.

III. METHODOLOGY

Study area

The research was carried out in Lafia Local Government Area of Nasarawa State, Nigeria. The city was picked since it is the state capital and home to a large number of unregulated bakeries. With a population of roughly 329,922 people, the territory serves as an administrative and metropolitan region [23]. It is the principal gateway connecting Nigeria's northern and southern halves, making it a popular spot for street food vendors [1].

Sample collection

In Lafia, a total of 20 samples were collected at random from four (4) separate bakeries. Aseptic samples were collected during the ingredient mixing, kneading, dough proofing cooling and packaging stages of the baking process. The samples were taken to the microbiology lab at Isa Mustapha Agwai 1 Polytechnic's Science Laboratory Technology Department for examination. For simple identification, the samples were labeled [6].

Preparation of Media

Nutrient Agar, MacConkey Agar, and Salmonella Shigella Agar were used to cultivate bacterial isolates, whereas Sabouraud Dextrose Agar was used to cultivate fungus. The different media were made in accordance with the manufacturer's guidelines.

Microbiological analysis

To make the stock solution for each sample, 10 g of each sample was weighed and suspended in 90 ml of buffered peptone water (BPW), homogenized in a beaker and mixed using a sterile mixer at 160 rpm for 5 minutes. The material was analyzed using a 5-fold dilution [4]. Pour plating was used to inoculate the samples, which were then incubated at 37 ° C for bacterial isolates and 25 ° C for fungal isolates. The total number of heterotrophic bacteria, coliform bacteria, and fungus were counted and recorded, and the results were expressed in cfu/g. Pure bacteria cultures were obtained by streaking representative colonies of various morphological kinds that formed on cultured plates on freshly prepared medium in an aseptic manner. Standard microbiological staining and biochemical identification procedures were used to identify the isolates [24].

Statistical Analysis

Data obtained was analyzed using Microsoft® Excel programme and presented in, tables, charts and graphs to show the number of microbial load found in the samples.

IV. RESULTS AND DISCUSSION

Results

The different stages analyzed were the critical control points in the processing of bread. The results reveal that the various stages are prone to contamination by microorganisms. Table 1 shows the mean count of heterophilic bacteria in different stages of bread production process from different bakeries. From the data presented, it is seen that during the mixing stage, the mean count range from 3.2 x 10^4 to 8.7 x 10^4 cfu/g, at the kneading stage from 6.7 x 10^4 to 1.2 x 10^5 cfu/g, at dough rising 7.2 x 10^4 to 9.7 x 10^4 cfu/g, at the cooling and packaging stage, the mean heterophilic bacterial count range from 0.3 x 10^4 cfu/g to 2.3 x 10^4 cfu/g. The mean coliform count is shown in Table 2. It is seen that during the mixing stage, the coliform count range from 1.2 x 10^4 to 6.7 x 10^4 cfu/g, during the kneading stage the count range from 3.7 x 10^4 to 7.2 x10^4 cfu/g, at the dough rising stage from 5.9 x 10^4 to 8.7 x 10^4 cfu/g, at the cooling stage from 0.9 x 10^4 cfu/g to 1.3 x 10^4 cfu/g. The mean fungal count range in the different bread production processes is show in Table 3. During the mixing stage, the mean count range from 0.9 x 10^4 to 1.4x 10^4 cfu/g, at the kneading stage the mean fungal count range from 1.2 x 10^4 to 1.8 x 10^4 cfu/g, at the dough rising stage the count range from 3.2 x 10^4 cfu/g to 6.9 x 10^4 cfu/g, at the cooling and packaging stage, the count was only seen in one bakery with count of 1.3 x10^4.

Table 1: Mean heterophilic bacteria count of bread production process from different bakeries.

	Bread Production Stages			
Bakery	**Mixing**	**Kneading**	**Dough rising**	**Cooling and packaging**
B1	5.8 x 10^4	9.9 x 10^4	9.2 x 10^4	1.2 x 10^4
B2	7.2 x 10^4	9.8 x 10^4	8.9 x 10^4	0.7 x 10^4
B3	3.2 x 10^4	6.7 x 10^4	7.2 x 10^4	0.3 x 10^4
B4	8.7 x 10^4	1.2 x 10^5	9.7 x 10^4	2.3 x 10^4

Key B1: Tony William Bakery B2: Abdullahi Rahama Bakery B3: Lagwada Bakery B4: Zuma Bakery

Table 2: Mean coliform bacteria count of bread production process from different bakeries in Lafia.

	Bread Production Stages			
Bakery	**Mixing**	**Kneading**	**Dough rising**	**Cooling and packaging**
B1	3.8 x 10^4	6.9 x 10^4	7.2 x 10^4	1.2 x 10^4
B2	2.6 x 10^4	4.8 x 10^4	5.9 x 10^4	1.3 x 10^4
B3	1.2 x 10^4	3.7 x 10^4	6.2 x 10^4	0.9 x 10^4
B4	6.7 x 10^4	7.2 x 10^4	8.7 x 10^4	1.0 x 10^4

Key B1: Tony William Bakery B2: Abdullahi Rahama Bakery B3: Lagwada Bakery B4: Zuma Bakery

Table 3. Mean fungal count of bread production process from different bakeries in Lafia.

Bread Production Stages				
Bakery/ stage	**Mixing**	**Kneading**	**Dough rising**	**Cooling and packaging**
B1	1.0×10^4	1.3×10^4	3.2×10^4	NG
B2	0.9×10^4	1.8×10^4	6.9×10^4	NG
B3	1.2×10^4	1.3×10^4	6.2×10^4	NG
B4	1.4×10^4	1.2×10^4	5.7×10^4	1.3×10^4

Key B1: Tony William Bakery B2: Abdullahi Rahama Bakery B3: Lagwada Bakery B4: Zuma Bakery
NG: No Growth

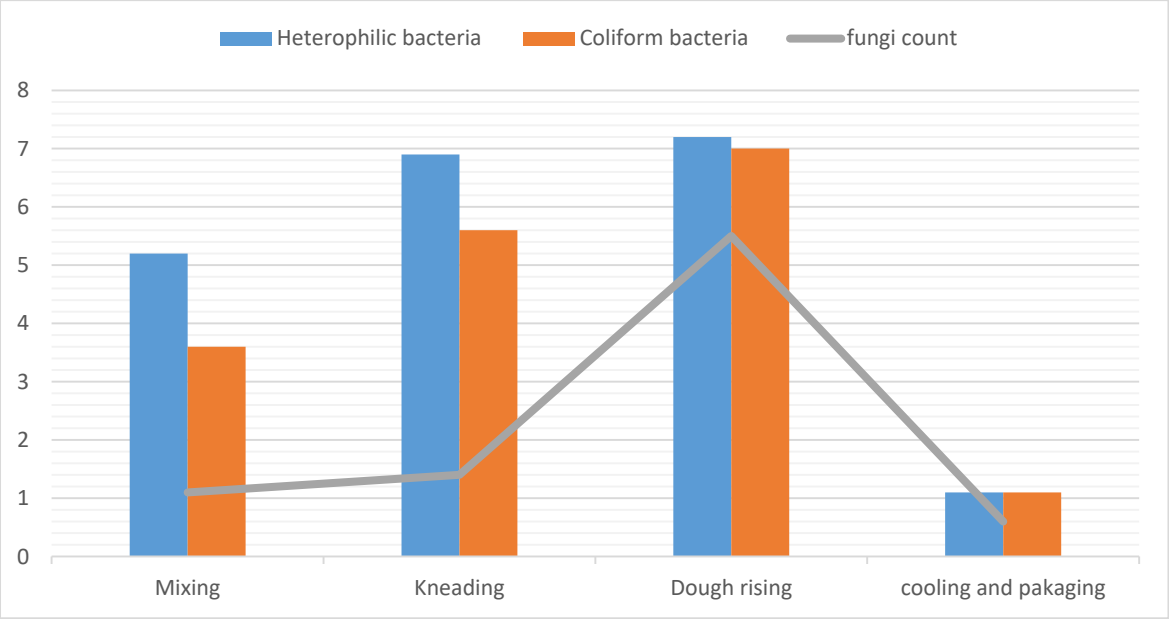

Figure 1: Chart showing the microbial load in the in bread making processes in different bakery in Lafia.

Table 4.0. Characteristics of the bacterial isolates identified in bread making processes in different bakery in Lafia.

Parameter	Isolate 1	Isolate 2	Isolate 3	Isolate 4	Isolate 5	Isolate 6
Cultural characteristics	Pink, Small, round, opaque, elevated on MacConkey agar	Large Creamy, circular, elevated on nutrient agar	Whitish to creamy irregular colonies on Nutrient agar	Peach, circular, elevated on MacConkey agar	Pinkish, Circular, elevated colonies on MacConkey agar	Pink, Small, round, opaque, elevated on MacConkey agar
Morphological characteristics	Cocci	Cocci	Rod	Cocci	Short Rod	Rod
Cell arrangement	Single	Clusters	Single	Single	Single	Single
Gram reaction	+	+	+	+	-	+
Catalase	-	+	+	-	+	-
Coagulase	-	+	-	-	-	-
Oxidase	-	-	-	-	-	-
Indole	-	-	-	-	+	-
Vogues Proskaur	-	+	+	+	-	-
Glucose	+	+	+	+	+	+
Lactose	-	-	-	+	-	+
Probable bacteria	*Lactococcus acidophilus*	*Staphylococcus aureus*	*Bacillus cereus*	*Enterococcus Fecalis*	*Escherichia coli*	*Lactobacillus spp*

Key: +: positive -: Negative

Table 5.0. Cultural and morphological characteristic of fungi isolates gotten identified in bread making processes in different bakery in Lafia.

Cultural characteristics	Microscopy	Isolate
Whitish, flat and dry	Cells are circular and appear in pairs which is an indication of budding	*Saccharromyces* spp
Cottony appearance; white to yellow and then turning black.	Septate hyphae with the conidial heads smoothly defined are radiate with conidiogenous cells biseriate	*Aspergillus* spp.
Colonies produced are circular, white with yellow reverse, dry.	Hyphae are large and separated. The hyphae are pointed at the ends	*Fusarium* spp
Cover agar surface. They are white and fluffy that later turned grey. Reverse side is white.	Sparsely septate, broad hyphae, sporangiophores, sporangia and spores were visualized	*Mucor* spp.

Tables 5 and 6 indicate the microbial isolates and their distribution respectively. Gram-stained smears obtained by each bakery revealed substantial development of Gram-positive cocci, Gram-positive bacilli, some Gram-negative rods and some species of fungus, according to microscopic analysis. *Staphylococcus aureus, Lactococcus acidophilus, Bacillus cereus, Enterococcus fecalis, Escherichia coli, Lactobacillus spp.* and *Saccharomyces spp., Aspergillus spp., Fusaruim spp., and Mucor spp.* were among the bacterial isolates found. The isolates are generally found in various stages. *Staphylococcus aureus* is the most common bacteria in the mixing phase, followed by *Enterococcus fecalis* and *Escherichia coli*. The main microbe during the kneading stage is *Staphylococcus aureus*, whereas the fermenters with *Lactococcus acidophilus* and *Lactobacillus spp*. are prominent while the dough is rising. The majority of the fungal isolates coexisted with *Staphylococcus aureus* after being cooled and packed.

Table 6.0. Distribution of the isolates in different bread processes

Isolates	Mixing	Kneading	Dough rising	Cooling and Packaging
Staphylococcus aureus	++	+++	+++	+
Lactococcus acidophilus	-	-	++	-
Bacillus cereus	-	++	++	+
Enterococcus fecalis	++	++	+	-
Escherichia coli	++	+	++	+
Lactobacillus spp	-	++	+++	
Saccharromyces spp	-	+	+++	+
Aspergillus spp.	-	-	+	-
Fusarium spp	-	-	+	-
Mucor spp	-	-	-	+

Key: +: rarely present ++: moderately present +++: present in large numbers -: absent

Discussion

The microbiological content of the bread manufacturing stages revealed various degrees of microbial contamination, with some samples having an acceptable microbial load of $<10^4$ cfu/g but a total number of coliforms above the minimum safe range (< 100 coliforms/g). The Total Viable Count is a quality indicator, not a safety indicator and while it cannot directly contribute to a safety evaluation of ready-to-eat meals, it may be used as part of a general quality assessment, which includes foods with an extended shelf life [1]. The microbiological requirements are regulated differently in each nation. TVC in the range of 0-10^3 cfu/g, 10^4-10^5 cfu/g and > 10^6 cfu/g is considered acceptable, moderately acceptable (tolerable) and unsatisfactory, according to ICMSF, [25] and [26].

However, [12] and [27] are tougher in their microbial regulatory standards, stating that RTE meals with a TVC of more than 10^5 cfu/g are of unsatisfactory quality and hence unfit for ingestion. The bread production processes at the selected bakeries in Lafia Metropolis Nigeria were considered acceptable based on international microbiological criteria. The findings of this investigation were consistent with those of [16], who discovered 2.73 x 10^3 - 2.86 x 10^4 cfu/g in local bread, baked biscuits, and pastries with Parle-G biscuit without microorganisms in Dehradun, India and agreed with the findings of [5] in Tangail City, Bangladesh, microbial safety of locally manufactured bread and pastries was investigated. But differs with [8] in local and branded bakery items in Bangladesh that reported 12.8 x 10^7 to 37.8 x 10^7 for bread. This study agreed with the finding of [6]; [28].

The coliform families are indicator bacteria that reveal how closely sanitary requirements are followed during the production process. The presence of coliforms in food samples might signal the presence of additional enteric pathogenic bacteria in the samples, which could lead to a larger danger to public health [6]. Coliform bacteria were found to be prevalent at all stages of bread production in this investigation. The kneading and dough rising phases had the largest quantity of coliforms, with 7.2 x 10^4 cfu /g and 8.7 x 10^4 cfu/g respectively. For coliform bacteria, international microbiological standards [25] and [26] established a safe intake limit of 10^2-10^3 cfu/g for ready-to-eat meals. According to the aforementioned safety limit, the bread-making procedure was dangerous for coliform contamination.

Several prior investigations in Pakistan and Australia found E. coli bacteria in cake samples ranging from 10^2 to 10^5 cfu/g [6]. Reference [8] found mean coliform levels of 7.2 x 10^4 cfu/g and 8.7 x 10^4 cfu/g in local and branded bakery products in Bangladesh and were found to be consistent with the current investigation. The high coliform levels detected during the bread manufacturing phases points to inefficient and ineffective pre-bake and post-bake conditions and procedures, such as washing, mixing, packing, handling, and storing [29]. As a result, the reported greater microbiological contamination in bread production and packing can be confirmed by the poor processing hygiene and packaging conditions found after baking [30].

Local bakeries use manual or hand packing to package baked goods, putting them at high risk of microbial contamination from packaging employees' hands. Due to automated sealing and packaging processes, this risk is minimized with branded baked items [31]; [8]. According to Reference [3] over 60% of bread sellers do not wash their hands before packing bread, which is contrary to [13] who recommended hygiene practice. The unhealthy practice of cleaning bread with foam has never been described in the literature and is a major mechanism for bread contamination because it provides ample opportunity to handle the bread with hands that are rarely washed before handling the bread [3]; the hands used to clean the bread are the same ones used to handle the handle money between transactions [32]. This is further compounded by the unhygienic and hazardous food safety practices of blowing of air with mouth into the wrapping bag in an attempt to open it during cooling and packaging process of *Staphylococcus aureus* was identified in large amounts from several phases of bread processing in this investigation. Because of the manual method, *Staphylococcus aureus* is the most common bacteria in these bakeries. As a human flora, *Staphylococcus aureus* is introduced into bread by human participation. *S. aureus* can usually be destroyed by heating, but due to the possibility of human contact after baking, it is reintroduced. *S. aureus* can be found in the air, water, milk, and on food-contact surfaces. Enterotoxigenic staphylococci in baked items in India have traditionally been connected with cream and coconut filling, according to [33]. *S. aureus*, which generates the enterotoxins A, B, and E, has been discovered in five bakeries' cakes, sweet puffs, vegetative puffs, and cream rolls [10]. *S. xylosus*, *S. cohnii* and *S. aureus* were found to be absent in bread and rolls from the same bakery [10]. *Staphylococcus spp*. were also detected in bread made with wheat flour, according to [46]. *S. aureus*, which lives in humans, is a major cause of product contamination during preparation or thereafter [10]. High levels of *S. aureus* can also be found in ingredients [34].

During the mixing, kneading, and dough-rising processes, *Escherichia coli* and *Enterococcus feacalis* were identified, but not during the cooling or packing phases. The existence of these bacteria is owing to feces-contaminated water, while their absence during the cooling phase is related to the heat from the baking process. The presence of *Escherichia coli* in bread in this investigation is consistent with a survey conducted in New Zealand, which found *E. coli* in 1.6 percent of baked items filled with cream in quantities of more than 100 cfu/g and that carried out in India [10]. The discovery of *E. coli* in baked products suggests probable unhygienic circumstances and necessitates an inquiry of the preparation state, as human contact might spread the bacteria [35].

Gram-positive bacteria are more abundant in baked products than gram-negative bacteria, according to reference [10]. During the kneading and rising of the dough, *Bacillus cereus* was found. *Bacillus cereus* is a foodborne disease-causing gram-positive, rod-shaped, facultative anaerobic endospore-forming bacteria. They can be found in soil, plant roots, the air, and the water. *Bacillus cereus* has been related to food poisoning, particularly grain and cereal products that have been cooked and kept at warm temperatures [36]. Toxins produced by these *Bacillus* species can induce pneumonia, bactermia, and bronchopneumonia [37]. The environment has a role in the introduction of *B. cereus*. *Bacillus* species are spore-forming and may survive the heating process during baking, therefore *B. cereus* may be present during cooling and packing. This was in line with [10], who suggested that the prevalence of *Bacillus spp*. might be attributable to the frequent occurrence of endospores in wheat and flour-based products, as well as in the bakery environment. Resistant to heat, they survive baking and under optimal conditions, develop to levels linked with toxin production. The spores' ability to survive baking is determined by the type of product, the internal temperature attained during baking, and the spores' thermal resistance [38]. It was revealed that the baked products in the present investigation had a substantially reduced population of *Bacillus spp*. consequently they are safe for human consumption. According to [39], the amount of *Bacillus spp*. necessary to create poison is roughly 10^5 to 10^9 spores/g food, with lower quantities considered acceptable for human nutrition.

Lactococcus acidophilus and *Lactobacillus spp* are the most significant bacteria that occur naturally in fermented items. The high content of these organisms in foods make them and excellent choice for creating probiotics [40].

The most significant microbe that is purposely added into bread to make the flour dough rise is *Saccharomyces spp*. Yeast functions as one of the leavening agents in the fermentation process, which is necessary for bread manufacturing. Any leavening agent's job is to generate the gas that causes the bread to rise. Yeast does this by feeding on the sugar in flour and producing carbon dioxide as a result [41].

Aspergillus spp., *Fusaruim spp*. and *Mucor spp*. were among the fungi discovered in this investigation. All baked products have been linked to *Aspergillus spp*., implying that it may grow on any food independent of nutritional makeup, moisture level, or pH [10]. The presence of the mold genera *Aspergillus*, *Fusaruim* and *Mucor*, which were

isolated in this study, is identical to that previously identified by [10]; [42] and [43]. Water activity, which is regarded to be one of the most critical elements in microbial deterioration in baked items [10], might explain why bread has greater mold levels than other baked goods. Bread is a high-moisture product found in a variety of baked foods, allowing all bacteria, yeasts, and molds to thrive [11]; [44]; [45]. The increased microbial counts in the bread-making operations in the chosen bakeries were most likely due to the high microbial load in flour and/or the bakery environment, which might have contaminated the bread throughout the cooling time [46].

Reference [47]; [46]; [10] and [48] who identified *B. subtilis*, *B. megaterium*, and *Staphylococcus aureus* from bread, are all in agreement with our findings. *Bacillus* species including *B. subtilis*, *B. megaterium*, and *B. licheniformis* have been blamed for rope deterioration in bread loaves [49]; [50]. According to [49], *Bacillus spp*. and *S. aureus* are the predominant sources of contamination of baked products during post-preparation handling, which can result in serious food poisoning outbreaks due to enterotoxin generation by these bacteria.

V. CONCLUSION AND FUTURE SCOPE

To assure food safety for a specific public health concern, this study investigated the microbiological safety of the bread production process in several chosen bakeries in Lafia metropolitan, Nasarawa state, Nigeria. According to the findings, different microorganisms are present at various phases of bread production. However, with the exception of coliforms, the microbial counts for the bread-making process were within international norms / rules for food safety.

During the mixing, kneading and rising of the dough, *Staphylococcus aureus*, *Enterococcus fecalis*, *Escherichia coli*, *Lactococcus acidophilus* and *Lactobacillus spp* were more prevalent. Other bacteria, such as *E. Coli*, are a source of worry since they increase substantial health risks for consumers and can lead to food poisoning outbreaks.

It is therefore, recommended that: throughout the manufacturing and packing of bread, handlers must maintain stringent cleanliness; dough mixing, kneading, and rising should be done in sanitary settings; bread processors should wear suitable protective clothes to prevent human flora from getting into the bread and utensils and materials should be cleaned thoroughly. The government should also take proactive measures to monitor and address problems on a regular basis. Non-governmental organizations (NGOs) should also contribute by increasing public awareness.

This study is a step toward evaluating the microbiological safety of bread production processes in a few bakeries. More research is needed, however, to assure food safety and improve public health.

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