Greener Journal of Biological Sciences
Vol. 16(1), pp. 5-12, 2026
ISSN: 2276-7762

https://gjournals.org/GJBS
DOI: https://doi.org/10.15580/gjbs.2026.1.050526062

Isolation and Characterization of Lactic Acid Bacteria Associated With Fermentation of Sauerkraut Production

***Obasi, Blessing Chidi; Ochojila, Anthony Oche**

Department of Microbiology, Federal University Wukari, PMB 1020, Taraba State, Nigeria.

ABSTRACT

Lactic acid bacteria (LAB) are a diverse group of Gram-positive, non-sporulating, microaerophilic bacteria that play a central role in the fermentation of foods. This study investigated the isolation and characterization of lactic acid bacteria associated with sauerkraut fermentation. Fresh cabbage samples were fermented under controlled conditions, and microbial analyses were conducted throughout the fermentation period. Results showed a progressive increase in lactic acid bacteria counts from 1.0×10^4 CFU/ml at the initial stage to 2.0×10^6 CFU/ml by day 14, indicating the typical dominance of LAB during fermentation. Concurrently, total bacterial and coliform counts declined rapidly, demonstrating the inhibitory effects of acid production and reduced pH on non-acid-tolerant microorganisms. Three major LAB species were identified based on morphological, cultural, and biochemical characteristics; *Lactobacillus plantarum, Pediococcus pentosus*, and *Aerococcus viridans*. All isolates exhibited acid tolerance, confirming their ability to survive and proliferate under acidic fermentation conditions. Antibiotic susceptibility testing revealed varying resistance patterns among the isolates, with general sensitivity to chloramphenicol and amoxicillin but resistance to several other antibiotics, consistent with intrinsic resistance traits commonly reported in LAB. The findings confirm that lactic acid bacteria play a central role in sauerkraut fermentation by producing organic acids that lower pH, inhibit spoilage and pathogenic microorganisms, and enhance product safety. The study also highlighted the potential importance of locally isolated LAB strains in developing starter cultures for controlled fermentation. From this study, it can be concluded that LAB dominate sauerkraut fermentation through acid production, microbial inhibition and adaptation to acidic conditions, thereby contributing to product safety, preservation and quality.

ARTICLE'S INFO

Article No.: *050526062*
Type**:** *Research*
Full Text: *PDF, PHP, HTML, EPUB, MP3*
DOI: *10.15580/gjbs.2026.1.050526062*

Accepted: *06/05/2026*
Published: *14/05/2026*

Keywords: *Lactic acid bacteria (LAB), microbial inhibition, sauerkraut fermentation, Antibiotic susceptibility, acid tolerance*

****Corresponding Author***

Obasi Blessing Chidi

E-mail: *obasibc@fuwukari.edu.ng*

Article's QR code

INTRODUCTION

Fermentation is one of the oldest food preservation techniques known to humanity and has been widely applied to enhance food safety, nutritional quality, flavor, and shelf life (Niyigaba *et al.,* 2025). Among fermented vegetable products, sauerkraut a fermented cabbage product remains one of the most extensively studied due to its simple production process and rich microbial ecology (Liu *et al*., 2023). The fermentation of sauerkraut occurs naturally through the metabolic activities of lactic acid bacteria (LAB) present on raw cabbage leaves, without the need for starter cultures. This natural fermentation process promotes the growth of beneficial microorganisms while suppressing spoilage and pathogenic organisms (Wang *et al.,* 2024).

Sauerkraut is traditionally produced by shredding fresh cabbage and fermenting it with a low concentration of salt, usually between 2–3% (Gaudioso *et al.,* 2022). This method has been practiced for centuries, particularly in Europe and North Eastern China, where it served as a major dietary component during periods when fresh vegetables were scarce. Proper fermentation preserves the nutritional quality of cabbage while improving its sensory attributes such as flavor, texture, and aroma (Kalam and Ahmad, 2020; Gaudioso *et al.,* 2022). The acidic environment created during fermentation ensures product stability and extends shelf life (Wang *et al.,* 2024).

The fermentation process is driven primarily by lactic acid bacteria, which dominate the microbial population under favorable conditions (Kalam and Ahmad, 2020). Although the microbial composition may vary during the early stages of fermentation, factors such as salt concentration, temperature, and anaerobic conditions favor the growth of LAB as the dominant microorganisms (Tlais *et al.,* 2022). Species such as *Leuconostoc*, *Lactobacillus*, and *Pediococcus* play key roles in the fermentation process. Initially, heterofermentative species such as *Leuconostoc* initiate acid production, followed by homofermentative species such as *Lactobacillus plantarum*, which further lower the pH and stabilize the product (Kalam and Ahmad, 2020; Fevria and Hartanto, 2020).

Sauerkraut is widely recognized as a functional food due to its high probiotic content and health-promoting properties (Fijan *et al.,* 2024). The fermentation process also increases the bioavailability of nutrients, making sauerkraut nutritionally superior to raw cabbage. Its simple composition primarily cabbage and salt make it an affordable and accessible source of beneficial microorganisms (Gaudioso *et al.,* 2022).

Lactic acid bacteria are responsible for the production of several bioactive compounds, including organic acids, bacteriocins, vitamins, and flavor compounds (Abdul-Hakim *et al.,* 2023; Wang *et al.,* 2024). These metabolites contribute significantly to the sensory qualities, safety, and nutritional value of sauerkraut. The accumulation of lactic acid inhibits the growth of spoilage and pathogenic microorganisms, thereby enhancing food safety and prolonging shelf life. In addition, LAB exhibit probiotic properties that support gut health, improve digestion, and contribute to immune function (Kalam, 2019; Satria, 2022).

Lactic acid bacteria have broad applications in food technology, agriculture, and medicine. They are Gram-positive microorganisms commonly used as starter cultures due to their ability to ferment carbohydrates and produce antimicrobial compounds (Wang *et al.,* 2024; Akpoghelie *et al.,* 2025). In vegetable fermentation, LAB significantly influence flavor, texture, nutritional quality, and microbial stability. However, variations in fermentation conditions, particularly in low-salt or salt-free fermentations, can affect microbial succession and product quality. In such cases, improper microbial balance may lead to excessive turbidity, undesirable flavors, or fermentation failure (Wang *et al.,* 2024).

Sauerkraut fermentation is a classic example of malolactic fermentation involving shredded cabbage (*Brassica oleracea* var. *capitata*) and sodium chloride under anaerobic conditions for approximately 14-21 days. This process allows LAB to dominate and convert sugars into lactic acid, producing the characteristic sour taste and extended shelf life associated with sauerkraut (Gaudioso *et al*., 2022). The ability of LAB to metabolize complex compounds into simpler organic acids also suppresses the growth of undesirable microorganisms and enhances product stability (Fevria and Hartanto, 2020).

Despite the long history and widespread consumption of sauerkraut, variations in fermentation practices and microbial populations can significantly influence its quality, safety, and nutritional value. Therefore, the isolation and characterization of lactic acid bacteria involved in sauerkraut fermentation are essential. Therefore, this study seeks to isolate and characterize lactic acid bacteria associated with sauerkraut fermentation, thereby contributing to improved fermentation practices and the development of functional fermented foods.

2.0 MATERIALS AND METHOD

2.1 Sample Collection

The cabbage used in this study was purchased from Wukati new market, Taraba State, Nigeria. The sample was conveyed to the Federal University Wukari, Microbiology Laboratory in a sterile, insulated container to maintain freshness and prevent contamination.

2.2 Sample Preparation

One kilogram (1kg) of cabbage was prepared. The heads of the cabbages were trimmed the outer leaves were detached that includes the soiled and bruised tissue. The

cabbage was washed in sterile distilled water, the cabbage heads were cut in half and the hard, central core removed. The cabbage was shredded into bits using a sterile knife before being placed into a clean glass jar, and 2% salt was added to make 200 ml volume. The shredded cabbage was completely submerged in distilled water and sealed to ensure anaerobic conditions. The setup was kept at room temperature 28 ± 1 ^{0}C) to ferment for 14 days, the method used was as described by Fadare *et al.,* (2023) with slight modification of the fermentation time.

2.3 Media Preparation

The culture media used in this study included De Man, Rogosa and Sharpe (MRS) agar for the isolation of lactic acid bacteria, Nutrient agar, and MacConkey agar. All media were prepared according to the manufacturers' instructions and sterilized by autoclaving at 121°C for 15 min, and allowed to cool before being poured into sterile Petri dishes for use in microbial analyses.

2.4 Isolation and Enumeration of Bacteria

The isolation of lactic acid bacteria from the fermented cabbage was carried out according to the method described by Fadare *et al.* (2023). Aseptically, 1 ml of the fermenting cabbage broth was withdrawn from the fermentation setup using a sterile pipette. To reduce the microbial concentration and facilitate isolation, a ten-fold serial dilution was performed. One milliliter of the cabbage broth was added to 9 mL of sterile peptone water, producing a 10^{-1} dilution. From this dilution, 1 mL was transferred to another 9 mL of sterile diluent to create a 10^{-2} dilution, and the process was repeated sequentially up to 10^{-10}, ensuring thorough mixing at each step.

From the prepared serial dilutions, 1 ml aliquots from the second (10^{-2}) and fourth (10^{-4}) dilutions were aseptically transferred into separate sterile Petri dishes. The pour plate technique was then employed by adding approximately 20 mL of molten agar (cooled to about 45 °C) into each plate. The contents were gently swirled in a circular motion to ensure uniform distribution of the inoculum within the medium. The plates were allowed to solidify. The inoculated MRS agar plates were incubated anaerobically using an anaerobic jar at 37 °C for 48 hours to favor the growth of lactic acid bacteria. While the nutrient agar and MacConkey agar plates were incubated aerobically at 37°C for 24 hours. After incubation, bacterial enumeration was carried out, colonies on plates that showed distinct and countable growth. Plates containing 30–300 colonies were selected as suitable for enumeration to ensure accuracy. The visible colonies were counted by direct visual observation and result recorded as cfu/ml.

2.6 Purification of Lactic Acid Bacteria

Distinct colonies were aseptically picked and subcultureed onto freshly prepared De Man, Rogosa and Sharpe (MRS) agar plates using the streak plate method to obtain pure cultures of lactic acid bacteria.

2.7 Characterization and Identification of Lactic Acid Bacteria

Lactic Acid Bacteria (LAB) identification and characterization were performed using a combination of cultural, colonial, morphological, Gram staining, biochemical, and physiological characteristics. Biochemical tests, such as catalase activity, carbohydrate fermentation, and gas production, characterized metabolic properties and physiological tests of the isolate by acid tolerance were all determined as described (John et al., 1994, Cheesbrough, 2006, Obasi, et al., 2025).

2.8 Antibiotic Susceptibility

Antibiotic Susceptibility Testing of the isolates was performed using the standard disc diffusion method. Sterile agar plates were inoculated evenly with the bacterial culture, and commercially available antibiotic discs were aseptically placed on the surface of the agar. The plates were then incubated under appropriate conditions, and after incubation, zones of inhibition around each disc were measured. The diameter of the inhibition zones was used to determine whether the isolates were sensitive, intermediate, or resistant to the tested antibiotics.

3.0 RESULTS AND DISCUSSION

The results in Table 1 for Total aerobic plate count of bacterial cells, coliform and lactic acid bacteria isolated from fermented Sauerkraut during storage showed a progressive increase in the total lactic acid bacteria (LAB) count as fermentation time increased. At day zero (0), the initial LAB population was relatively low (1.0×10^4 CFU/ml), reflecting the natural microflora present on fresh cabbage before fermentation began. By day 1, there was a slight increase to 1.5×10^4 CFU/ml, indicating the early adaptation and initial growth of LAB in the fermenting environment. A rise was observed by day 7, where the LAB count increased sharply to 1.4×10^6 CFU/ml. This rapid growth corresponds to the active fermentation phase, during which LAB multiply extensively and produce lactic acid, leading to a reduction in pH and suppression of undesirable microorganisms. By day 14, the LAB count further increased to 2.0×10^6 CFU/ml, suggesting that the fermentation process had reached a mature stage with LAB dominance and stable microbial activity. The trend demonstrates that lactic acid bacteria proliferate steadily during sauerkraut fermentation, playing a crucial role in

acid production, preservation, and development of the characteristic flavor and safety of the final product.

The results in Table 1 showed a decrease in both total bacterial and coliform counts during the early stage of sauerkraut fermentation. At day zero (0), the total bacterial count was 2.0×10^4 CFU/ml, while the coliform count was relatively high at 1.8×10^4 CFU/ml, reflecting the natural microflora and possible contaminants present on fresh cabbage before fermentation commenced. By day 1, both counts had declined, with total bacteria reducing to 1.0×10^4 CFU/ml and coliforms decreasing to 1.2×10^4 CFU/ml. This reduction can be attributed to the rapid growth of lactic acid bacteria, which produce organic acids that lower the pH of the fermenting medium. The increasingly acidic environment inhibits the growth and survival of many non-acid-tolerant bacteria, particularly coliforms. This trend indicates the early establishment of lactic acid fermentation, where acid production begins to suppress undesirable microorganisms and promotes microbial safety of the fermenting sauerkraut.

The result in Table 1 revealed that sauerkraut fermentation was characterized by a steady increase in lactic acid bacteria (LAB) counts, reflecting the typical microbial succession observed in vegetable fermentations. The LAB population increased from 1.0×10^4 CFU/ml at day 0 to 2.0×10^6 CFU/ml by day 14, demonstrating the progressive dominance of LAB as fermentation advanced. The progressive increase in lactic acid bacteria (LAB) counts during sauerkraut fermentation obtained in this study is consistent with the report of Gaudioso *et al.,* (2022) who reported that LAB populations are low at the start but rapidly increase as fermentation proceeds, outcompeting other microbiota as pH decreases and lactic acid accumulates.

Fresh cabbage naturally harbours only low numbers of LAB on its surface; however, during fermentation, these organisms rapidly proliferate by metabolizing available fermentable sugars into lactic acid. The accumulation of lactic acid lowers the environmental pH, thereby creating selective conditions that favour acid-tolerant LAB while inhibiting competing microorganisms. This ecological shift is a defining feature of vegetable fermentations and ensures both product preservation and microbial safety (Ghosh, 2021). The increase in LAB observed in this study is in agreement with the findings of Han *et al.,* (2025) who reported LAB abundance accompanied by progressive acidification in sauerkraut fermentations, where *Lactobacillus plantarum* and *Pediococcus pentosaceus* are commonly identified as dominant species during later stages due to their strong acid tolerance and metabolic efficiency.

The observed decline in total bacterial and coliform counts between day zero (0) and day 1 demonstrates the inhibitory effect of acidification on non-acid-tolerant microorganisms. Early fermentation typically involves a mixed microbial population, including environmental bacteria and enteric contaminants; however, as LAB produce organic acids and salt exerts osmotic stress, many spoilage and pathogenic bacteria, including coliforms, are suppressed (Rahman *et al.,* 2026). This reduction plays a crucial role in improving the microbial safety and shelf stability of fermented cabbage products. The observed decline in total bacteria and coliform count is in line with the findings of Gaudioso *et al.* (2022) who reported acid production during sauerkraut fermentation which leads to rapid inhibition of coliforms and other undesirable bacteria. In addition to organic acids, LAB are known to produce antimicrobial metabolites such as bacteriocins, hydrogen peroxide, and diacetyl, which further inhibit competing microorganisms and contribute to the decline of non-LAB genera during fermentation (Fugaban *et al.,* 2022; Liu *et al.,* 2023). Similarly, Ghosh (2021) reported the absence of acid and gas formation in MacConkey broth inoculated with sauerkraut brine, confirming the elimination of coliform bacteria as fermentation progressed.

The results in Table 2 showed that the bacterial isolates obtained during sauerkraut fermentation were predominantly Gram-positive, catalase-negative organisms, which are typical characteristics of lactic acid bacteria (LAB). The bacterial isolates obtained from the fermenting sauerkraut were identified as *Lactobacillus plantarum*, *Aerococcus viridans*, and *Pediococcus pentosus* based on their morphological and biochemical characteristics. The isolates indicate that lactic acid bacteria, particularly *Lactobacillus* and *Pediococcus* species, were the dominant microorganisms associated with sauerkraut fermentation.

The result of these isolates identified in this study are consistent with the microbial composition commonly reported in sauerkraut fermentation as reported by other researchers (Azevedo and Gierus, 2025) showed that *L. plantarum* and *P. pentosaceus* are frequently dominant LAB species because of their ability to tolerate acidic environments, efficiently metabolize sugars, and produce antimicrobial compounds that suppress competing microorganisms. Kalam and Ahmad, (2022) reported that earlier stages of fermentation of sauerkraut are typically dominated by heterofermentative LAB such as *Leuconostoc mesenteroides* and *Lactobacillus brevis,* which initiate fermentation before being replaced by more acid-resistant species like *L. plantarum* and *Pediococcus* spp. Molecular community analyses of sauerkraut as described by (Choińska *et al.,* 2025) also confirms that strains of *Pediococcus* are among the most abundant taxanomic in traditional products, which corresponds closely with our culture-based identification of *L. plantarum* and *P. pentosaceus* as obtained in this present study.

Although *Aerococcus* species are less commonly emphasized in vegetable fermentations, they may occur as part of the natural epiphytic microbiota of plant materials or as transient environmental contaminants (Minervini *et al.,* 2015; Gaudioso *et al.,* 2022).

The isolation of *Lactobacillus plantarum, Aerococcus viridans*, and *Pediococcus pentosaceus* are in agreement with other previous findings. Zabat *et al.*

(2018) identified *Lactobacillus* species as predominant LAB in sauerkraut fermentation, Georgieva *et al.* (2023) reported the presence of *Pediococcus pentosaceus* during fermentation, Liu *et al.* (2023) reported *Lactobacillus* species representing approximately 73% of total isolates, and Fevria and Hartanto (2020) similarly reported the isolation of *Lactobacillus* spp. from sauerkraut.

The results in Table 3 showed that the bacterial isolates demonstrated consistent acid tolerance throughout the fermentation period. Test tube A (pH buffer) and test tube B (MRS broth) both remained cloudy from day zero (0) to day 14, while their respective controls remained clear. The persistent turbidity indicates active bacterial growth under acidic conditions. This finding confirms that the isolates are acid-tolerant organisms, a key characteristic of lactic acid bacteria. Their ability to survive and grow in low pH environments explains their dominance during sauerkraut fermentation, where they produce lactic acid that lowers the pH and inhibits non-acid-tolerant microorganisms.

All isolates in this study demonstrated acid tolerance throughout fermentation, a key physiological characteristic of LAB that enables their survival and dominance in low-pH environments. Acid tolerance mechanisms in LAB include proton pump activity, intracellular pH regulation, and adaptive stress response systems that protect cellular proteins and membranes. These physiological adaptations ensure sustained lactic acid production and contribute to the stability and safety of fermented foods. Acid tolerance is therefore widely recognized as an essential trait for LAB involved in vegetable fermentations (Fevria and Hartanto, 2020; Han *et al*., 2025).

The results in Table 4 showed varying antibiotic susceptibility patterns among the bacterial isolates. *Lactobacillus plantarum* exhibited resistance to most of the tested antibiotics but showed sensitivity to chloramphenicol, amoxicillin, and augmentin, as indicated by measurable zones of inhibition. This suggests a limited susceptibility profile, which is common among some lactic acid bacteria. *Aerococcus viridans* demonstrated the highest level of susceptibility, showing sensitivity to several antibiotics including chloramphenicol, sparfloxacin, ciprofloxacin, amoxicillin, augmentin, pefloxacin, and ofloxacin. However, it remained resistant to ampicillin, septrin, gentamicin, streptomycin, ceporex, and nalidixic acid. *Pediococcus pentosus* showed a high level of resistance, being sensitive only to chloramphenicol and amoxicillin, while resistant to all other antibiotics tested. The findings indicated that the isolates possess multiple antibiotic resistance traits but retain susceptibility to a few broad-spectrum antibiotics, particularly chloramphenicol and amoxicillin. This pattern is typical of many lactic acid bacteria, which naturally exhibit intrinsic resistance to several antibiotics while remaining sensitive to selected ones. Antibiotic susceptibility testing revealed varied resistance patterns among the isolates, reflecting both intrinsic and acquired resistance mechanisms. *Lactobacillus plantarum* exhibited a high level of resistance to multiple antibiotics, including Ampicillin, Septrin, Sparfloxacin, Ciprofloxacin, Gentamicin, Pefloxacin, Ofloxacin, Streptomycin, Ceporex, and Nalidixic acid, while remaining susceptible to Chloramphenicol, Amoxicillin, and Augmentin. This is consistent with the findings of Floris *et al.* (2025) who reported that *Lactobacillus* and *Leuconostoc* strains frequently exhibit resistance to multiple antibiotics, including vancomycin and tetracycline, and that many LAB strains carry transferable resistance genes such as tetK. This finding suggests that LAB in fermented foods may act as reservoirs of antibiotic resistance determinants, potentially contributing to resistance gene dissemination within food microbiota and the human gut. Khablenko *et al.* (2024) revealed that lactic acid bacteria isolated from sauerkraut were resistant to ampicillin and kanamycin but showed sensitivity to chloramphenicol, erythromycin, and tetracycline.

This observed resistance pattern may be due to intrinsic characteristics of LAB, such as reduced cell wall permeability, efflux pump systems, and the absence of specific antibiotic target sites (Martínez *et al.,* 2020). Additionally, Álvarez-Cisneros and Ponce-Alquicira, (2018) reported that LAB commonly harbour antibiotic resistance genes that may be naturally occurring or acquired through horizontal gene transfer within microbial ecosystems.

Aerococcus viridans demonstrated a broader susceptibility profile but still showed resistance to several antibiotics, including Ampicillin, Septrin, Gentamicin, Streptomycin, Ceporex, and Nalidixic acid. This trend is consistent with the findings Ali *et al.,* (2016) who reported a high resistance rate among *Aerococcus* isolates to multiple antibiotic classes. Guccione *et al*. (2013) also reported extensive multidrug resistance in *Aerococcus viridans*, particularly against penicillins, cephalosporins, and sulfonamide combinations, while noting retained susceptibility to macrolides and tetracyclines.

The susceptibility of *Aerococcus* to Chloramphenicol, fluoroquinolones, and beta-lactam suggests variability in resistance mechanisms within this species. Resistance in *Aerococcus* is often associated with cell wall structural characteristics, enzymatic antibiotic inactivation, and genetic determinants that limit antibiotic penetration.

Pediococcus pentosaceus exhibited susceptibility to all tested antibiotics, as indicated by measurable zones of inhibition. This finding suggests the absence of major acquired resistance determinants and supports its potential safety for use in food fermentation. The high susceptibility observed may be attributed to limited exposure to antibiotic selective pressures and the absence of mobile resistance genes. Yi *et al*. (2025) similarly reported strong antimicrobial activity of *Pediococcus pentosaceus* strains against multidrug-resistant pathogens, highlighting their potential probiotic and bio-preservative applications. However, Shani *et al.* (2021) found that although *Pediococcus* genomes were generally free of known resistance genes, certain strains

displayed elevated minimum inhibitory concentrations for chloramphenicol and tetracycline. Such discrepancies may be explained by strain-specific genetic variability, differences in environmental exposure to antibiotics.

Table 1: Total aerobic plate count (TAPC) of bacterial cells, coliform and lactic acid bacteria isolated from fermented Sauerkraut during storage

Fermentation time (days)	TAPC	Coliform count	Total LAB
0	2.0×10^4	1.8×10^4	1.0×10^4
1	-	-	1.5×10^4
7	-	-	1.4×10^6
14	-	-	2.0×10^6

Table 2: Morphological and biochemical characterizations of bacteria isolates

						TSI					
Colony morphology	Gram rxn	CAT	OXI	CIT	IND	GLU	SUC	LAC	H_2S	GAS	Identity of organisms
Pin point, circular, entire, smooth, milky, flat	+ rods	-	-	-	-	+	+	-	-	-	*Lactobacillus plantarum*
Round, convex, grayish-white colonies with a butyrous to slightly mucoid texture, slightly raised elevation, and smooth, entire margins	+ cocci	-	-	+	-	-	-	-	-	-	*Aerococcus viridans*
Small, circular, convex, creamy-white, smooth, shiny	+ cocci	-	-	-	-	+	+	+	-	-	*Pediococcus pentosaceus*

Key: CAT = Catalase test; OXI = Oxidase test; IND = Indole test; CIT = Citrate utilization test; GLU = Glucose fermentation; SUC = Sucrose fermentation; LAC = Lactose fermentation; H_2S = Hydrogen sulfide production; GAS = Gas production; TSI = Triple Sugar Iron agar test; Gram rxn = Gram reaction; - = negative, + = positive.

Table 3: Acid tolerance test

Days	Test tube A (pH buffer)	Control	Test tube B (MRS broth)	Control
0	Cloudy	Clear	Cloudy	Clear
1	Cloudy	Clear	Cloudy	Clear
7	Cloudy	Clear	Cloudy	Clear
14	Cloudy	Clear	Cloudy	Clear

Key: Coudy = acid tolerant

Table 4: Antibiotic susceptibility of bacteria isolates

Isolates	PN	SXT	CH	SP	CPX	AM	AU	CN	PEF	OFX	S	CEP	NA
A	R	R	2.0	R	R	2.3	2.1	R	R	R	R	R	R
B	R	R	2.5	2.0	2.3	2.5	2.5	R	1.9	2.0	R	R	R
C	1.0	1.5	2.3	1.1	1.1	2.8	1.2	1.0	1.0	1.0	1.2	1.0	1.5

Key: SXT = Septrin (Trimethoprim–Sulfamethoxazole); CH = Chloramphenicol; SP = Sparfloxacin; CPX = Ciprofloxacin; AM = Amoxicillin; AU = Augmentin (Amoxicillin–Clavulanic acid); CN = Gentamicin; PEF = Pefloxacin; OFX = Ofloxacin; S = Streptomycin; CEP = Ceporex (Cephalexin); NA = Nalidixic acid; PN = Ampicillin, A= *Lactobacillus plantarum,* B= *Aerococcus viridans* and C= *Pediococcus pentosaceus*

CONCLUSION

This study showed a progressive increase in lactic acid bacteria during sauerkraut fermentation with a corresponding decline in total bacterial and coliform counts, confirming the dominance of acid-tolerant LAB as fermentation progressed. The identified species *Lactobacillus plantarum*, *Pediococcus pentosaceus*, and *Aerococcus viridans* are consistent with microorganisms commonly reported in sauerkraut fermentation. The antibiotic susceptibility patterns observed also agree with previous studies, where some LAB exhibited resistance to certain antibiotics while *Pediococcus pentosaceus* remained largely susceptible. The findings demonstrate that LAB dominate sauerkraut fermentation through acid production, microbial inhibition, and adaptation to acidic conditions, contributing to product safety, preservation, and quality.

Recommendations

Based on the findings of this study, which demonstrated the presence, diversity, and beneficial roles of lactic acid bacteria (LAB) in the fermentation of sauerkraut, the following recommendations are proposed:

1. Identified beneficial LAB strains such as *Lactobacillus* and *Leuconostoc* species should be developed and used as starter cultures to ensure consistent fermentation quality and safety
2. Strict hygienic conditions should be maintained during processing to prevent contamination by undesirable microorganisms
3. Advanced molecular techniques should be employed in future studies to accurately identify LAB strains and determine their probiotic potentials

Disclosure of Conflict of Interest

There is no conflict of interest, all authors agree to the subject.

REFERENCES

Abdul Hakim, B. N., Xuan, N. J., and Oslan, S. N. H. (2023). A comprehensive review of bioactive compounds from lactic acid bacteria: Potential functions as functional food in dietetics and the food industry. *Foods, 12*(15), 2850. https://doi.org/10.3390/foods12152850

Akpoghelie, P. O., Edo, G. I., Mafe, A. N., Isoje, E. F., Igbuku, U. A., Ali, A. B., and Alamiery, A. A. (2025). Food, health, and environmental impact of lactic acid bacteria: The superbacteria for posterity. *Probiotics and Antimicrobial Proteins, 17*(5), 2819–2855. https://doi.org/10.1007/s12602-025-10123-4

Ali Bayane, Bréhima Diawara, Robin Dauphin Dubois, Jacqueline Destain, Dominique Roblain and Philippe Thonart (2016). Isolation and characterisation of new spore-forming lactic acid bacteria with prospects of use in food fermentations and probiotic preparations. Advanced Journal of Microbiology Research pp 1-10. 2016

Álvarez-Cisneros, Y. M., and Ponce-Alquicira, E. (2018). Antibiotic resistance in lactic acid bacteria. In *Antimicrobial Resistance—A Global Threat* (pp. 53–73). IntechOpen. https://doi.org/10.5772/intechopen.73844

Azevedo, P. O. D. S. D., and Gierus, M. (2025). Lactic acid bacteria and bacteriocins in feed preservation: Mechanisms and antifungal properties. *Grass and Forage Science, 80*(1), e12711. https://doi.org/10.1111/gfs.12711

Cheesbrough, M. (2006). *District laboratory practice in tropical countries (Part 2)* (2nd ed., pp. 35, 64–70, 157–158, 179–191). Cambridge University Press.

Choińska, R., Piasecka-Jóźwiak, K., Świder, O., Żak-Kułakowicz, A., Włodarczyk, K., and Załuski, J. (2025). Microbiota and quality indexes of commercial sauerkraut and fermented cucumbers. *Environmental Microbiology Reports, 17*(6), e70250. https://doi.org/10.1111/1758-2229.70250

Fadare, O. S., Anyadike, C. H., Momoh, A. O., and Bello, T. K. (2023). Antimicrobial properties, safety, and probiotic attributes of lactic acid bacteria isolated from sauerkraut. *African Journal of Clinical and Experimental Microbiology, 24*(1), 61–72.

Fevria, R., and Hartanto, I. (2020, August). Isolation and characterization of lactic acid bacteria (Lactobacillus sp.) from sauerkraut. In *International Conference on Biology, Sciences and Education (ICoBioSE 2019)* (pp. 74–77). Atlantis Press.

Fijan, S., Fijan, P., Wei, L., and Marco, M. L. (2024). Health benefits of kimchi, sauerkraut, and other fermented foods of the genus *Brassica*. *Applied Microbiology, 4*(3), 1165–1176. https://doi.org/10.3390/applmicrobio403009

Floris, I., Battistini, R., Tramuta, C., Garcia-Vozmediano, A., Musolino, N., Scardino, G., Masotti, C., Brusa, B., Orusa, R., Serracca, L., Razzuoli, E., Martucci, F., and Bianchi, D. M. (2025). Antibiotic resistance in lactic acid bacteria from dairy products in Northern Italy. *Antibiotics, 14*(4), Article 375. https://doi.org/10.3390/antibiotics14040375

Fugaban, J. I. I., Holzapfel, W. H., and Todorov, S. (2022). The overview of natural by-products of beneficial lactic acid bacteria as promising antimicrobial agents. *Applied Food Biotechnology, 9*(2), 127–143. https://doi.org/10.22037/afb.v9i2.32364

Gaudioso, G., Weil, T., Marzorati, G., Solovyev, P., Bontempo, L., Franciosi, E., Bertoldi, L., Pedrolli, C., Tuohy, K. M., and Fava, F. (2022). Microbial and metabolic characterization of organic artisanal sauerkraut fermentation and study of gut health-promoting properties of sauerkraut brine. *Frontiers in*

Microbiology, 13, 929738. https://doi.org/10.3389/fmicb.2022.929738

Georgieva, A., Petkova, M., Todorova, E., Gotcheva, V., and Angelov, A. (2023). Isolation and selection of sauerkraut lactic acid bacteria producing exopolysaccharides. *BIO Web of Conferences, 58*, Article 02001. https://doi.org/10.1051/bioconf/20235802001

Ghosh, D. (2021). Studies on the changes of biochemical, microbiological and sensory parameters of sauerkraut and fermented mixed vegetables. *J. Homepage*, *5*, 78–83.

Guccione, J., Nizza, S., Mallardo, K., Cantiello, A., Fiorito, F., Di Loria, A., and De Martino, L. (2013). Penicillin-resistant *Aerococcus viridans* bacteremia associated with bovine severe respiratory syndrome. *Open Journal of Veterinary Medicine, 3*, 131–135. https://doi.org/10.4236/ojvm.2013.32021

Han, M. Y., Lou, W. Y., and Li, M. F. (2025). Lactic acid bacteria in Chinese sauerkraut: Its isolation and in vitro probiotic properties. *Foods, 14*(15), 2690. https://doi.org/10.3390/foods14152690

John,G.H; Neol, R.K; Peter, H.A; Sneath, J.T.S. and Stanley, Y.W. (1994). Bergey's Manual of Determinative Bacteriology (1994).Publisher: Lippincott William and Willkims, New York. ISBN. 9788-0683-00603-2.PP: 187-

Kalam, A. (2019). Antimicrobial action of a bacteria (SAKBNC-4) isolated from sauerkraut and its characterization. *Life Science Informatics Publications*, 1–9. https://doi.org/10.26479/2019.0502.82

Kalam, A., and Ahmad, S. R. (2020). Antifungal activity of bacteria isolated from sauerkraut and its partial characterization. *Indian Journal of Pure and Applied Biosciences, 8*(6), 137–145. http://dx.doi.org/10.18782/2582-2845.8439

Khablenko, A., Holubchyk, D., Danylenko, S., & Duhan, O. (2024). Antibiotic susceptibility of lactic acid bacteria isolates isolated from sauerkraut. In *Global society in formation of new security system and world order* (Conference proceedings, Dnipro, Ukraine).

Liu, Y., Chen, X., Li, F., Shi, H., He, M., Ge, J., Ling, H., and Cheng, K. (2023). Analysis of microbial diversity and metabolites in sauerkraut products with and without microorganism addition. *Foods, 12*, 1164. https://doi.org/10.3390/foods12061164

Martínez, B., Rodríguez, A., Kulakauskas, S., and Chapot-Chartier, M. P. (2020). Cell wall homeostasis in lactic acid bacteria: Threats and defences. *FEMS Microbiology Reviews, 44*(5), 538–564. https://doi.org/10.1093/femsre/fuaa018

Minervini, F., Celano, G., Lattanzi, A., Tedone, L., De Mastro, G., Gobbetti, M., and De Angelis, M. (2015). Lactic acid bacteria in durum wheat flour are endophytic components of the plant during its entire life cycle. *Applied and Environmental Microbiology, 81*(19), 6736–6748. https://doi.org/10.1128/AEM.01832-15

Niyigaba, T., Küçükgöz, K., Kołożyn-Krajewska, D., Krolikowski, T., and Trząskowska, M. (2025). Advances in fermentation technology: A focus on health and safety. *Applied Sciences, 15*(6), 3001.

Obasi, B.C; Ngutsewen, B.K; Shehu, U (2025). Effect of Drying Methods on the Nutritional Composition and Microbiological Quality of Selected Vegetables (Okra and Tomatoes).*Greener Journal of Life Sciences*, 7(1): 1-11, https://doi.org/10.15580/gjls.2025.1.123124211.

Rahman, M. M., Sazili, A. Q., Ahmad, S. A., Khalil, K. A., Ismail-Fitry, M. R., Karim Sarker, M. S., and Kumar, P. (2026). Lactic acid bacteria and their antimicrobial substances: Modern approaches for the biopreservation of meat and meat products. *Food Quality and Safety*, fyag008. https://doi.org/10.1093/fqs/fyag008

Satria, A. H. B. M. (2022). Isolation and characterization of biosurfactant-producing lactic acid bacteria from sauerkraut. *Enhanced Knowledge in Sciences and Technology, 2*(2), 60–69.

Shani, N., Oberhaensli, S., and Arias-Roth, E. (2021). Antibiotic susceptibility profiles of *Pediococcus pentosaceus* from various origins and their implications for the safety assessment of strains with food-technology applications. *Journal of Food Protection, 84*(7), 1160–1168.

Tlais, A. Z. A., Lemos Junior, W. J. F., Filannino, P., Campanaro, S., Gobbetti, M., and Di Cagno, R. (2022). How microbiome composition correlates with biochemical changes during sauerkraut fermentation: A focus on neglected bacterial players and functionalities. *Microbiology Spectrum, 10*(4), e00168-22. https://doi.org/10.1128/spectrum.00168-22

Wang, W., Li, W., Huang, Y., Yang, Y., Liu, H., Yu, C., Zhang, F. (2024). Optimisation of *Lactobacillus* fermentation conditions and its application in the fermentation of salt-free sauerkraut. *Frontiers in Microbiology, 15*, 1482163. https://doi.org/10.3389/fmicb.2024.1482163

Yi, G.-S., Jin, X., Zheng, Q., Nguyen, T. T. M., Yang, S.-J., and Yi, T.-H. (2025). Antimicrobial activity of *Pediococcus pentosaceus* PMY2 against multidrug-resistant pathogens. *Antibiotics, 14*, 389. https://doi.org/10.3390/antibiotics14040389

.

Cite this Article: Obasi, BC; Ochojila, AO (2026). Isolation and Characterization of Lactic Acid Bacteria Associated With Fermentation of Sauerkraut Production. *Greener Journal of Biological Sciences*, 6(1): 5-12, https://doi.org/10.15580/gjbs.2026.1.050526062.