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# Microbial Contamination of Street-Vended Soybean Cake (Awara) And Antimicrobial Activity of Onion and Cabbage Extracts Against Isolated Microorganisms in Zuru, Nigeria

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***Abstract*—Glycine max cake (Awara) is a nutritious, street-vended food in Nigeria, but its safety is often compromised by poor hygiene. This study evaluated the microbial contamination of Awara sold in Zuru Town and the efficacy of Allium cepa (onion) and Brassica oleracea (cabbage) extracts as natural antimicrobials. A total of 150 samples were collected from 30 vendors across Zuru North, Central and South. Microbial analysis involved serial dilution, pour plate culture and biochemical identification. The agar well diffusion method was used to assess the antimicrobial activity of aqueous onion and cabbage extracts against isolated pathogens. High bacterial loads were recorded, with total viable counts ranging from $9.63 \times 10^4$ to $1.18 \times 10^7$ CFU/g. Isolated bacteria included Staphylococcus aureus, Escherichia coli, Shigella spp., Salmonella spp., and Pseudomonas spp. Fungal isolates comprised Aspergillus niger, A. flavus, Penicillium spp., Rhizopus spp. and Candida spp. Onion extract exhibited significantly stronger ($p < 0.05$) antibacterial (15.50–22.00 mm inhibition zones) and antifungal (12.00–18.50 mm) activity compared to cabbage extract. The findings indicate that hawked Awara in Zuru poses significant microbial risks. However, the potent antimicrobial activity of onion extract highlights its potential as a natural, affordable preservative to enhance the safety of street-vended foods.**

***Index Terms*—Allium cepa, Brassica oleracea, Awara, Food Safety, Microbial Contamination, Natural Preservatives.**

# I. INTRODUCTION

Street-vended foods are a vital source of affordable nutrition in urban and peri-urban Nigeria (Israel & Samuel, 2020). Among these, Glycine max cake, locally known as Awara or Tofu, is a popular, protein-rich snack. However, the informal nature of its production and vending, often under unhygienic conditions, raises serious public health concerns (Makinde et al., 2020). The high moisture and nutrient content of Awara create a favourable environment for the growth of pathogenic microorganisms, leading to food spoilage and foodborne illnesses (Sivakumar et al., 2021). Studies have consistently isolated bacteria such as Escherichia coli, Staphylococcus aureus and Salmonella spp. as well as toxigenic fungi like Aspergillus flavus from street foods, linking them to outbreaks of gastroenteritis and mycotoxicoses (Dominguez-Gonzalez et al., 2022; Ezekiel et al., 2020). The rising challenge of antimicrobial resistance and consumer demand for clean label products have intensified the search for natural preservatives (WHO, 2020). Plants like Allium cepa (onion) and Brassica oleracea (cabbage) are rich in bioactive compounds with documented antimicrobial properties (Tanyitiku, 2022; Favela-González et al., 2020). Their application in food safety presents a sustainable, culturally acceptable and affordable strategy for small-scale vendors. While the nutritional value of Awara is recognized data on its microbial safety in specific locales like Zuru Town in Kebbi State is scarce.The potential of locally available vegetables as biocontrol agents for contaminants in this specific food matrix is underexplored. Therefore, this study aimed to evaluate the bacterial and fungal contamination of Glycine max cake (Awara) hawked in Zuru Town and assess the in vitro antimicrobial efficacy of Allium cepa and Brassica oleracea extracts against the isolated microorganisms.

# II. MATERIALS AND METHODS

## 2.1. Study Area and Sample Collection

The study was conducted in Zuru Town, Kebbi State, Nigeria, located at coordinates 11°26'6" N, 5°14'6" E (Grace et al., 2023). Using a cross-sectional design, a total of 150 Awara samples were collected randomly from 30 active street vendors across three geographical zones (Zuru North, Central and South) over one month. Samples were aseptically collected into sterile containers and transported immediately to the laboratory for analysis.

## 2.2. Microbial Analysis

2.2.1. Bacterial and fungal enumeration: One gram of each sample was homogenized in 9 mL of sterile distilled water to create a $10^{-1}$ dilution. Further serial dilutions up to $10^{-5}$ were prepared. For bacterial count, 1 mL of appropriate dilutions was inoculated using the pour plate method on Nutrient Agar (NA) and incubated at 37°C for 24-48 hours. For fungal count, Sabouraud Dextrose Agar (SDA) plates were inoculated and incubated at 25°C for 7 days (Terrones-Fernandez et al., 2023). Colony forming units per gram (CFU/g) were calculated.

2.2.2. Identification of isolates: Distinct bacterial colonies were sub-cultured for purity. Identification was based on Gram staining, colony morphology and biochemical tests (catalase, coagulase, oxidase, urease and methyl red) following standard microbiological procedures .Fungal isolates were identified based on macroscopic (colony texture, colour) and microscopic characteristics (hyphal and spore structures) using lactophenol cotton blue mounts (Ezekiel et al., 2020).

2.3. Preparation of Plant Extracts

Fresh bulbs of Allium cepa and leaves of Brassica oleracea were purchased locally, washed and chopped. Fifty grams of each were blended with 100 mL of sterile distilled water. The slurry was filtered first through sterile muslin cloth and then through Whatman No. 1 filter paper. The resulting aqueous extracts were stored at 4°C for antimicrobial assays (Barbu et al., 2023).

2.4. Antimicrobial Susceptibility Testing

The agar well diffusion method was employed (Balouiri et al., 2016). 100 µL of standardized microbial suspension (0.5 McFarland standard) was spread on NA (for bacteria) or SDA (for fungi). Wells (8 mm diameter) were punched into the agar and filled with 100 µL of each plant extract. Negative control (sterile distilled water) and positive controls (Ciprofloxacin 10 µg/mL for bacteria, Ketoconazole 10 µg/mL for fungi) were included. Plates were incubated (bacteria at 37°C for 24h; fungi at 25°C for 72h). The diameter of the zones of inhibition (ZOI) was measured in millimetres.

2.5. Data Analysis

Data on colony counts and inhibition zones were analyzed using SPSS version 20.0. Descriptive statistics (mean ± standard deviation) were used. The significance of differences in antimicrobial activity was determined using one-way ANOVA, followed by Duncan's Multiple Range Test (DMRT) at a 95% confidence interval ($p < 0.05$).

## III. RESULTS

3.1. Microbial Load and Identification

The bacterial contamination of Awara samples varied significantly across Zuru Metropolis, with Zuru South exhibiting the highest levels, ranging from $9.33 \times 10^4$ to $1.65 \times 10^7$ CFU/g and a peak in sample ZS4 ($1.65 \times 10^7$ CFU/g). Zuru Central and North showed moderate to high contamination (ranges: $4.20 \times 10^4$–$9.60 \times 10^6$ CFU/g and $9.63 \times 10^4$–$8.60 \times 10^6$ CFU/g respectively).

| Location | Sample Code | Total Viable Count Range (CFU/g) | Mean Count (CFU/g) |
|---|---|---|---|
| Zuru North | ZN1 | $9.63 \times 10^4 – 3.90 \times 10^6$ | $1.66 \times 10^6$ |
| | ZN2 | $1.47 \times 10^5 – 4.37 \times 10^6$ | $1.94 \times 10^6$ |
| | ZN3 | TFTC (Too Few To Count) | TFTC |

| | | | |
|---|---|---|---|
| | ZN4 | $7.60 \times 10^4 – 8.60 \times 10^6$ | $3.12 \times 10^6$ |
| | ZN5 | $4.37 \times 10^4 – 6.13 \times 10^6$ | $2.12 \times 10^6$ |
| Zuru Central | ZC1 | $1.74 \times 10^5 – 9.60 \times 10^6$ | $3.51 \times 10^6$ |
| | ZC2 | $8.57 \times 10^4 – 8.57 \times 10^6$ | $2.91 \times 10^6$ |
| | ZC3 | TFTC (Too Few To Count) | TFTC |
| | ZC4 | $4.60 \times 10^4 – 6.00 \times 10^6$ | $2.15 \times 10^6$ |
| | ZC5 | $4.20 \times 10^4 – 5.20 \times 10^6$ | $1.91 \times 10^6$ |
| Zuru South | ZS1 | $2.13 \times 10^5 – 1.18 \times 10^7$ | $4.59 \times 10^6$ |
| | ZS2 | $1.12 \times 10^5 – 6.30 \times 10^6$ | $2.46 \times 10^6$ |
| | ZS3 | $9.33 \times 10^4 – 7.00 \times 10^6$ | $2.62 \times 10^6$ |
| | ZS4 | $2.11 \times 10^5 – 1.65 \times 10^7$ | $6.28 \times 10^6$ |
| | ZS5 | $1.50 \times 10^5 – 9.57 \times 10^6$ | $3.74 \times 10^6$ |

Note. ZN = Zuru North, ZC = Zuru Central, ZS = Zuru South, TVC = total viable count; CFU/g = colony forming units per gram. Calculated means are approximate based on provided CFU/g values across dilutions. TFTC = Too Few To Count ($<3.00 \times 10^4$ CFU/g).

Five key bacterial pathogens were identified: Staphylococcus aureus, Escherichia coli, Shigella spp., Salmonella spp. and Pseudomonas spp. (Table 2). Fungal contamination was prevalent across all zones, with Aspergillus niger and A. flavus being the most frequently isolated. Other fungi included Rhizopusspp., Penicillium spp. and Candida spp.

Table 2: Morphological and Biochemical Characteristics of Bacterial Isolates

| SN | M C | GR | Ca | Ur | Ox | Co | MR | Micro |
|---|---|---|---|---|---|---|---|---|
| 1. | Golden yellow colonies with entire edge | + Cocci | + | - | + | + | + | Staphylococcus aureus |
| 2. | Pale color colonies | - Rod | - | - | + | - | - | Shigella |
| 3. | Smooth pink colonies that ferment lactose | - Rod | + | + | + | - | - | Escherichia coli |
| 4. | Large grey white mucord colonies | - Rod | + | + | - | - | - | Salmonella |
| 5. | Greenish medium colonies with odor | - Rod | - | + | + | + | - | Pseudomonas |

Key words; Morphological Characteristic (M C), Gram Reaction (GR), Catalase (Ca), Urease (Ur) Oxidase (Ox),Coagulase (Co), Methly Red (MR) and Microorganism (Micro)

3.2. Antimicrobial Activity of Plant Extracts

Both plant extracts showed concentration dependent antimicrobial activity. However, onion (Allium cepa) extract consistently produced significantly larger ($p < 0.05$) zones of inhibition compared to cabbage (Brassica oleracea) extract against all tested bacterial and fungal isolates (Tables 3 and 4).Onion extract was most effective against Shigella spp. (22.00 mm ZOI) and least against Pseudomonas spp. (15.50-16.50 mm). Cabbage extract showed moderate activity,

with ZOIs between 9.00 and 15.00 mm (table 3) and onion extract also demonstrated superior antifungal activity, particularly against Aspergillus flavus (18.50 mm ZOI). Cabbage extract showed weaker but significant inhibition against all fungal isolates (table 4).

Table 3: Antifungal Activity (Zone of Inhibition in mm) of Plant Extracts against Bacterial Isolates

| Bacterial Isolates | Location | Onion (mm) | Cabbage (mm) | PC (Cpr10 µg/mL) | N C (D W) |
|---|---|---|---|---|---|
| S. aureus | ZN | 18.50 ± 0.58 | 13.00 ± 0.58 | 27.00 ± 0.58 | 0 |
| | ZC | 17.50 ± 0.58 | 12.50 ± 0.58 | 27.50 ± 0.58 | 0 |
| | ZS | 19.50 ± 0.58 | 14.00 ± 0.58 | 27.00 ± 0.58 | 0 |
| E. coli | ZN | 17.00 ± 0.58 | 12.00 ± 0.58 | 27.00 ± 0.58 | 0 |
| | ZC | 16.00 ± 0.58 | 11.00 ± 0.58 | 27.50 ± 0.58 | 0 |
| | ZS | 17.50 ± 0.58 | 12.50 ± 0.58 | 27.00 ± 0.58 | 0 |
| Shigella spp. | ZN | 21.00 ± 0.58 | 14.00 ± 0.58 | 27.00 ± 0.58 | 0 |
| | ZC | 20.00 ± 0.58 | 13.00 ± 0.58 | 27.50 ± 0.58 | 0 |
| | ZS | 22.00 ± 0.58 | 15.00 ± 0.58 | 27.00 ± 0.58 | 0 |
| Pseudomonas spp. | ZN | 16.50 ± 0.58 | 11.00 ± 0.58 | 27.00 ± 0.58 | 0 |
| | ZC | 15.50 ± 0.58 | 10.00 ± 0.58 | 27.50 ± 0.58 | 0 |
| | ZS | 16.00 ± 0.58 | 11.50 ± 0.58 | 27.00 ± 0.58 | 0 |

Positive control – Ciprofloxacin (10 µg/mL); Negative control – Sterile distilled water. Values represent mean ± standard deviation (n = 3).Values are mean ± SD (n=3). Means in the same row with different superscripts are significantly different ($p < 0.05$).

Table 4: Antifungal Activity (Zone of Inhibition in mm) of Plant Extracts against Fungal Isolates

| Fungal Isolates | Location | Onion Ex (mm) | Cabbage Ex (mm) | PC(Ktz 10 µg/mL) | NC (DW) |
|---|---|---|---|---|---|
| A. niger | Z N | 13.00 ± 0.58 | 9.50 ± 0.58 | 23.00 ± 0.58 | 0 |
| | Z C | 12.00 ± 0.58 | 9.00 ± 0.58 | 23.00 ± 0.58 | 0 |
| | Z S | 14.00 ± 0.58 | 10.00 ± 0.58 | 23.00 ± 0.58 | 0 |
| A. flavus | Z N | 18.00 ± 0.58 | 12.00 ± 0.58 | 23.00 ± 0.58 | 0 |
| | Z C | 17.00 ± 0.58 | 11.00 ± 0.58 | 23.00 ± 0.58 | 0 |
| | Z S | 18.50 ± 0.58 | 12.50 ± 0.58 | 23.00 ± 0.58 | 0 |
| Penicillium spp. | Z N | 13.00 ± 0.58 | 9.00 ± 0.58 | 23.00 ± 0.58 | 0 |
| | ZC | 12.50 ± 0.58 | 8.50 ± 0.58 | 23.00 ± 0.58 | 0 |
| | Z S | 13.50 ± 0.58 | 9.00 ± 0.58 | 23.00 ± 0.58 | 0 |

Positive control – Ciprofloxacin (10 µg/mL); Negative control – Sterile distilled water. Values represent mean ± standard deviation (n = 3).Values are mean ± SD (n=3). Means in the same row with different superscripts are significantly different ($p < 0.05$).

## IV. DISCUSSION

The high microbial loads and diversity of pathogens isolated from Awara in this study confirm the significant food safety risk associated with street-vended foods in Zuru Town. Bacterial counts exceeding $10^5$ CFU/g, as recorded particularly in Zuru South, are above acceptable limits for ready to eat foods and indicate poor hygiene during processing, handling or vending (ICMSF, 2011; Adebayo-Tayo and Adegoke, 2008). The isolation of E. coli (a faecal indicator) and Salmonella spp. points to contamination from water, unclean utensils or handlers. The presence of S. aureus suggests contamination from human skin or nasal passages, often due to poor personal hygiene (Olayemi et al., 2021). The prevalence of Aspergillus flavus and A. niger is of particular concern due to their potential to produce aflatoxins and ochratoxins, which are hepatotoxic and carcinogenic (Ezekiel et al., 2020). Their presence indicates exposure to airborne spores and possibly inadequate drying or prolonged unsafe storage of the product.

The potent antimicrobial activity of onion extract aligns with previous studies attributing its efficacy to organosulfur compounds like allicin and flavonoids such as quercetin, which disrupt microbial cell membranes and inhibit essential enzymes (Tanyitiku, 2022; Benítez et al., 2021). The stronger activity against Shigella spp. and S. aureus compared to Pseudomonas spp. may be due to the inherent resistance mechanisms in Gram-negative bacteria, such as their outer membrane permeability barrier (Fernández et al., 2018). Nonetheless, the significant inhibition observed suggests that onion extract can still overcome these defences at the tested concentrations. The moderate activity of cabbage extract can be linked to glucosinolates and their breakdown products, such as isothiocyanates, which possess antimicrobial properties (Favela-González et al., 2020). The superior performance of onion extract over cabbage highlights the variability in bioactive compound composition and potency among different plant species.

## V. CONCLUSION

This study reveals that Glycine max cake (Awara) hawked in Zuru Town is heavily contaminated with pathogenic bacteria and fungi posing a substantial risk to consumer health. This underscores an urgent need for improved hygiene education and regulatory oversight for street food vendors. However, the findings also offer a promising low-cost intervention: aqueous extracts of onion, a readily available vegetable, demonstrated potent in vitro antimicrobial activity against the major contaminants. Therefore, integrating such natural extracts as surface treatments or wash solutions during Awara processing could significantly enhance its microbial safety and shelf life. Future

research should focus on formulating practical, consumer acceptable applications of these extracts for use in informal food vending settings.

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