International Journal of Biotechnology and Microbiology
www.biotechnologyjournals.com
Online ISSN: 2664-7680, Print ISSN: 2664-7672
Received: 25-10-2025, Accepted: 24-11-2025, Published: 09-12-2025
Volume 7, Issue 4, 2025, Page No. 72-76

Microbial Quality of Bread Production Using *Cassava* Plants in Bauchi Metropolis, Bauchi State, Nigeria

Rabiu Ibrahim
Department of Science Laboratory Technology, School of Science and Technology, Abubakar Tatari Ali Polytechnic, Bauchi, Bauchi State, Nigeria

Abstract
This study investigated the microbial quality of *cassava* bread produced in selected communities of Bauchi Local Government Area, Bauchi State. The research aimed to identify and characterize the bacterial contaminants associated with *cassava* bread, considering its growing importance as a substitute for wheat bread in Nigeria. Laboratory analyses were carried out using cultural, morphological, and biochemical methods to determine the types and frequency of microbial isolates. The results revealed the presence of three bacterial species: *Staphylococcus aureus*, Escherichia coli, and Salmonella spp. Morphological and biochemical tests confirmed their identities, with S. aureus showing positive catalase and coagulase activity, E. coli being catalase and indole positive, and Salmonella spp. displaying distinct Gram-negative rod characteristics. Frequency analysis indicated that S. aureus was the most prevalent isolate (45.43%), followed by E. coli (36.86%), while Salmonella spp. was the least frequent (18.18%). The findings demonstrated that *cassava* bread sold in the study area is susceptible to microbial contamination due to poor hygiene during production, handling, and storage. The predominance of S. aureus suggests contamination from food handlers, while the presence of E. coli points to possible fecal contamination from water or the environment. Although less frequent, the detection of Salmonella spp. underscores the risk of foodborne illnesses associated with *cassava* bread consumption. It is concluded that *cassava* bread, despite its nutritional and economic benefits, poses potential public health risks if produced under unhygienic conditions. The study recommends strict adherence to hygiene by food handlers, regular monitoring by health authorities, use of treated water in production, and public awareness on food safety.

Keywords: Microbial quality, bread production, *Cassava*, bread

Introduction

Background to the Study

Bread, a staple food globally, is traditionally made from wheat flour, which forms a robust gluten network essential for its structure and texture. However, in regions like Bauchi Local Government Area (L-G-A) in Nigeria, reliance on imported wheat flour poses economic challenges, driving the need for alternative, locally sourced ingredients. *Cassava* (Manihot esculenta), a carbohydrate-rich root crop abundant in Nigeria, presents a viable substitute due to its availability, affordability, and adaptability to local agricultural systems. Despite its potential, *cassava*-based bread production faces significant hurdles, including the absence of gluten, which impacts dough elasticity, and the risk of microbial contamination, which affects safety and shelf life. Ensuring hygienic production and assessing microbial quality are critical to developing safe, acceptable, and sustainable *cassava*-based bread for communities in Bauchi LGA.

The microbial quality of bread is a pivotal concern in food safety, as contamination can occur at various stages of production, from raw material handling to post-baking processes. A comprehensive review by Vermelho *et al*. (2024) in Fermentation highlights the complexities of microbial preservation and contamination control in the baking industry, offering insights directly applicable to *cassava*-based bread production. The review emphasizes that while high baking temperatures (typically 180–200°C) eliminate most vegetative microorganisms in dough, post-baking contamination during cooling, slicing, packaging, or handling can introduce spoilage organisms such as molds (e.g. *Penicillium* spp., *Aspergillus* spp.), yeasts (e.g., *Saccharomyces cerevisiae*, *Rhodotorula mucilaginosa*), and bacteria (e.g., *Bacillus cereus*, *Staphylococcus aureus*). These findings underscore the importance of good manufacturing practices (GMPs) and environmental control in bakeries, particularly in resource-constrained settings like Bauchi L-G-A, where hygiene standards may vary.

Cassava flour, unlike wheat flour, introduces unique microbial challenges due to its processing methods (e.g., fermentation, sun-drying) and high moisture content, which can harbor microorganisms like Enterobacteriaceae, Lactobacillus spp., and fungi. Vermelho *et al*. (2024) note that raw ingredients, including flour and water, are primary sources of microbial contamination, with water activity (a_w) between 0.6 and 0.84 promoting mold growth. For *cassava*-based bread, controlling moisture content and ecological parameters such as temperature is crucial to extend shelf life and ensure safety. Additionally, the review discusses innovative biopreservation strategies, such as using lactic acid bacteria (LAB) like Lactiplantibacillus plantarum and Furfurilactobacillus rossiae, which exhibit antifungal properties, inhibiting fungal growth for up to 21 days. These biological methods align with consumer preferences for natural, chemical-free preservation, offering a promising approach for *cassava* bread production in Bauchi L-G-A.

Statement of the problem

Bread, a vital staple food for millions of Nigerians, is traditionally produced both industrially and locally using

wheat flour, which has become prohibitively expensive due to Nigeria's dependence on costly imports and fluctuating global prices, making it unaffordable for many average households, particularly in Bauchi Local Government Area (L-G-A). This economic challenge restricts daily access to bread, exacerbating food insecurity in the region. *Cassava* (Manihot esculenta), a locally abundant and cost-effective crop, presents a promising alternative to wheat flour, offering the potential to lower bread production costs and enhance food security.

Aims and Objectives of the study

Aims: This study focuses Microbial Quality of Bread Production Using *Cassava* Plant in Some Selected Communities of Bauchi LGA, Bauchi State

Objectives

The specific objectives were to:

1. To produce hygienic bread using locally sourced *cassava*
2. To determine the microbial quality of the bread to ensure safety, and
3. To assess ecological parameters (temperature and moisture content) influencing microbial growth and shelf life.

Literature Review

1. Overview of *Cassava* (Manihot esculenta) as a Staple Crop in Nigeria

Cassava (Manihot esculenta Crantz), a perennial, vegetatively propagated shrub, is a vital staple crop cultivated throughout the lowland tropics for its starchy, thickened roots, which serve as a primary source of carbohydrates. Known for its resilience to drought and poor soil conditions, *cassava* thrives in diverse agroecological zones, making it a cornerstone of food security in tropical regions, particularly in sub-Saharan Africa (SSA). According to FAOSTAT (2020), global *cassava* production reached approximately 278 million metric tons in 2018, with Africa contributing about 61% of this total. Over the past decade, world production has steadily increased from 240 million metric tons in 2010, driven by rising demand for both food and industrial uses (FAOSTAT, 2020). Nigeria, the world's largest *cassava* producer, accounted for 42.5 million metric tons in 2010 (18% of global output), with its share rising to 21.5% by 2018, underscoring its critical role in global supply chains. The Food and Agriculture Organization (FAO) projects that by 2025, SSA will contribute 62% of global *cassava* production, reflecting the crop's growing importance in the region.

In SSA, *cassava* is the second most important food staple in terms of per capita calorie consumption, trailing only maize, and provides a major source of energy for approximately 40% of the population (IFAD/FAO, 2005; Rosenthal & Ort, 2012) [16, 27]. Its versatility as a food crop—consumed as boiled roots, processed into products like gari, fufu, and flour—or used in industrial applications such as starch, ethanol, and animal feed, enhances its socioeconomic value. *Cassava*'s ability to grow in marginal soils with minimal inputs makes it a critical crop for smallholder farmers, who constitute the majority of producers in Nigeria and other SSA countries. In Nigeria, *cassava* is cultivated across diverse regions, including Bauchi Local Government Area (L-G-A), where it supports livelihoods and diets of rural communities.

2. Microbial Quality of *Cassava*

Cassava (Manihot esculenta Crantz) is a critical staple crop in sub-Saharan Africa, valued for its carbohydrate-rich roots, which are processed into flour for various food applications, including bread production. However, its high perishability, with a post-harvest shelf life of 24–48 hours, makes it susceptible to microbial spoilage, necessitating rapid and hygienic processing (Westby, 2002). In Nigeria, including Bauchi L-G-A, *cassava* is typically processed through peeling, grating, fermentation, and sun-drying, methods that can introduce microbial contaminants if not controlled. Studies reveal that *cassava* flour harbors a diverse microbial population, including Enterobacteriaceae (e.g., Escherichia coli, Salmonella spp.), lactic acid bacteria (LAB) such as Lactobacillus spp., and molds like *Aspergillus* spp. and *Penicillium* spp. (Adebayo-Oyetoro *et al*., 2013; Ogiehor & Ikenebomeh, 2005) [2, 25].

3. Bread Production

Bread production transforms raw ingredients into a structured, palatable product, traditionally relying on wheat flour for its gluten content, which forms a viscoelastic dough network. In Nigeria, where wheat is imported at high cost, *cassava* flour offers a cost-effective alternative, being 50–70% cheaper than wheat flour in local markets (Nweke, 2004) [23]. However, *cassava* flour's lack of gluten poses challenges, resulting in poor dough elasticity and bread structure, necessitating additives like hydrocolloids (xanthan gum, guar gum) or protein-rich flours (soybean, groundnut) to improve texture (Iwe *et al*., 2017; Ogunjobi *et al*., 2018) [17, 18, 26]. Vermelho *et al*. (2024) describe two primary bread production methods: straight dough and sourdough. Straight dough, dominant in industrial settings, uses commercial *Saccharomyces cerevisiae* yeast for rapid fermentation, involving mixing all ingredients, resting, modeling, proofing, and baking. This method is efficient but produces bread with a shorter shelf life and less complex flavor compared to sourdough (Chavan & Chavan, 2011) [8].

Research Methodology

1. Materials

1.1 Sterile Whirl-Pak Bags

- **Purpose:** To collect and store 100 g samples of *cassava* flour, dough, and bread (72 samples + spares).
- **Storage:** Sealed and kept at 4°C in a cooler box during transport.

1.2 Sterile Cotton Swabs

- **Purpose:** To collect environmental samples from mixing surfaces, hands, and utensils (45 swabs + spares).
- **Storage:** Placed in tubes with buffered peptone water, sealed, and stored at 4°C.

1.3 Sterile Bottles

- **Purpose:** To collect 250 mL water samples for coliform testing (3 samples + spares).
- **Storage:** Sealed and kept at 4°C in a cooler box.

1.4 Sterile Spoons/Scoops
- **Purpose:** To aseptically collect flour, dough, and bread samples.
- **Storage:** Sterilized before use, stored in sealed sterile bags.

1.5 Cooler Box with Ice Packs
- **Purpose:** To maintain samples at 4°C during transport to the laboratory (within 4 hours).
- **Storage:** Ice packs refreshed before each sampling session.

1.6 Labels and Permanent Markers
- **Purpose:** To label samples with date, time, batch number, and sample type.
- **Storage:** Kept in a dry, clean container during fieldwork.

1.7 Steril Gloves **
- **Purpose:** To ensure aseptic handling during sample collection.
- **Storage:** Stored in sealed packages to maintain sterility.

1.8 Hand Sanitizer
- **Purpose:** To maintain hand hygiene during sample collection.
- **Storage:** Kept in a portable bottle for field use.

Results

The results obtained from the analysis on microbial quality of bread production using *cassava* plants (*Manihot esculentus)* were as follows:

1. Stages of Bread Production

Bread production involves sequential stages, each with microbial and quality implications, particularly when using *cassava* flour, which introduces unique challenges due to its microbial load and lack of gluten. Vermelho *et al*. (2024) and supporting literature detail these stages as follows:

2. Mixing

Ingredients, including flour, water, yeast, salt, and additives, are combined to form dough. For *cassava* flour, hydrocolloids or emulsifiers (e.g., diacetyl tartaric acid esters of monoglycerides) are added to mimic gluten's functionality (Iwe *et al*., 2017) [17, 18]. Microbial contamination can occur from flour (Enterobacteriaceae, Bacillus spp.), water (Pseudomonas spp.), or unsanitized equipment. Studies show that potable water quality varies, with Italian samples revealing microbial differences impacting dough microbiota (Minervini *et al*., 2019) [19, 20]. In Bauchi, reliance on untreated water sources increases contamination risks (Muhammad & Ibrahim, 2023) [22].

3. Resting

Dough rests to allow hydration and relaxation, facilitating starch gelatinization in *cassava* dough, as it lacks gluten. Contamination from air or equipment can introduce molds (*Penicillium* spp.) or bacteria (*Staphylococcus aureus*), especially in unhygienic settings (Santos *et al*., 2016). Bauchi's warm climate accelerates microbial growth during this stage if not controlled. Modeling: Dough is shaped into loaves, exposing it to environmental microbes via handling or surfaces.

4. Proofing

Fermentation occurs, driven by S. cerevisiae in straight dough or LAB and wild yeasts in sourdough, producing CO_2 for dough expansion. *Cassava* dough's high moisture content (40–50%) can promote undesirable microbes like Enterobacteriaceae if fermentation is uncontrolled (Ogiehor & Ikenebomeh, 2005) [25]. Controlled proofing at 30–35°C and 70–80% relative humidity optimizes fermentation while minimizing spoilage risks (Chavan & Chavan, 2011) [8].

5. Baking

Dough is baked at 180–220°C, killing most vegetative microbes, including E. coli and S. aureus. However, spore-forming *Bacillus cereus* and mold spores (*Aspergillus* spp.) survive, posing spoilage risks (Vermelho *et al*., 2024; Thompson *et al*., 1998). *Cassava* bread's denser structure may retain more moisture post-baking, increasing susceptibility to mold growth (Iwe *et al*., 2017) [17, 18].

6. Cooling, Slicing, and Packaging

Post-baking stages are critical contamination points. Cooling exposes bread to air-borne fungi (*Penicillium* paneum), while slicing and packaging introduce microbes from equipment or handlers (Garcia *et al*., 2019) [15]. In Bauchi's humid climate (a_w 0.6–0.84), molds proliferate rapidly without proper packaging (Dagnas *et al*., 2017) [11]. Studies in Brazil and Nigeria show that post-baking contamination from air and handling significantly increases microbial loads, necessitating GMPs like glove use and sanitized surfaces (Santos *et al*., 2016; Muhammad & Ibrahim, 2023) [22]. For *cassava*-based bread in Bauchi, each stage requires stringent hygiene to mitigate microbial risks from flour and environmental factors.

7. Microorganisms Associated with Baked Products

Baked products, including *cassava*-based bread, host a diverse microbial community influenced by raw materials, processing, and environmental factors. Vermelho *et al*. (2024) identify key microorganisms in bread production:

8. Bacteria

Bacillus cereus, a spore-forming bacterium, survives baking and causes rope spoilage, characterized by a fruity odor and sticky texture (Thompson *et al*., 1998). Enterobacteriaceae (E. coli, Salmonella spp.) and *Staphylococcus aureus* contaminate bread post-baking due to poor handling or environmental exposure, as observed in Nigerian and Bangladeshi bakeries (Das *et al*., 2020; Muhammad & Ibrahim, 2023) [12, 22]. LAB, such as Lactiplantibacillus plantarum, dominate sourdough, contributing to fermentation and biopreservation by producing antifungal compounds (Axel *et al*., 2016) [6].

9. Yeasts

Saccharomyces cerevisiae is the primary fermenting yeast in straight dough, while wild yeasts (Kazachstania, Pichia) occur in sourdough, enhancing flavor (Van Kerrebroeck *et al*., 2017). Spoilage yeasts like Saccharomycopsis fibuligera cause chalky defects in bread (Cremonesi *et al*., 2022) [10].

10. Molds

Penicillium spp. (P. paneum, P. polonicum) and *Aspergillus* spp. are major spoilage fungi, thriving in post-baking stages due to high a_w (0.6–0.84) and warm temperatures (Dagnas *et al*., 2017) [11]. These molds produce mycotoxins, compromising safety (Trombete *et al*., 2014). Studies in Brazil show cross-contamination from flour to bread via air in cooling and packaging areas (Garcia *et al*., 2019) [15].

Table 1: Cultural and Morphological Characteristics of Bacteria Isolates from *Cassava* Bread

Cultural Appearance	Morphological appearance	Shape	Organism Identified
Circular, golden-yellow, convex, smooth, shining, opaque colony	+	Cocci in clusters	*Staphylococcus aureus*
White, glistering, flat, large, smooth, opaque, moist growth	–	Short rods	*Escherichia coli*
Colorless, convex, smooth colony	–	Rods	*Salmonella* spp.

Key: + present and - Absent

Interpretation: The results revealed the presence of three distinct bacterial organisms in *cassava* bread samples: *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella* spp. Morphological and staining reactions were key indicators for preliminary identification. The detection of both Gram-positive and Gram-negative bacteria indicates possible contamination at different processing stages.

Table 2: Biochemical Characteristics of the Bacterial Isolates

Catalase	Coagulase	Citrate	Indole	Organism Identified
+	+	–	–	*Staphylococcus aureus*
+	–	–	+	*Escherichia coli*
+	–	+	–	*Staphylococcus* spp.

Interpretation

The biochemical tests validated the identities of the bacterial isolates. *S. aureus* was positive for catalase and coagulase, confirming its pathogenic capability. *E. coli* tested positive for catalase and indole but negative for citrate, which is typical of this species. Meanwhile, *Staphylococcus* spp. was positive for catalase and citrate but negative for coagulase, indicating the presence of multiple Staphylococcus species in *cassava* bread.

Table 3: Microbial and Percentage Occurrence of Bacterial Isolates

Bacterial Isolates	Number of Occurrence	Percentage Occurrence (%)
Staphylococcus aureus	5	45.43
Escherichia coli	4	36.86
Salmonella spp.	2	18.18
Total	11	100

Interpretation

The frequency analysis showed that *Staphylococcus aureus* was the most dominant isolate (45.43%), followed by *E. coli* (36.86%). *Salmonella* spp. had the least occurrence (18.18%). The high frequency of *S. aureus* suggests poor hygiene and possible contamination from food handlers, while the presence of *E. coli* and *Salmonella* spp. points to unsafe handling, contaminated raw materials, or unhygienic storage conditions.

Conclusion

The study concluded that *cassava* bread, though an innovative and affordable substitute for wheat bread, is highly susceptible to microbial contamination if hygienic standards are not strictly observed during its preparation, handling, and storage. The presence of *Staphylococcus aureus* as the most frequently isolated microorganism reflects poor handling practices, as this bacterium is commonly spread through direct human contact. Its pathogenic nature, particularly its capacity to produce toxins, makes its dominance in *cassava* bread a serious health concern.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. **Strict enforcement of hygiene among food handlers:** Producers and sellers of *cassava* bread must be trained and compelled to adhere to strict personal hygiene practices such as regular hand washing, wearing clean protective clothing, and avoiding direct contact with bread during packaging.

2. **Improved sanitation during processing and storage:** Production facilities should be equipped with clean working surfaces, sanitized equipment, and safe storage conditions to minimize contamination. This will help prevent both *S. aureus* and *E. coli* from entering *cassava* bread at different stages of processing.

3. **Regular monitoring by health authorities:** Regulatory bodies such as the National Agency for Food and Drug Administration and Control (NAFDAC) and local health units should carry out routine inspections and microbial testing of *cassava* bread to ensure compliance with food safety standards.

4. **Use of treated water in production:** Since *E. coli* contamination is often linked to water, *cassava* bread producers should be encouraged or mandated to use only clean, treated water in mixing, processing, and cleaning activities. This will significantly reduce the chances of fecal contamination.

5. **Public awareness campaigns:** Consumers need to be educated about the potential risks of consuming contaminated *cassava* bread and encouraged to purchase bread only from trusted, hygienic sources. Awareness campaigns can also stress the importance of safe food handling at home.

References

1. Adams MR, Moss MO, McClure P. Food Microbiology. Royal Society of Chemistry, 2016.
2. Adebayo-Oyetoro AO, *et al*. Microbiological and sensory evaluation of bread produced from composite *cassava*–wheat flour. Journal of Food Science and Technology,2013:50(2):347–352.
3. Akinrele IA. Fermentation studies on *cassava*. Journal of the Science of Food and Agriculture,2006:21(12):619–622.

4. Ali MA, Hashish MH, Fekry MM. Microbiological quality of some packed and unpacked bread products in Alexandria, Egypt. Journal of the Egyptian Public Health Association,2023:98:16.
5. APHA. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, 2017.
6. Axel C, Brosnan B, Zannini E, Furey A, Coffey A, Arendt EK. Antifungal sourdough lactic acid bacteria as biopreservation tool in quinoa and rice bread. International Journal of Food Microbiology,2016:239:86–94.
7. Bao Z, Fan M, Hannachi K, Li T, Zhao J, Li Y, *et al*. Antifungal activity of star anise extract against *Penicillium roqueforti* and *Aspergillus niger* for bread shelf life. Food Research International,2023:172:113225.
8. Chavan RS, Chavan SR. Sourdough technology—A traditional way for wholesome foods: A review. Comprehensive Reviews in Food Science and Food Safety,2011:10(3):169–182.
9. Chilundo M, *et al*. Microbial contamination and food safety aspects of *cassava* roasted flour in Mozambique. Food Control, 2024. PMC11767957.
10. Cremonesi P, Garofalo C, Picozzi C, Castiglioni B, Mangieri N, Milanović V, *et al*. Development of quantitative real-time PCR and digital droplet-PCR assays for rapid and early detection of the spoilage yeasts *Saccharomycopsis fibuligera* and *Wickerhamomyces anomalus* in bread. Food Microbiology,2022:101:103894.
11. Dagnas S, *et al*. Quantifying the effect of water activity and storage temperature on single spore lag times of three moulds. International Journal of Food Microbiology,2017:240:75–84.
12. Das KK, Sarkar A, Hossain A. Isolation of pathogenic microorganisms and determination of their antibiotic resistance patterns collected from different bakery products of Dhaka city. Food Research, 2020, 4.
13. Debonne E, Van Bockstaele F, Samapundo S, Eeckhout M, Devlieghere F. The use of essential oils as natural antifungal preservatives in bread products. Journal of Essential Oil Research,2018:30(5):309–318.
14. FAO/WHO. Codex Alimentarius General Principles of Food Hygiene. Food and Agriculture Organization/World Health Organization, 2003.
15. Garcia MV, Bernardi AO, Parussolo G, Stefanello A, Lemos JG, Copetti MV. Spoilage fungi in a bread factory in Brazil diversity and incidence through the bread-making process. Food Research International,2019:126:108593.
16. IFAD/FAO. A review of *cassava* in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin. International Fund for Agricultural Development and Food and Agriculture Organization, 2005.
17. Iwe MO, *et al*. Nutritional enhancement of *cassava* flour-based bread using protein concentrates. Journal of Food Science and Technology,2017:54(9):2764–2772.
18. Iwe MO, Okereke GO, Agiriga AN. Enhancement of nutritional quality of *cassava* flour-based bread using protein concentrates. Journal of Food Science and Technology,2017:54(9):2764–2772.
19. Minervini F, Dinardo FR, De Angelis M, Gobbetti M. Tap water is one of the drivers that establish and assemble the lactic acid bacterium biota during sourdough preparation. Scientific Reports,2019:9:570.
20. Minervini F, *et al*. Lactic acid bacteria and water quality in bakery production. Journal of Food Science, 2019, 56.
21. Montagnac JA, Davis CR, Tanumihardjo SA. Nutritional value of *cassava* for use as a staple food and recent advances for improvement. Comprehensive Reviews in Food Science and Food Safety,2009:8(3):181–194.
22. Muhammad SM, Ibrahim SG. Determination of microbiological quality of bread and sanitation conditions of local bakeries in Aliero Town, Kebbi State. Applied Science and Technology Research Journal,2023:1:1–9.
23. Nweke FI. New challenges in the *cassava* transformation in Nigeria and Ghana. Environment and Production Technology Division Discussion Paper 118, International Food Policy Research Institute, 2004.
24. Obadina AO, Oyewole OB, Odusami AO. Microbiological safety and quality of *cassava*-based traditional foods in Nigeria. Journal of Food Safety,2009:29(3):423–436.
25. Ogiehor IS, Ikenebomeh MJ. Microbial quality of *cassava* flour and its products in Nigeria. African Journal of Biotechnology,2005:4(9):981–986.
26. Ogunjobi MA, Ogunwole OA, Adebayo AO. Quality evaluation of bread produced from *cassava* flour enriched with soybean flour. Journal of Food Processing and Preservation,2018:42(3):13521.
27. Rosenthal DM, Ort DR. Examining *cassava*'s potential to enhance food security under climate change. Tropical Plant Biology,2012:5(1):30–38.
28. Starek-Wójcicka A, Różyło R, Niedźwiedz I, Kwiatkowski M, Terebun P, Polak-Berecka M, Pawlat J. Pilot study on the use of cold atmospheric plasma for preservation of bread. Scientific Reports,2022:12:22003.