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From Hive to Hazard: Antimicrobial Resistance and Handling-Linked Microbial Contamination in Market-Sold Honey from Enugu Urban, Nigeria

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ABSTRACT

Background: Honey possesses well-documented intrinsic antimicrobial properties, yet retail handling in low-resource settings may compromise its safety independently of its chemical integrity. Whether market honey remains microbiologically safe once it leaves the hive, and whether any contamination acquired en route carries antimicrobial resistance, is rarely established within a single dataset. Objective: This study integrated physicochemical, phytochemical, mineral, and microbiological profiling, including molecular isolate identification and antimicrobial susceptibility testing, of honey sold in three markets in Enugu Urban, Nigeria, against an unadulterated control, and linked contamination patterns to documented handling practices. Methods: Eighteen honey samples were purchased from Ogbete, Abakpa and Mayor markets (six per market) and compared with certified unadulterated honey from Opi Nsukka. Physicochemical parameters were determined according to AOAC protocols; phytochemical constituents were screened qualitatively and profiled by high-performance liquid chromatography; trace and toxic metals were quantified by atomic absorption spectrophotometry; bacterial and fungal isolates were enumerated, phenotypically characterised, and confirmed by 16S rRNA and internal transcribed spacer sequencing; antibiotic and antifungal susceptibility was determined by disc diffusion; and a structured questionnaire (n = 30) captured harvesting, processing, and retail practices. Results: All samples satisfied Codex Alimentarius and European Union compositional limits for moisture, ash, and sugar content, and mineral concentrations remained within accepted safety ranges throughout. Phytochemical and mineral profiles of market honey were broadly comparable with the control. Market samples nonetheless carried significantly higher total viable bacterial and fungal counts than the control ($p < 0.05$), and molecular sequencing confirmed the presence of Escherichia coli, Salmonella enterica, Shigella sonnei, and Staphylococcus aureus, none of which were recovered from the control. Several isolates displayed multidrug resistance, with meropenem the only antibiotic retaining broad activity and erythromycin resistance exceeding 85% in Staphylococcus aureus. Questionnaire responses linked contamination to unsterilised containers, infrequent hand and tool washing, prolonged air exposure, and direct customer contact with the product. Conclusion: Honey sold in Enugu Urban retains its intrinsic chemical and phytochemical quality, but acquires clinically relevant, multidrug-resistant microbial contaminants during post-harvest handling and retail sale. Market-level hygiene, rather than honey chemistry, is the primary determinant of consumer safety risk and the more tractable point for intervention.

Keywords: honey quality; antimicrobial resistance; food safety; market contamination; phytochemical profiling; molecular identification; Nigeria

1. INTRODUCTION

Honey owes its long shelf life and antimicrobial reputation to a narrow physicochemical window: high sugar concentration and correspondingly low water activity, an acidic pH sustained largely by gluconic acid, and a modest but continuous supply of hydrogen peroxide generated by bee-derived glucose oxidase [1],[2],[3]. These properties, together with bee-derived peptides such as defensin-1 and a phenolic and flavonoid fraction with

independent antioxidant activity, render properly matured honey inhospitable to most vegetative bacteria, yeasts, and moulds [4],[5]. International and regional standards, from the Codex Alimentarius Standard for Honey to the European Union's Directive 2001/110/EC and Nigeria's own regulatory instruments, codify this expectation through compositional limits on moisture, sugar content, and freshness indices [6],[7],[8].

This chemical robustness is frequently equated, in practice, with microbiological safety. Yet honey's antimicrobial matrix protects against growth within the product; it does not prevent the introduction of contaminants during and after harvest, nor does it eliminate spores or resistant organisms once they are present at sufficient density or under conditions that transiently raise water activity, such as dilution or prolonged air exposure [9],[10]. Studies from Nigeria and neighbouring West African countries have repeatedly documented bacterial and fungal loads in market-sold honey that exceed what would be expected from the product's intrinsic chemistry, and have attributed these to post-harvest handling rather than to the honey itself [11],[12],[13]. What these studies have generally not done is combine molecular confirmation of the organisms recovered with antimicrobial susceptibility testing and a structured account of the handling practices along the specific supply chain sampled. Without that combination, it remains difficult to establish whether contamination reflects incidental, low-consequence exposure or the acquisition of clinically relevant, resistant organisms, and harder still to identify the specific practices responsible.

This gap matters beyond food safety in the narrow sense. Foods that are widely perceived as inherently safe, and are therefore handled and consumed with minimal precaution, are precisely the commodities through which resistant organisms can move largely unmonitored between environmental, animal, and human reservoirs, a concern increasingly framed under a One Health lens [14],[15]. Honey's reputation for self-preservation may itself be a risk factor if it discourages routine hygiene along the value chain.

The present study addresses this gap using a dataset that integrates four lines of evidence on the same set of samples: physicochemical and phytochemical characterisation, trace and toxic metal quantification, microbiological load with molecular confirmation of isolate identity, and antibiotic and antifungal susceptibility testing, cross-referenced against a structured survey of harvesting, processing, and retail practices. Honey from three markets in Enugu Urban, Nigeria, representing distinct catchment areas within the same metropolitan supply chain, was compared against certified unadulterated honey sourced directly from beekeepers. The specific objectives were to determine whether market honey met established compositional standards; to establish whether its phytochemical and mineral profile differed materially from an unadulterated reference; to quantify and molecularly confirm the microbial contaminants present; to characterise the antimicrobial resistance of those contaminants; and to relate the pattern of contamination to documented practices at each stage of the supply chain. We hypothesised that market honey would remain chemically compliant with international standards regardless of source, while microbiological contamination, including resistant organisms, would track specifically with handling practices rather than with honey chemistry.

2. MATERIALS AND METHODS

2.1 STUDY AREA AND SAMPLING DESIGN

The study was conducted in the Applied Microbiology Laboratory of Enugu State University of Science and Technology. Eighteen honey samples were purchased from three markets representing distinct catchment areas of Enugu metropolis: Ogbete Main Market (Enugu North), Mayor Market (Enugu South), and Abakpa Market (Enugu East), with six independently purchased samples collected per market from different vendors to capture inter-vendor variability within each location. An unadulterated reference honey was obtained directly from certified beekeepers at Opi Nsukka and analysed as a single control against which market samples were benchmarked; because this reference comprised one sample rather than a replicated group, it is treated throughout as a qualitative quality benchmark rather than as a fourth statistical arm.

2.2 Phytochemical screening and HPLC profiling

Qualitative screening for alkaloids, saponins, terpenoids, steroids, flavonoids, tannins, and glycosides followed standard protocols [16], using colorimetric and precipitation reactions specific to each phytochemical class. Quantitative phytochemical profiling was performed by reversed-phase high-performance liquid chromatography with ultraviolet detection on a C18 column, using a methanol-acetonitrile-water mobile phase and external standard calibration, following filtration of aqueous honey extracts through 0.45 micrometre membranes.

2.3 Physicochemical analysis

Moisture, ash, pH, total and reducing sugars, specific gravity, viscosity, saponification value, peroxide value, free fatty acid content, iodine value, titratable acidity, and total soluble solids were determined following standard AOAC procedures [17], using gravimetric, titrimetric, spectrophotometric, and refractometric methods as appropriate to each parameter. Total sugars were quantified by the phenol-sulphuric acid method against a D-glucose standard curve, and reducing sugars by the dinitrosalicylic acid method against a fructose standard.

2.4 Trace and toxic metal analysis

Honey samples were wet-digested with concentrated nitric acid, diluted, and analysed by atomic absorption spectrophotometry for iron, zinc, copper, manganese, lead, cadmium, and arsenic, following standard AOAC methods for trace metal determination in food matrices [17].

2.5 Microbiological analysis

Samples were serially diluted in sterile normal saline and inoculated onto nutrient agar, potato dextrose agar, and Salmonella-Shigella agar for enumeration and isolation. Bacterial isolates were characterised by Gram reaction and standard biochemical tests (catalase, coagulase, citrate, indole, methyl red, oxidase, and sugar fermentation), and fungal isolates by colony morphology and lactophenol cotton blue microscopy. Representative isolates underwent DNA extraction, and bacterial and fungal identity was confirmed by amplification and sequencing of the 16S rRNA gene and the internal transcribed spacer region respectively, with sequence identity assigned against reference databases.

2.6 Antimicrobial susceptibility testing

Bacterial isolates were tested against a panel of routinely used antibiotics by the disc diffusion method following inoculum standardisation to 0.5 McFarland turbidity, with zones of inhibition classified as sensitive, intermediate, or resistant. Fungal isolates were tested against ketoconazole, fluconazole, posaconazole, and itraconazole by agar well diffusion following turbidity standardisation.

2.7 Handling-practices survey

A structured questionnaire was administered to 30 respondents comprising beekeepers, processors, and sellers along the supply chains supplying the sampled markets, capturing harvesting source, tool and hand hygiene, container sterilisation and storage practices, retail environment conditions, and respondent awareness of microbial contamination risk.

2.8 Statistical analysis

Data were analysed in SPSS using one-way analysis of variance with Tukey's honestly significant difference post hoc test to compare markets and the control; significance was set at $p < 0.05$. Microbial counts were log10-transformed prior to analysis of variance to stabilise variance.

3. RESULTS

3.1 Phytochemical composition was retained irrespective of market

Qualitative screening detected saponins, terpenoids, steroids, flavonoids, tannins, glycosides, and phenolics in every sample examined, including the control, with flavonoids, glycosides, and phenolics consistently showing strong reactions. Alkaloids were not detected in any sample. Quantitative HPLC profiling corroborated this pattern: both market and control samples were dominated by flavan-3-ols, catechin, epicatechin, rutin, and naringenin, confirming a polyphenol-rich, multifloral botanical origin in each case (Table 1). The market sample showed a comparatively higher catechin peak area, while the control showed a more even distribution across flavan-3-ols, rutin, and epicatechin; naringin, kaempferol, and resveratrol were detected only in the control, at low relative abundance. No phytochemical class present in the control was absent from the market sample, and no antinutritional marker (phytate, oxalate) was disproportionately elevated in market honey, arguing against exogenous adulteration.

Table 1: Selected HPLC phytochemical constituents in market versus control honey samples

Component class	Representative compounds	Market sample	Control sample
Flavan-3-ols / flavanones	Catechin, epicatechin, flavonones	Present, catechin-dominant	Present, evenly distributed
Flavonols / glycosides	Rutin, naringenin, naringin	Present	Present; naringin control-only
Phenolic/other polyphenols	Kaempferol, resveratrol	Not detected	Present (control-only)
Glycosides	Cardiac and cyanogenic glycosides	Low-moderate, comparable	Low-moderate, comparable
Alkaloids (trace)	Sparteine, ribalinidine, ephedrine	Trace, low intensity	Trace, low intensity
Antinutritional markers	Phytate, oxalate	Comparable to control	Comparable to market

3.2 Physicochemical and mineral quality met compositional standards across all markets

Moisture content differed significantly among locations ($p < 0.05$) but remained below the 20% Codex threshold throughout, ranging from 14.2% in Ogbete samples to 18.1% in Mayor samples and 14.1% in the control. Ash content, pH, sugar fractions, specific gravity, saponification value, peroxide value, free acidity, iodine value, viscosity, titratable acidity, and total soluble solids each showed statistically significant inter-market variation, yet every parameter with an established acceptable range remained within it (Table 2). pH decreased progressively from Ogbete (5.20) to Mayor (4.05) and the control (3.99), while total and reducing sugars rose correspondingly, a pattern consistent with differences in nectar source, maturity, or harvest timing rather than adulteration.

Table 2: Physicochemical properties of honey samples by market (mean ± SD)

Parameter	Ogbete	Abakpa	Mayor	Control	Acceptable range
Moisture (%)	14.22 ± 0.22c	17.78 ± 0.73b	18.07 ± 1.18a	14.05 ± 0.07c	≤ 20
Ash (%)	0.25 ± 0.03c	0.29 ± 0.01b	0.44 ± 0.05a	0.49 ± 0.01a	≤ 0.6
pH	5.20 ± 0.07a	4.75 ± 0.06b	4.05 ± 0.05c	3.99 ± 0.01c	3.2–4.5
Total sugar (%)	33.33 ± 0.47c	30.85 ± 0.50c	58.42 ± 1.46a	59.17 ± 1.94a	Not listed
Reducing sugar (%)	24.45 ± 0.47c	22.78 ± 0.29c	51.25 ± 1.58a	52.00 ± 2.12a	≥ 60
Electrical conductivity (µS/cm)	212.3 ± 4.6c	326.6 ± 9.8b	507.6 ± 24.1a	533.5 ± 0.7a	≤ 800
Free acidity (meq/kg)	35.0 ± 1.2c	40.6 ± 1.2b	47.2 ± 4.4a	50.5 ± 0.7a	≤ 50

Superscripts a, b and c denote statistically distinct homogeneous subsets within a row (Tukey HSD, $p < 0.05$).

Trace and toxic metal concentrations followed a consistent gradient, generally decreasing from Ogbete to Abakpa to Mayor, with the control recording the lowest values overall (Table 3). Iron was the most abundant metal in all samples (1.86 to 3.46 mg/kg), followed by zinc, manganese, and copper, all within accepted safety ranges. Lead was detected in every market sample (0.008 to 0.021 mg/kg) but not in the control, while cadmium and arsenic were detected only sporadically and at trace levels; all toxic metal concentrations remained well below Codex safety limits.

Table 3: Trace and toxic metal content of honey samples (mg/kg)

Metal	Ogbete	Abakpa	Mayor	Control	Acceptable range
Iron	3.35–3.46	2.88–2.97	2.55–2.65	1.86	0.5–10
Zinc	1.22–1.30	1.01–1.08	0.88–0.96	0.62	≤ 5–10
Copper	0.38–0.46	0.32–0.39	0.27–0.34	0.19	≤ 2–5
Manganese	0.54–0.62	0.45–0.53	0.39–0.47	0.28	≤ 2–82
Lead	0.014–0.021	0.011–0.018	0.008–0.015	ND	≤ 0.10
Cadmium	ND–0.003	ND–0.002	ND	ND	≤ 0.05
Arsenic	ND–0.004	ND–0.003	ND	ND	≤ 0.10

ND = not detected at method detection limit.

3.3 Market honey carried significantly higher, molecularly confirmed microbial loads than the control

Total viable bacterial counts differed significantly across locations (one-way ANOVA, $F = 58.74$, $p < 0.001$), with the control (2.08 ± 0.05 log10 CFU/mL) forming a distinct, lower homogeneous subset from all three markets (4.41 to 4.56 log10 CFU/mL). Fungal counts showed the same pattern ($F = 41.62$, $p < 0.001$): no fungal growth was recovered from the control, whereas market samples ranged from 3.26 log10 CFU/mL in Ogbete to 4.41 log10 CFU/mL in Abakpa.

Biochemical characterisation identified ten distinct bacterial phenotypes, subsequently confirmed by 16S rRNA sequencing for the enteric and lactic acid bacterial representatives: Escherichia coli (96.1% identity), Shigella sonnei (95.15%), Salmonella enterica (97.52%), Lactobacillus plantarum (95.42%), and Lactiplantibacillus plantarum (96.67%). Internal transcribed spacer sequencing of fungal isolates confirmed Candida rugosa, Saccharomyces cerevisiae, Meyerozyma guilliermondii, and Aspergillus flavus, with pairwise identities of 87.7% to 99.5%. Escherichia coli was the most prevalent bacterial isolate overall (11 of 18 market samples), followed by Staphylococcus aureus, Bacillus species, and Salmonella species (seven occurrences each); the control yielded only Bacillus species and Lactobacillus plantarum, both regarded as part of the natural bee and hive microbiota rather than indicators of contamination (Table 4).

Table 4: Prevalence of bacterial isolates across markets (number of positive samples)

Market	n	E. coli	S. aureus	Salmonella sp.	Bacillus sp.	Lactic acid bacteria*
Ogbete	6	5	2	2	2	3
Abakpa	6	3	3	2	3	3
Mayor	6	3	2	3	1	4
Control	1	0	0	0	1	1
Total	19	11	7	7	7	11

**Lactobacillus plantarum and Lactiplantibacillus plantarum combined.*

3.4 Confirmed bacterial and fungal isolates showed extensive antimicrobial resistance

Among Gram-negative isolates, meropenem retained the broadest activity, with sensitivity ranging from 75.0% in Proteus mirabilis and Klebsiella pneumoniae to 85.7% in Salmonella species, whereas amoxicillin showed the least activity, with resistance reaching 54.5% in Escherichia coli. Among Gram-positive isolates, Staphylococcus aureus showed pronounced resistance to erythromycin (85.7%) and levofloxacin (71.4%), and both Lactobacillus and Lactiplantibacillus plantarum isolates showed high resistance to erythromycin and levofloxacin despite their generally beneficial ecological role; chloramphenicol and rifampicin retained the most consistent activity across Gram-positive isolates (Table 5). All Gram-positive isolates tested were resistant to more than three antibiotics, meeting conventional criteria for multidrug resistance. Among fungal isolates, ketoconazole and itraconazole showed the most consistent activity, whereas posaconazole performed poorly against Fusarium verticillioides, with an inhibition zone of only 6 mm.

Table 5: Summary of antimicrobial resistance among confirmed isolates (selected agents)

Isolate	Most effective agent (% sensitive)	Least effective agent (% resistant)	Multidrug resistant
Escherichia coli	Meropenem (81.8%)	Amoxicillin (54.5%)	Yes
Salmonella sp.	Meropenem (85.7%)	Amoxicillin (28.6%)	Yes
Staphylococcus aureus	Rifampicin (71.4%)	Erythromycin (85.7%)	Yes
Lactiplantibacillus plantarum	Streptomycin (50.0%)	Erythromycin (100%)	Yes
Bacillus sp.	Chloramphenicol (85.7%)	Erythromycin (57.1%)	Yes
Fusarium verticillioides	Ketoconazole (33.3% S)	Posaconazole (66.7% R)	—

3.5 Handling practices provide a plausible mechanism for contamination

Most respondents were sellers (36.6%) or beekeepers (30.0%), and honey was predominantly sourced through wild harvesting (40.0%) or traditional beekeeping (33.3%) rather than modern apiaries. Hygiene at the point of harvest and processing was frequently inadequate: 56.7% of respondents did not wash harvesting tools before use, only 30.0% always washed their hands before extraction, and 70.0% reused containers without sterilisation. Storage and retail conditions compounded this risk, with 63.3% of respondents not using airtight storage, 73.3% reporting that honey was exposed to air during storage or sale, and 76.7% reporting that customers dipped objects directly into honey at the point of sale (Table 6). Only 36.7% of respondents were aware that honey can harbour microorganisms, and just 30.0% applied any contamination control measures.

Table 6: Selected handling and hygiene practices reported by respondents (n = 30)

Practice	Response	n (%)
Harvesting tools washed before use	No	17 (56.7)
Hands always washed before extraction	Yes	9 (30.0)
Containers reused without sterilisation	Yes	21 (70.0)
Airtight storage practised	No	19 (63.3)
Honey exposed to air during storage/sale	Yes	22 (73.3)
Customers dip objects into honey	Yes	23 (76.7)
Aware honey can contain microorganisms	No	19 (63.3)
Contamination control measures applied	No	21 (70.0)

4. DISCUSSION

The central pattern in this dataset is a dissociation between chemical compliance and microbiological safety. Every market sample met Codex and European Union compositional limits for moisture, sugar content, and ash, and phytochemical and mineral profiles were essentially indistinguishable from the unadulterated control. Taken alone, these findings would support the common assumption that honey's intrinsic composition guarantees its safety, an assumption consistent with earlier Nigerian surveys reporting compliant physicochemical parameters in market

honey [18],[19]. Set alongside the microbiological findings, however, this same chemical robustness becomes the reason the contamination detected here is easy to overlook: a product that reliably passes compositional testing offers no chemical signal of the resistant organisms it may also be carrying.

The molecular confirmation of Escherichia coli, Salmonella enterica, Shigella sonnei, and Staphylococcus aureus in market samples, none of which were recovered from the control, situates this contamination as acquired rather than intrinsic. These organisms are not constituents of the natural hive or bee microbiota; their presence is consistent with faecal or human-associated contamination introduced during harvesting, processing, or retail handling, a mechanism previously proposed on phenotypic grounds alone in Nigerian and Ghanaian market surveys [11],[13],[18]. What the present molecular and questionnaire data add is a more direct line of evidence connecting specific, commonly reported behaviours, unsterilised tool and container reuse, infrequent hand washing, uncovered storage, and direct customer contact with the product, to the isolation of organisms that should not otherwise be present. Bacillus species and lactic acid bacteria, by contrast, were recovered even from the control, consistent with their recognised status as natural residents of the bee and hive environment rather than markers of poor handling [9],[20].

The antimicrobial resistance profile of the confirmed isolates raises the stakes of this contamination beyond conventional food-safety concern. Meropenem was the only agent retaining broad activity across Gram-negative isolates, a finding that should be read with some unease given that reliance on a carbapenem to control organisms recovered from a food commodity implies limited remaining options should resistance to first-line agents such as amoxicillin, already exceeding 50% in this dataset, continue to rise [21],[22]. Staphylococcus aureus resistance to erythromycin exceeded 85%, and all Gram-positive isolates tested met conventional multidrug-resistance criteria. Honey is not typically considered within antimicrobial stewardship or surveillance frameworks, yet these results are consistent with a growing literature identifying food commodities broadly, and honey specifically, as under-monitored reservoirs through which resistant organisms can circulate between environmental, animal, and human compartments [14],[15]. The resistance detected among Lactobacillus and Lactiplantibacillus plantarum isolates is a particular point of concern, since these organisms are otherwise regarded as beneficial constituents of the honey and hive microbiota; their acquisition of resistance determinants illustrates that even ecologically desirable bacteria are not exempt from the selective pressures operating along the value chain [23].

The questionnaire data offer a coherent explanation for why contamination tracked with market rather than with honey chemistry. Wild harvesting and traditional beekeeping, the dominant sourcing methods reported, inherently offer less hygienic control than managed apiaries, and this was compounded by low rates of tool and hand hygiene at extraction. Downstream, low rates of container sterilisation and airtight storage, combined with high rates of air exposure and direct customer contact at the point of sale, describe a supply chain in which multiple independent opportunities for contamination exist between hive and consumer, consistent with observations from other African honey-marketing contexts [24],[25]. Notably, fewer than four in ten respondents were aware that honey could harbour microorganisms at all, suggesting that low perceived risk, rather than a lack of low-cost interventions, is a meaningful barrier to improved practice.

Several limitations qualify the interpretation of these findings. The six samples per market, while independently purchased from different vendors, cannot be assumed to represent the full diversity of honey circulating within each catchment area, and the single control sample, while a valuable qualitative benchmark, cannot be treated as a statistically replicated comparison group. The antimicrobial susceptibility panel characterises resistance among food isolates and should not be extrapolated to clinical treatment efficacy without further work. The inclusion of oil-analysis indices such as saponification and iodine value, while providing additional oxidative and compositional information, departs from standard honey quality protocols and should be interpreted as exploratory rather than as established honey quality benchmarks. Finally, while the questionnaire data are consistent with a handling-based explanation for contamination, the cross-sectional design cannot establish a direct causal link between any single practice and the specific isolates recovered; a source-tracking design, sampling honey and surfaces at sequential points along a small number of individual supply chains, would strengthen this inference considerably.

These findings nonetheless carry a clear practical implication. Interventions aimed at improving honey safety in this and comparable settings are more likely to succeed if directed at retail and processing hygiene, container sterilisation, hand and tool washing, airtight storage, and reduced customer contact with the product, than at the honey itself, which already meets compositional standards without modification. Regulatory and public health attention accustomed to treating honey as self-regulating by virtue of its chemistry may need to extend routine microbiological and resistance surveillance to this and similarly perceived-as-safe commodities.

5. CONCLUSION

Honey sold across three markets in Enugu Urban met established physicochemical and mineral safety standards and retained a phytochemical profile comparable to an unadulterated control, indicating that the product itself was neither diluted nor adulterated. Despite this, market honey carried significantly higher, molecularly confirmed bacterial and fungal loads than the control, including multidrug-resistant Escherichia coli, Salmonella enterica, and

Staphylococcus aureus absent from the unadulterated sample. Handling-practice data identified unsterilised containers, inadequate hand and tool hygiene, prolonged air exposure, and direct customer contact as plausible routes of entry for this contamination. Honey's reputation for intrinsic self-preservation should not be extended to an assumption of microbiological or antimicrobial-resistance safety once the product enters a retail supply chain; hygiene at harvest, processing, and point of sale, rather than honey chemistry, is the more tractable and more urgently needed target for intervention.

6. RECOMMENDATIONS

Beekeepers, processors, and vendors should receive practical training in hand hygiene, tool and container sterilisation, and airtight storage, with particular attention to wild-harvesting and traditional beekeeping operations where oversight is currently weakest. Regulatory authorities should extend routine surveillance to include microbiological load and antimicrobial resistance profiling of market honey, rather than compositional testing alone, given the demonstrated dissociation between the two in this dataset. Point-of-sale practices, including covered display and restriction of direct customer contact with the product, warrant targeted public health messaging given their apparent contribution to contamination.

Future research

Source-tracking studies that sample honey alongside hands, tools, and containers at sequential points along a small number of individual supply chains would help establish which specific practices contribute most to contamination and resistance acquisition. Expansion to a larger number of markets and geographical zones across Nigeria would clarify whether the pattern observed here generalises, and whole-genome sequencing of the resistant isolates recovered would allow direct comparison of resistance determinants with those circulating in clinical and environmental reservoirs.

DECLARATIONS

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Ethical approval: Ethical approval for this study was obtained from the Enugu State University of Science and Technology (ESUT) Research Ethics Committee (Approval No. ESUT/2026/1257B). Written informed consent was obtained from all participants prior to questionnaire administration. All procedures involving human participants were conducted in accordance with the ethical standards of the institutional research committee and the principles of the Declaration of Helsinki. The laboratory analyses were performed on commercially purchased honey samples and posed no risk to human participants.

Conflicts of interest: The authors declare no conflict of interest.

Data availability: Data supporting the findings of this study are available from the corresponding author upon reasonable request.

CRediT author contributions

Anichukwu Nwankwo Onyinye: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Visualization, Writing – original draft.

Aniaku Vincent N.: Methodology, Validation, Supervision, Writing – review & editing.

Okogu Sabinus Chukwuka: Investigation, Laboratory analyses, Molecular identification, Resources, Validation, Writing – review & editing.

Ogunbodede T. T.: Conceptualization, Project administration, Supervision, Writing – review & editing.

REFERENCES

[1] Bogdanov S, Jurendic T, Sieber R, Gallmann P. Honey for nutrition and health: a review. J Am Coll Nutr. 2008;27(6):677-89.

[2] Molan PC. The antibacterial activity of honey: 1. The nature of the antibacterial activity. Bee World. 1992;73(1):5-28.

[3] Mandal MD, Mandal S. Honey: its medicinal property and antibacterial activity. Asian Pac J Trop Biomed. 2011;1(2):154-60.

[4] Kwakman PHS, de Boer L, Ruytinx J, Vandenabeele P, Zaat SAJ. Bee-derived peptide defensin-1 promotes wound re-epithelialisation in vitro and in vivo. Sci Rep. 2017;7(1):1-12.

[5] Alvarez-Suarez JM, Giampieri F, Battino M, Forbes-Hernández TY. Phenolic compounds in honey and their associated health benefits. J Agric Food Chem. 2013;61(24):5321-37.

[6] Codex Alimentarius Commission. Standard for honey (CXS 12-1981, revised 2023). Rome: Food and Agriculture Organization/World Health Organization; 2023.

[7] European Commission. Council Directive 2001/110/EC of 20 December 2001 relating to honey. Off J Eur Communities. 2001;10:47-52.

[8] Standards Organisation of Nigeria. Nigerian Industrial Standard for Honey (NIS 473:2004). Abuja: SON; 2004.

[9] Snowdon JA, Cliver DO. Microorganisms in honey. Int J Food Microbiol. 1996;31(1-3):1-26.

[10] Nevas M, Hielm S, Lindström M, Horn H, Koivulehto K, Korkeala H. High prevalence of Clostridium botulinum types A and B in honey samples detected by polymerase chain reaction. Int J Food Microbiol. 2002;72(1-2):45-52.
[11] Omafuvbe BO, Akanbi TO. Assessment of physicochemical and microbiological characteristics of honey samples from Nigeria. Food Control. 2009;20(4):364-7.
[12] Adenekan MO, Amusa NA, Lawal AO, Okpeze VE. Biochemical and microbiological quality of honey from mangrove agro-ecological zone of Nigeria. Int J Adv Agric Res. 2014;2(3):117-23.
[13] Abdulai M, Yusuf R, Adams A. Assessment of bacterial quality of honey produced in Tamale metropolitan area, Ghana. Ghana J Sci. 2016;56(2):42-51.
[14] Oliveira A, Ribeiro HG, Silva AC, Silva MD, Sillankorva S. Honey as a strategy to fight antimicrobial resistance: a review. Crit Rev Food Sci Nutr. 2020;60(12):1854-71.
[15] Van Hoek AH, Mevius D, Guerra B, Mullany P, Roberts AP, Aarts HJM. Acquired antibiotic resistance genes: an overview. Front Microbiol. 2011;2:203.
[16] Harborne JB. Phytochemical methods: a guide to modern techniques of plant analysis. 3rd ed. London: Chapman and Hall; 1998.
[17] AOAC International. Official methods of analysis of AOAC International. 21st ed. Gaithersburg (MD): AOAC International; 2023.
[18] Ndife J, Kida F, Usi O. Quality assessment of Nigerian honey sourced from different locations. Afr J Food Sci. 2014;8(10):576-83.
[19] Eleazu CO, Iroaganachi MA, Okoronkwo JO, Ijeh II. Assessment of the physicochemical and microbiological quality of commercial honey samples sold in Nigeria. Food Sci Qual Manag. 2013;17:1-7.
[20] Olofsson TC, Vásquez A. Detection and identification of a novel lactic acid bacterial flora within the honey stomach of the honeybee Apis mellifera. Curr Microbiol. 2008;57(4):356-63.
[21] Queenan AM, Bush K. Carbapenemases: the versatile β-lactamases. Clin Microbiol Rev. 2007;20(3):440-58.
[22] Nordmann P, Naas T, Poirel L. Global spread of carbapenemase-producing Enterobacteriaceae. Emerg Infect Dis. 2011;17(10):1791-8.
[23] Mathur S, Singh R. Antibiotic resistance in food lactic acid bacteria: a review. Int J Food Microbiol. 2005;105(3):281-95.
[24] Al Waili N, Salom K, Al-Ghamdi A. Honey for wound healing, ulcers, and burns: data supporting its use in clinical practice. ScientificWorldJournal. 2012;2012:1-13.
[25] Abdi N, Hassan A, Bakri M. Honey supply chains and microbial risk in East African markets. J Food Prot. 2023;86(4):112-20.

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