IPS Journal of Nutrition and Food Science
ISSN: 3115-5391
IPS J Nutr Food Sci, 4(4): 569-577 (2025)
DOI: https://doi.org/10.54117/012d8612

Evaluation of Lactobacillus Fermented Chicken Feather Meal on Blood Lipoproteins and Lymphocyte Count in Rats

Iheukwumere, I. H. [1], Iheukwumere, C. M. [2], Idigo, M. A.[3], Ezekwueche, S. N.[4]

[1]Department of Microbiology, Faculty of Natural Science, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.
[2]Department of Applied Microbiology & Brewing, Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[3]Department of Biological Sciences, Faculty of Natural Science, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.
[4]Department of Microbiology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria.

*Corresponding author email: ik.iheukwumere@coou.edu.ng/ ikpower2007@yahoo.com

Abstract

This study investigates the impact of *Lactobacillus* fermented chicken feather meal on blood lipoproteins and lymphocytes in rats using *in vivo* techniques, researchers evaluated the effects of fermented feeds on rats, utilizing *Lactobacillus acidophilus* strain DSN20079 (LADSM) as the fermenter. The study showed significant decreases ($P<0.05$) in lipid profiles: Cholesterol: 147.50 mg/dL; LDL-C: 28.45 mg/dL; HDL-C: 64.15 mg/dL and triglycerides: 91.75 mg/dL. Blood lymphocyte count analysis revealed that dexamethasone (200 mg/g) significantly reduced lymphocyte count to 113.82 ($P<0.05$), levamisole (50 mg/g) increased lymphocyte count to 273.15 ($P<0.05$) and treatment with 100 mg/g of chicken feather meal increased lymphocyte count to 271.86, although this change was non-significant ($P>0.05$) compared to the levamisole group. The study concludes that Lactobacillus fermented chicken feather meal exhibits pronounced activity in modulating lipoproteins and blood lymphocytes, suggesting potential benefits for cardiovascular health and immune function. These findings highlight the potential of fermented chicken feather meal as a valuable feed supplement.

Keywords: Blood, *Lactobacillus*, Feed, Lipoproteins

Article History
Received: 23 Jul 2025
Accepted: 17 Sept 2025
Published: 21 Sept 2025

Scan QR Code to view[1]

How to cite this paper: Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025). Evaluation of *Lactobacillus* fermented chicken feather meal on blood lipoproteins and lymphocyte count in rats. *IPS Journal of Nutrition and Food Science, 4*(4), 569–577. https://doi.org/10.54117/012d8612

Introduction

The search for sustainable, nutrient-rich poultry feed ingredients has intensified in recent years due to rising feed costs, environmental concerns, and the growing demand for eco-friendly livestock production systems. Chicken feathers, constituting approximately 5–7% of poultry processing by-products, represent an underutilized protein-rich resource. They are composed predominantly of keratin, a fibrous, sulfur-containing protein that is naturally resistant to degradation because of strong disulfide bonds and a packed molecular structure (Tesfaye et al., 2017). Although keratin has an excellent amino acid profile, its low digestibility limits direct use in poultry feed.

Fermentation using Lactobacillus species offers a promising solution to this limitation. During fermentation, Lactobacillus produces keratinolytic enzymes that cleave disulfide bonds, hydrolyze protein chains, and release amino acids and peptides in a form that can be efficiently absorbed by poultry (Karthikeyan et al., 2019). Beyond improving digestibility, the process enriches the feather meal with probiotic bacteria, organic acids, and bioactive compounds that can influence key physiological parameters such as lipid metabolism and immune cell function.

The introduction of Lactobacillus-fermented chicken feather meal (LFCFM) in broiler diets can positively modulate lipoprotein levels. Probiotic Lactobacillus strains have been shown to assimilate cholesterol directly from the intestinal lumen, deconjugate bile salts—thereby increasing their excretion—and inhibit the intestinal absorption of dietary cholesterol (Patel et al., 2018). Additionally, fermentation

produces short-chain fatty acids (SCFAs) such as propionate, acetate, and butyrate. Propionate, in particular, can suppress hepatic cholesterol synthesis by inhibiting the enzyme HMG-CoA reductase (Hidayat et al., 2021).

Studies have shown that fermented feed additives have consistently shown a reduction in LDL and VLDL levels, alongside an increase in HDL concentration, thereby improving the lipid profile (Safari et al., 2024). Such changes not only enhance the metabolic efficiency of broiler chickens but also contribute to leaner meat production, which aligns with consumer demand for healthier poultry products.
Lymphocytes—comprising B cells, T cells, and natural killer (NK) cells—are central to adaptive immune responses. Their abundance and functionality are key indicators of an animal's ability to resist disease and respond to vaccination. Diets supplemented with LFCFM may enhance lymphocyte production by modulating the gut-associated lymphoid tissue (GALT) through probiotic action.

Probiotic Lactobacillus enhances immune surveillance by improving gut microbiota balance, suppressing the growth of pathogenic bacteria, and stimulating cytokine production. Bacteriocins, lactic acid, and hydrogen peroxide produced during fermentation contribute to pathogen suppression, while Lactobacillus-derived metabolites interact with intestinal epithelial cells to trigger immune responses (Sugiharto, 2016). Hence, this study was undertaken to evaluate the corollary of Lactobacillus fermented chicken feather on blood lipoproteins and lymphocytes.

Materials and Methods

Isolation of the Test Sample

The media used for this isolation was de Man Rogosa and Sharpe broth (MRS) (BIOTECH). A 1.0 ml of fermented yoghurt (Aqua yoghurt) and banana extract were aseptically introduced into sterile Petri dishes (90 mm x 15 mm), then 20 ml of MRS which was prepared according to the manufacturers instruction and the procedures described in Cheesbrough (2010), Iheukwumere *et al*. (2020a), Iheukwumere and Iheukwumere, (2022a) and Iheukwumere *et al*. (2022b), was added into the plates, allowed to solidified. The plates were incubated in a microaerophilic environment (containing a candle used to evacuate all traces of oxygen, thereby creating an environment with only carbon dioxide). The incubation was done for 24 – 48 h at (30 ± 2^0C).

Purification of the Isolates

The plate that showed discrete colonies were selected after 24 - 48 h and each colony was aseptically streaked using a sterile wire loop on a sterile poured plate (90mm x 15mm) containing nutrient agar (BIOTECH) prepared according to the manufacturers description, after which it was incubated at their required growth conditions (Iheukwumere and Iheukwumere, 2022c; Iheukwumere *et al*., 2022d; and Iheukwumere and Iheukwumere, 2022e).

Characterization of the Bacteria Pure Isolates

The pure isolates were characterized using the morphological, biochemical and molecular characteristics as described by Iheukwumere *et al*. (2018), Iheukwumere *et al*. (2022f), Iheukwumere *et al*. (2023a) and Iheukwumere *et al*. (2023b).

Morphological characteristics of the Bacteria isolates

The cultural descriptions (size, appearance, edge, elevation, colour) of the isolates were carried out as described in Iheukwumere *et al*. (2024) and Iheukwumere *et al*. (2022g). The Gram staining technique which revealed the Gram reaction, cell morphology and cell arrangement were also carried out using the procedure described by Obianom *et al*., (2024), Egbe *et al*. (2025a) and Manasseh *et al*. (2025). The presence or absence of capsule was also carried out as described by Ekechukwu *et al*. (2025a). The presence or absence of flagellum was determined by carrying out motility test as described by Ekechukwu *et al*. (2025b).

Gram staining technique

A thin smear was made in a cleaned grease free microscopic slide (75mm×25mm), air dried heat fixed. The smear was flooded with crystal violet solution (0.2%) for 60 seconds and rinsed with cleaned water. Gram iodine solution (0.01%) was then applied and allowed for 60 seconds. This was rinsed with cleaned water. This was followed by decolourizing the slide content with 95%w/v ethyl alcohol for 10seconds and then rinsed with cleaned water. The smear was then counter stained with safranin solution (0.025%) for 60 seconds, rinsed with cleaned water, blot drained and air dried. The stained smear was covered with a drop of immersion oil and observed under a binocular compound light microscope using × 100 objective lens as described by Ekechukwu *et al*. (2025c), Egbe *et al*. (2025b) and Egbe *et al*. (2025c).

Motility test: This was done using the method described by Iheukwumere *et al*. (2025a), Iheukwumere *et al*. (2025b) and Iheukwumere *et al*. (202c). A semi-solid medium prepared by mixing 5.0g of bacteriological agar (BIOTECH) with 2.0g of nutrient broth (BIOTECH) in 1 Litre of distilled water was used. The solution was dissolved and sterilized using autoclaving technique after dispensing 10 ml portion in different test tubes. The test tubes were allowed to set in vertical positions and then inoculate the test organisms by performing a single stab down the centre of the test tube to half the depth of the medium using sterile stabbing needle. The test tubes were kept in an incubator in vertical position at 35 ± 2^0C for 24h.T

Biochemical characteristics of the isolates

Indole test: Indole is a nitrogen containing compound formed when the amino acid tryptophan is hydrolyzed by bacteria that have the enzyme tryptophanase. This is detected by using KOVAC's reagent. This was done using the method described by Iheukwumere *et al*. (2025d), Iheukwumere *et al*. (2025e) and Iheukwumere *et al*. (2025f). The isolates were cultured in peptone water in 500.0 ml of deionized water. Ten millilitres of peptone water was dispensed into the test tubes and sterilized. The medium was then inoculated with the isolates and kept in an incubator at 37˚C for 48 hr. Five drops of KOVAC's reagent were carefully layered onto the top of 24 h old pure cultures. The presence of indole was revealed by the development of red layer colouration on the top of the broth cultures.

Sugar fermentation test: The capability of the isolates to metabolize some sugars (glucose, xylose, ducitol, maltose, arabinose, inositol, mucate and lactose) with the resulting formation of acid and gas or either were carried out using sugar fermentation test. One litre of 1% (w/v) peptone water was added to 3 mL of 0.2% (w/v) bromocresol purple and 9 ml was dispensed in the test tube that contained inverted Durham tubes. The medium was then sterilized by autoclaving. The sugar solution were prepared at 10% (w/v) and sterilized. One milliliter of the sugar was dispensed aseptically into the test tubes as described by Dim *et al*. (2025a) and Dim *et al*. (2025b). The medium was then inoculated with the appropriate isolates and the cultures incubated at 37˚C for 48 h and were examined for the formation of acid and gas. Change in colour from purple to yellow indicated acid formation while gas formation was assessed by the presence of bubbles in the inverted

Methyl red test: Using the method described by Dim *et al*. (2025c), Iheukwumere *et al*. (2025g). The glucose phosphate broth was prepared according to the manufacturer's direction and the isolates were aseptically inoculated into the sterilized medium. This was incubated at 37˚C for 48 hr. After incubation, five drops of 0.4 % solution of alcoholic methyl red solution was added and mixed thoroughly, and the result was read immediately. Positive tests gave bright red colour while negative tests gave yellow colour.

Voges-Proskauer test: Using the method described by Iheukwumere *et al*. (2025h), Ike *et al*. (2025a). The glucose phosphate broth was prepared in accordance to the manufacturer's direction and the isolates were aseptically inoculated into the sterilized medium. This was incubated at 37˚C for 48hr. After incubation, 1.0 mL of 40% potassium hydroxide (KOH) containing 0.3% Creatine and 3 ml of 5% solution of α-naphthol was add ed in the absolute alcohol. Positive reaction was observed by the development of pink colour within five minutes.

Citrate utilization test: The Simmon's Citrate Agar was prepare according to the manufacturer's direction and the isolates were inoculated by stabbing directly at the center of the medium in the test tubes and incubated at 37˚C for 48 hr. Positive test was shown by the appearance of growth with blue colour, while negative test showed no growth and the original green colour was retained as described by Ike *et al*. (2025b) and Ike *et al*. (2025c).

Catalase test: The test was carried out as described by Ike *et al*. (2025d) and Ike *et al*. (2025e). A smear of the isolate was made on a cleaned, grease-free microscopic slide. Then, a drop of 30% hydrogen peroxide (H_2O_2) was added on the smear. Prompt effervescence indicated catalase production.

Oxidase test: The test was carried out using the method described by Ugwu *et al*. (2025a). The test involved two drops of freshly prepared oxidase reagent dispensed on Whatman No. 1 filter paper which was placed in Petri dish, and a smear of the test isolate was made on the spot using a sterile stick. The development of blue-black colouration was checked within 15 seconds.

Urease test: This was carried out as described by Ugwu *et al*. (2025b). The urea agar slant was prepared in accordance to the manufacturer's direction and the isolates were aseptically inoculated into sterilized medium. This was incubated at 37^0C for 48 h. After incubation, observation was made for the presence of purple-pink colouration.

Molecular characterization of the isolates

Extraction and purification of DNA: All strains were plated on Nutrient Agar (Biotech) and incubated at 37℃ for 24 hr. Using the Zymo Research (ZR) DNA miniprepTM kit (Category No. D6005; Irvine, California, USA), bacterial genomic DNA was extracted and purified as described by Iheukwumere et al. (2018), Iheukwumere *et al*. (2020) with the procedures outlined in the kit.

Determination of the quality of extracted DNA: Using mass spectrophotometer (Nanodrop), One micro litre (1µL) was aseptically dropped into a fresh space in the chamber and the chamber was lightly closed which was then linked to a computer system which showed the window that discovered the value of the sample at 260/280nm as described by (Iheukwumere *et al.*, 2017a; Chude *et al*., 2020).

Amplification of DNA and gel electrophoresis of PCR product: This was analysed using Master cycler Nexus Gradient (Eppendorf). A mixture of primer (20 µL), template DNA (20µL), water (72 µL) and master mix (108 µL), which comprises taq polymerase, dimethylsulfoxide (DMSO), magnesium chloride ($MgCl_2$) and nucleotides triphosphates (NdTPs), was made in 1.5 mL tube and homogenized using vortex mixer (Eppendorf). This was then positioned in the block chamber of the master cycler and then programmed. The PCR program for conditions were as follows: initial incubation at 94℃ for 5 mins, followed by 35 cycles of denaturation at 94℃ for 15 secs, annealing at 55℃ for 15 secs, elongation at 72℃ for 21 secs and final extension period for 10 mins at 72℃. The amplified products were electrophorezed in 1.0% agarose gel and a1kb DNA ladder was used as a size reference. After staining with 3µL of nucleic acid stain (GR green), the gel was documented with gel documentation apparatus (Iheukwumere *et al.*, 2017b; Iheukwumere *et al*., 2017c; and Iheukwumere *et al*., 2018b).

DNA sequencing of 16s rRNA fragment: The 16S rRNA amplified PCR products generated from universal primer (16S), was used for the sequencing using ABI DNA sequencer (Applied Biosystem Inc) at International Institute of Tropical Agriculture (IITA), Ibadan using the method of Iheukwumere *et al*. (2017d), and Iheukwumere *et al*. (2018c).

Computational Analysis: This was analysed making use of the modified method of Iheukwumere *et al*. (2025i) and Iheukwumere *et al*. (2025j). The chromatograms generated from the sequences were cleaned to obtain regions with normal sequences. The cleaned nucleotides were aligned using pair wise alignment tool. The consensus sequences formed by the alignment of the forward and reverse

sequences were used to perform the Basic Local *Alignment* Search Tool (BLAST) using National Centre for Biotechnology Information BLAST over the internet. The sequences of the isolates with 95% and above similarities were accepted. Also the maximum scores, total scores and accession numbers of the isolates were assessed. The relatedness of the isolates was determined by tracing their phylogenetic tree using DNA distance neighbour phylogenetic tree tool.

Preparation of Feed Supplement

Preparation of the chicken feather

The chicken feather was properly collected from the appropriate sites, washed and air dried. The material was ground using an electrical blender, packed in 500 ml beaker (PYREX) sealed with aluminium foil and then autoclave at 121^0C for 15 min at 15psi.

Fermentation Process

This was carried out using the modified method of Iheukwumere *et al*. (2017), Iheukwumere *et al* (2022) and Iheukwumere *et al*. (2025k). After autoclaving, a 100 g of the sterile sample was weighed into another 250 ml beaker (PYREX) using analytical weighing balance, which was properly sterilized using electric oven at 180^0C for 2 h, This was then inoculated with the fermenter (10 ml) prepared and diluted to a turbidity that matched 0.5 MacFarland standard that was prepared by mixing 0.6mL of 1% $BaCl_2$. $2H_2O$ and 99.4 mL of 1% Conc. H_2SO_4. This was allowed for 7 days.

Storage and packaging

After fermentation, the fermented samples were aseptically dried using an electric oven at 80^0C for 7days**.** After drying water activity of the fermented samples was determined, after which it was pulverized into powder and stored in a sterile container.

Moisture Content Determination

A crucible was dried, cooled, and weighed (initial weight recorded as W1). Then, 2.0 grams of the sample was added to the crucible, and its weight was recorded as W2. The crucible with the sample was heated in an oven at 105℃ for 4 to 6 hours. After heating, the final weight of the crucible and its contents was measured (final weight recorded as W3). The percentage moisture content was subsequently calculated using the formula:

$$\%\ \text{moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1}$$

Experimented Rats: A total of twenty four (24) rats (3 weeks old) were purchased from poultry market located at Ihiala market, Ihiala L. G. A. in Anambra State were used for the study. The rats were kept in separate, thoroughly cleaned and disinfected house and provided with feeds and water ad libitum. All the chicks were vaccinated against Newcastle disease using Lasota vaccine strains at 6 and 19 days of age, against infectious bronchitis using live H120 strain at 6 days old and also against avian influenza (A1) disease using inactivated H5N1virus vaccine strain at 7 days old. All the vaccines were given via eye drop instillation except (A1) vaccine, which was given through the subcutaneous route at the back of the neck from the folder report collected from the poultry farmer.

Feed Additive

The fermented chicken feather and the feed in a ratio of 1:20. This mixture was properly and thoroughly mixed and administered to the rats. The rats were divided into two groups (A and B). Group A was given the *Lactobacillus* fermented feed, whereas Group B was given only the feed. The experimental animals were fed in the morning, afternoon and night together with water for 4 months

Experimental protocols for the *in vivo* models: A total of 36 albino Wistar rats were used for this study. The rats were grouped into six groups, and each group comprises 6 rats. The body weights and blood absolute lymphocytes were assessed from the blood samples drawn from the rats after 11 days.

Blood lipoproteins: The blood samples collected from the rats were examined using an Automated Hematology Analyzer (MIN DRAY BC – 360), and the variations in the red blood cells (RBCs), lymphocytes, monocytes, neutrophils, eosinophils and basophils were assessed and recorded as described in the work published by Ejike *et al.* (2017), Nwobodo *et al*. (2018) and Ekesiobi *et al*. (2025).

Lymphocytes: The blood samples collected from the rats were examined using Automated Hematology Analyzer (MIN DRAY BC – 360), and the differential white blood cell (WBC) counts were carried out and the percentage of lymphocytes were calculated. The absolute lymphocytes were calculated as stated below, assessed and recorded as described in the work published by Agiang *et al.* (2017)

Statistical Analysis: The data obtained in this study were presented in tables and figures. Their percentages were also calculated. The sample means and standard deviations of some of the analytical data were also calculated. The significance of this study was determined at 95% using one way analysis of variance (ANOVA). Pairwise comparison was analyzed using student "t" test.

Results

The cultural and morphological characteristics of the fermenter are shown in Table 1. The result revealed that isolate P showed cream white appearance on MRS agar with a low convex elevation, smooth edge, and surface. The isolate has a Gram-positive rod, non-sporing and non-motile rods. The biochemical characteristics of the fermenters revealed that isolate P was catalase, citrate, oxidase, urase, gelatin, methyl red, Voges Proskauer negative. The isolate showed complex utilization to glucose, lactose, maltose and fructose while it was unable to utilize xylose and sorbitol. The isolate showed varying utilization to D mannitol, inositol, Trehalose and Dulcitol as shown in table 2. The nucleic acid extracted from the fermenters revealed that it was deoxyribonucleic acid (DNA) at the ratio of 260nm/280nm, ranging from 1.80-1.83, as shown in Table 3. The molecular characteristics of the fermenter reveal the presence of *Lactobacillus acidophilus* strain DSM20079

chromosome with a complete genome (LADSM) as shown in Table 4.

The blood lipoproteins of the fermented feather meal significantly (P<0.05) reduced the lipid profile levels of the test group of rats compared to the control group, as shown in Table 5.

The total lymphocyte level of the rats shows that the mean lymphocyte count of the untreated control group was 152.16, but the administration of dexamethasone (200 mg/g), which is an immunosuppressant, revealed a significant (P<0.05) reduction in the lymphocyte count (113.82) compared to the untreated control group. Also, when the control group was treated with levamisole (50 mg/g), there was a highly significant (P<0.05) increase in the lymphocyte count (273.15) compared to the normal control group. But when the test group was treated with 100 mg/g of chicken feather, there was an increase in the lymphocyte count (271.86) compared to the normal control group, but this was non-significant (P>0.05) to the control group treated with levamisole as shown in Table 6.

Table 1: Cultural and morphological characteristics of the fermenter

Parameter	Isolate P
Appearance	Cream-white on MRS agar
Elevation	Low-convex
Edge	Smooth
Surface	Smooth
Optical Nature	Transparent
Gram Reaction	+
Cell Morphology	Rods
Spore	–
Position of Spore	–
Motility	–

+ + Positive; - = Negative

Table 2: Biochemical characteristics of the fermenters

Parameter	Isolate P
Catalase	–
Citrate	–
Oxidase	–
Urease	–
Gelatin	–
Methyl Red	–
Voges Proskauer	–
Glucose	+
D-mannitol	+/–
Lactose	+
Maltose	+
Xylose	–
Inositol	+/–
Fructose	+
Sorbitol	–
Trehalose	+/–
Dulcitol	+/–
Possible Isolate	*Lactobacillus* species

Table 3: Authentication of nucleic acids extracted from the fermenters

Sample ID	Nucleic Acid Conc(µg/mL)	260 nm	280 nm	260/280
P	142.40	3.1915	1.7440	1.83

Table 4: Molecular identities of the fermenters

Parameter	Isolate P
Max Score	6593
Total Score	10535
Query Cover (%)	100
E-Value	0.0
Identity (%)	100
Accession Length	2009973
Accession Number	CP020620.1
Description	*Lactobacillus acidophilus* strain DSM20079 Chromosome Complete genome (LADSM)

Table 5: lipid profiles of rats

Parameter	Control group	Test group
CT (mg/dL)	158.40	147.50
LDL – C (mg/dL)	40.15	28.45
HDL-C (mg/dL)	52.60	64.15
TG (mg/dL)	122.15	91.75

Table 6: Total lymphocyte level

Group	Dose (mg/g)	Mean lymphocytes
Control (Normal)	-	152.16 ± 1.02
Control (Dexamethasome)	200	113.82 ± 1.12
Control (Levamisole)	50	273.15 ± 1.21
Test	100	271.86 ± 1.03

DISCUSSION

Lactobacillus is a diverse genus of Gram-positive, non-spore-forming, rod-shaped bacteria that are facultative anaerobes and predominantly produce lactic acid through the fermentation of carbohydrates (Tufail *et al*., 2011). Their ability to ferment carbohydrates by producing beneficial metabolites, which aid and support gut health and boost immune response, has gained significant insight (Mannan *et al*., 2017). This present study concentrates on the corollary of *Lactobacillus* fermented chicken feather on the blood lipoprotein and total lymphocyte level in rats. The cultural, morphological and biochemical characteristics of the *Lactobacillus* species agree with the findings of many researchers (Tufail *et al*., 2011; Mannan *et al*., 2017; Divisekera *et al*., 2019; and Celik *et al*., 2021) who isolated and characterized *Lactobacillus* species from yoghurt and banana. The ability of the isolates to utilize common sugars such as glucose, lactose, sucrose, maltose and some alcoholic sugars such as mannitol, sorbitol and xylitol indicates their potential to produce beneficial metabolites which support gut health and aid food fermentation. These potentials were also described by many researchers (Tufail *et al*., 2011; Mannan

et al., 2017; Divisekera *et al*., 2019; and Celik *et al*., 2021). The molecular characterization of the *Lactobacillus* species revealed the presence of *Lactobacillus acidophilus* strain DSM20079 (LADSM). The occurrence of *Lactobacillus acidophilus* in strains had been reported by Li *et al*. (2011), Anjum *et al*. (2014), and Mannan *et al.* (2017), who stated that the occurrence may be due to antagonism.

The results of the blood lipoprotein revealed that the *Lactobacillus* fermented feather supplement was able to reduce the lipid levels of the rats, and these findings corroborated with the findings of many researchers (Alahayaribeik *et al*., 2022; Xu *et al*., 2023; Yu *et al*., 2024) who evaluated the effect of *Lactobacillus* fermented feather meal on the lipid profile of rats. The results obtained from the study revealed that *Lactobacillus* fermented chicken feathers significantly improved the production of blood lymphocytes in the lymphoid organ and this was in line with the findings of most researchers (Zhu *et al*., 2020; Hossain *et al*., 2025; and Safri *et al*., 2025) who investigated the effect of *Lactobacillus* fermented feather meal on blood lymphocytes of rats, but findings disagree with the findings of Cabel *et al*. (1998) and Sjofjan *et al*. (2021) who reported the that fermented feather meal did not affect blood lymphocytes.

Conclusion

Lactobacillus fermented chicken feather meal significantly reduced lipid profiles and modulated blood lymphocyte counts in rats, exhibiting potential as a nutritious feed supplement with cardiovascular and immunomodulatory benefits, warranting further research for optimal utilization in animal nutrition and potential human health applications.

Acknowledgments

We are grateful to all our study participants who join the study voluntarily. We are grateful to ZAHARM Analytical and Research Laboratory, Amawbia, Awka Anambra State, Nigeria for providing enabling environment, resources and techniques for this study. We really salute their wonderful efforts.

Conflict of interests: The authors declare that they have no conflict of interests.

Funding: This research did not receive specific grant from any funding agencies.

References

Alahyaribeik, S., Nazarpour, M., Tabandeh, F., Honarbakhsh, S., & Sharifi, S. D. (2022). Effects of bioactive peptides derived from feather keratin on plasma cholesterol level, lipid oxidation of meat, and performance of broiler chicks. *Tropical Animal Health and Production*, *54*(5), 271

Amadi, R.E., Iheukwumere, I.H. and Unaeze, B.C. (2017). Effects Of Crude Alkaloid Extracted From Ocimum Gratissimum On The Activity Of Ciprofloxacin Against Salmonella Enterica Serovar Typhi. *Advances in Life Science and Technology* 58.

Anjum, N., Maqsood, S., Masud, T., Ahmad, A., Sohail, A., & Momin, A. (2014). Lactobacillus acidophilus: characterization of the species and application in food production. *Critical reviews in food science and nutrition*, *54*(9), 1241-1251.

Cabel, M. C., Goodwin, T. L., & Waldroup, P. W. (1988). Feather meal as a nonspecific nitrogen source for abdominal fat reduction in broilers during the finishing period. *Poultry Science*, *67*(2), 300-306.

Celik, O. F., Con, A. H., Saygin, H., Şahin, N., & Temiz, H. (2021). Isolation and identification of lactobacilli from traditional yogurts as potential starter cultures. *LWT*, *148*, 111774.

Chude,C.O., Iheukwumere, I.H., Iheukwumere, C.M., Nwaolisa,C.N., Egbuna, C.,Nwakoby, N.E.and Egbe, P.A. (2020). Cidal activity of proteins secreted by *Bacillus thuringensis* against *Ascaris lumbricoides*. *International Journal of Research Publications* 49(1): 1033 – 1045.

Dim, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Ugwu, C. H., Ike, V. E., Ezendianefo, . J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025a). Multiple Antibiotic Resistance Bacterial Strains in Frozen Meat Sold at Abagana, Anambra State: A Public Health Concern. *IPS Journal of Applied Microbiology and Biotechnology*, *4*(3), 181–186. https://doi.org/10.54117/ijamb.v4i3.75

Dim, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Ugwu, C. H., Ike, V. E., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025b). The Burden of Antibiotic Resistance: Evaluating the Impact of Multiple Antibiotic-Resistant Enteric Bacteria in Academic Environments. *IPS Interdisciplinary Journal of Biological Sciences*, *4*(4), 144–149. https://doi.org/10.54117/iijbs.v4i4.78

Dim, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Ugwu, C. H., Ike, V. E., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025c). Antimicrobial resistance in aquaculture: evaluating pseudomonas aeruginosa from fish ponds. *IPS Intelligentsia Multidisciplinary Journal*, *4*(1), 32–36. https://doi.org/10.54117/iimj.v4i1.10

Divisekera, D. M. W. D., Samarasekera, J. K. R. R., Hettiarachchi, C., Gooneratne, J., Choudhary, M. I., & Gopalakrishnan, S. (2019). Isolation and identification of lactic acid bacteria with probiotic potential from fermented flour of selected banana varieties grown in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, *47*(1).

Egbe, P. A., Umeaku, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Onwuasoanya, U. F., Ezenwata, I. S., Afulukwe, S. C., Ike, V. E., & Ezeumeh, E. N. (2025a). Antibiotic Susceptibility of Helicobacter pylori Isolates from Patients at Nnewi Teaching Hospital, Anambra State. *IPS Journal of Basic and Clinical Medicine*, 2(2), 51–57. https://doi.org/10.54117/ijbcm.v2i2.11.

Egbe, P. A., Umeaku, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Onwuasoanya, U. F., Ezenwata, I. S., Afulukwe, S. C., Ike, V. E., Ezeumeh, E. N., & Egbuna, C. (2025b). Helicobacter pylori Inhibition by Medicinal Plant Extracts: An In Vitro Assessment. IPS Journal of Drug Discovery Research and Reviews, 3(1), 32–37. https://doi.org/10.54117/ijddrr.v3i1.28.

Egbe, P. A., Umeaku, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Onwuasoanya, U. F., Ezenwata, I. S., Afulukwe, S. C., Ike, V. E., & Ezeumeh, E. N. (2025c). Medicinal Plant Extracts Enhance Conventional Antibiotic Activity against Helicobacter pylori: An In Vitro Assessment. IPS Interdisciplinary Journal of Biological Sciences, 4(2), 93–99. https://doi.org/10.54117/iijbs.v4i2.51.

Ejike, C.E., Iheukwumere, I.H. and Armadi, R.E. (2017). Susceptibility of Escherichia coli Isolated from Oligospermia Patient to *Gongronema latifolium* leaves extract. J. *Biol. Agriculture. Healthcare* 7(14).

Ekechukwu, C. C., Umeh, S. O., Iheukwumere, I. H., & Iheukwumere, C. M. (2025a). Bacterial Loads of Smoked Fish and Chicken: Role of pH and Moisture Content. *IPS Applied*

Journal of Nutrition, Food and Metabolism Science, 3(1), 44–49. https://doi.org/10.54117/iajnfms.v3i1.102.

Ekechukwu, C. C., Umeh, S. O., Iheukwumere, I. H., & Iheukwumere, C. M. (2025b). Biological Inhibition of Pathogenic Bacteria Isolated from Smoked Fish and Chicken: An In Vitro Study. IPS Interdisciplinary Journal of Biological Sciences, 4(2), 85–92. https://doi.org/10.54117/iijbs.v4i2.50.

Ekechukwu, C. C., Umeh, S. O., Iheukwumere, I. H., & Iheukwumere, C. M. (2025c). Prophylactic Potential of the Most Potent Synergistic Biological Agent against Bacterial Infections from Smoked Fish and Chicken. IPS Journal of Applied Microbiology and Biotechnology, 4(2), 153–160. https://doi.org/10.54117/ijamb.v4i2.57.

Ekesiobi, A. O., Iheukwumere, C. M., Iheukwumere, I. H., Ejike, C. E., Ilechukwu, C. C., Ike, V. E., Okereke, F. O., & Ochibulu, S. C. (2025). Hyping the Inhibitory Activity of Xylopia aethiopica against Vibrio cholerae using Azithromycin. IPS Journal of Basic and Clinical Medicine, 2(3), 93–98. https://doi.org/10.54117/ijbcm.v2i3.16

Hidayat, C., Darmawan, A., Astuti, D. A., Supriyati, S., and Wina, E. (2021). The role of short-chain fatty acids in lipid metabolism of poultry: A review. *Veterinary World*, 14(4), 1079–1087. https://doi.org/10.14202/vetworld.2021.1079-1087

Hossain, H., Nuradji, H., Miah, M. Y., Islam, M. N., & Siddiqui, M. S. I. (2025). Impact of synbiotic on growth performance, histo-architectural modulation of lymphoid organ, hematology, blood biochemistry and humoral immune response in naked neck chicken. *Tropical Animal Health and Production*, *57*(1), 4.

Iheukwumere, C. M., & Iheukwumere, I. H. (2022a). Nutritive and Antinutrient Values of Soybean Condiments Produced from Indigenous Fermenters. *IPS Applied Journal of Nutrition, Food and Metabolism Science*, 1(1): 1-5. https://doi.org/10.54117/iajnfms.v1i1.8

Iheukwumere, C. M., & Iheukwumere, I. H. (2022e). Hematological indices and sensory quality of fermented soybean condiments. *World Journal of Advanced Research and Reviews*, 14(2), 435-42

Iheukwumere, C. M., Ekesiobi, A. O., Iheukwumere, I. H., Ejike, C. E., Ilechukwu, C. C., Dim, C. N., & Ochibulu, S. C. (2025g). Dual Approach Therapy: Assessing Xylopia aethiopica and Ciprofloxacin Synergy against Salmonella enterica Serovar Typhi. *IPS Intelligentsia Multidisciplinary Journal*, *4*(1), 27–31. https://doi.org/10.54117/iimj.v4i1.9.

Iheukwumere, C. M., Ekesiobi, A. O., Iheukwumere, I. H., Ejike, C. E., Ilechukwu, C. C., Dim, C. N., Ochibulu, S. C., Unegbu, C. C., & Egbuna, C. (2025h). Food Safety Implications: Assessing the Potential of Desmodium velutinum Leaves Extracts to Control the Most Predominant Fungal Contamination in Ready-To-Eat Fried Chicken. *IPS Journal of Nutrition and Food Science*, *4*(3), 494–500. https://doi.org/10.54117/ijnfs.v4i3.111

Iheukwumere, C. M., Iheukwumere, I. H., Okoli, U. O., & Ugwu, C. H. (2023a). Immunological Impact of Fermented Soybean Condiments Produced from Indigenous Fermenters. *Journal of Advances in Microbiology* 23(10): 27-37

Iheukwumere, C. M., Iheukwumere, I. H., Ugwu, C. H., & Okoli, U. O. (2023b). Toxicity of Prepared Fermented Soybean Condiments from Indigenious Fermenters. *Journal of Advances in Microbiology* 23(10): 38 – 51.

Iheukwumere, C. M., Umeaku, C. N., Chukwura, E. N., & Iheukwumere, I. H. (2022f). Characterization of the indigenous fermenters for the production of fermented condiments from soybean seeds. *World Journal of Advanced Research and Reviews*, *14*(2), 423-434.

Iheukwumere, I. H., & Ejike, C. E. (2017b). Comparative study of the inhibitory activities of Ocimum gratissimum and Nepeta cataria against Salmonella enterica serovar Typhi and their larvicidal effect against Anopheles gambiae. *African Journal of Education, Science and Technology (AJEST)*, *3*(4), 16-24

Iheukwumere, I. H., Ajeh, J. C., Iheukwumere, C. M., Ike, V. E., Obianom, A. O., Ihenatuoha, U. A. ., Igboanugo, E. U., Onwuasoanya, U. F., Okereke, F. O., Nnadozie, C. H., Agbaugo, C. F., Nwike, M. I., Nwakoby, N. E., & Ilechukwu, C. C. (2025c). Exploring the Phytochemical and Antimicrobial Properties of Fruit Vinegar: A Study on Phoenix Dactylifera and Malus Sylvestris. *IPS Journal of Applied Microbiology and Biotechnology*, 4(1), 115–122. https://doi.org/10.54117/ijamb.v4i1.48

Iheukwumere, I. H., Ajeh, J. C., Iheukwumere, C. M., Ike, V. E., Obianom, A. O., Ihenatuoha, U. A., Igboanugo, E. U., Onwuasoanya, U. F., Okereke, F. O., Nnadozie, C. H., Agbaugo, C. F., Nwike, M. I., Nwakoby, N. E., & Ilechukwu, C. C. (2025d). Microbial Quality and Sensory Assessment of Vinegar from Date Palm and Apple Fruits: Implications for Consumer Preference. IPS Journal of Nutrition and Food Science, 4(2), 410–417. https://doi.org/10.54117/ijnfs.v4i2.100.

Iheukwumere, I. H., Ajeh, J. C., Iheukwumere, C. M., Ike, V. E., Obianom, A. O., Ihenatuoha, U. A., Igboanugo, E. U., Onwuasoanya, U. F., Okereke, F. O., Nnadozie, C. H., Nwike, M. I., Nwakoby, N. E., & Ilechukwu, C. C. (2025f). Safety Evaluation of Vinegar from Phoenix Dactylifera and Malus Sylvestris: Toxicity and Acetic Acid Content. IPS Journal of Applied Microbiology and Biotechnology, 4(1), 123–131. https://doi.org/10.54117/ijamb.v4i1.49

Iheukwumere, I. H., Ajeh, J. C., Iheukwumere, C. M., Ike, V. E., Obianom, A. O., Ihenatuoha, U. A. ., Igboanugo, E. U., Onwuasoanya, U. F., Okereke, F. O., Nnadozie, C. H., Agbaugo, C. F., Nwike, M. I., Nwakoby, N. E., & Ilechukwu, C. C. (2025k). Exploring the Phytochemical and Antimicrobial Properties of Fruit Vinegar: A Study on Phoenix Dactylifera and Malus Sylvestris. *IPS Journal of Applied Microbiology and Biotechnology*, 4(1), 115–122. https://doi.org/10.54117/ijamb.v4i1.48

Iheukwumere, I. H., Amadi, E. R., & Chude, C. (2018b). Synergistic Effects of Probiotics and Autogenous Bacterin Against Inositol Negative Motile Salmonella Species. *Journal of Biology, Agriculture and Healthcare* 8(6).

Iheukwumere, I. H., Amadi, R. E., Unaeze, B. C., & Campus, N. (2017c). Enterotoxigenicity Profile of Salmonella Enterica Serovar Typhimurium in Suckling Albino Mice. Journal of Natural Sciences Research 7(14).

Iheukwumere, I. H., Chukwura, E. I., & Chude, C. (2018c). In vivo activities of some selected antimicrobial agents against enteric bacteria isolated from chicken feeds on broiler layers. *Journal of Biology, Agriculture and Healthcare*, *8*(6).

Iheukwumere, I. H., Ejike, C. E., & Okeke, C. E. (2017d). A trial to prevent sorbitol negative Escherichia coli infections in chicks using autogenous bacteria and probiotics. *Journal of Natural Sciences Research*, *7*, 56-63.

Iheukwumere, I. H., Iheukwumere, C. M., Obianom, A. O., Nnadozie, C. H., Okereke, F. O., Onwuasoanya, U. F., … Ihenatuoha, U. A. (2025a). Cross-Sectional Study of Different Strains of Bacillus cereus among Pap Sold in Major Towns in Ihiala LGA, Anambra State. IPS Journal of Public Health, 5(2), 199–204. https://doi.org/10.54117/ijph.v5i2.39.

Iheukwumere, I. H., Iheukwumere, C. M., Obianom, A. O., Nnadozie, C. H., Okereke, F. O., Onwuasoanya, U. F., … Destiny, E. C. (2025b). Cross-Sectional Study of Major Strains of Salmonella enterica Subspecies Enterica Serovar Typhi among Borehole Used in Uli Community. IPS Journal of Public Health, 5(2), 205–210. https://doi.org/10.54117/ijph.v5i2.40.

Iheukwumere, I. H., Iheukwumere, C. M., Obianom, A. O., Nnadozie, C. H., Okereke, F. O., Onwuasoanya, U. F.,

Udeagbara, O. E., Unaeze, B. C., Obiefuna, O. H., Ike, V. E., Onyemekara, N. N., & Ihenatuoha, U. A. (2025e). Quotidian of Substantial Strain of Shigella dysenteriae among Ready To-Eat Fruit Salad Sold in Uli Community. Journal of Pollution Monitoring, Evaluation Studies and Control, 4(1), 95–99. https://doi.org/10.54117/jpmesc.v4i1.17

Iheukwumere, I. H., Iheukwumere, C. M., Obianom, A. O., Nnadozie, C. H., Okereke, F. O., Onwuasoanya, U. F., … Ihenatuoha, U. A. (2025i). Cross-Sectional Study of Different Strains of Bacillus cereus among Pap Sold in Major Towns in Ihiala LGA, Anambra State. IPS Journal of Public Health, 5(2), 199–204. https://doi.org/10.54117/ijph.v5i2.39.

Iheukwumere, I. H., Iheukwumere, C. M., Obianom, A. O., Nnadozie, C. H., Okereke, F. O., Onwuasoanya, U. F., … Destiny, E. C. (2025j). Cross-Sectional Study of Major Strains of Salmonella enterica Subspecies Enterica Serovar Typhi among Borehole Used in Uli Community. IPS Journal of Public Health, 5(2), 205–210. https://doi.org/10.54117/ijph.v5i2.40.

Iheukwumere, I. H., Iheukwumere, M. C., & Nwakoby, N. E. (2022d). Sequential Pathogenicity Study of SOR+ and SOR- Escherichia coli Isolated from Roasted Meat. *IPS Intelligentsia Multidisciplinary Journal*, *1*(1), 1-11.

Iheukwumere, I. H., Obi, P. C. and Unaeze, B. C. (2017a). A trial to prevent *Vibrio cholerae* in albino mice using autogenous bacterin. *Advances in Life Science and Technology* 58:34–42

Iheukwumere, I. H., Uneze, B. C., & Ejike, C. E. (2017e). Efficacy of some selected antimicrobial substances in prevention of enteric bacterial infection in broiler chicks. *J. Biol. Agriculture. Healthcare*, *7*, 58-66.

Iheukwumere, I.H and Umedum, C.U. (2014). A Study on The Ecology of Dematiaceous Fungi in Awka and Its Environs. *Journal of Applied Sciences* 17 (1): 11148 – 11157.

Iheukwumere, I.H. , Iheukwumere, C.M. , Nnadozie, H. C. ,Unaeze, C.B. , Obiefuna, O.H. Obianom, A.O. and Ejike, C. E. (2024). Hematotoxicological and mosquito larvicidal studies of crystal proteins secreted by Bacillus thuringiensis and Bacillus sphaericus. *Tropical Journal of Applied Natural Sciences* 2(2): 61 – 92.

Iheukwumere, I.H. and Iheukwumere, M.C. (2022c). Streptococcus suis in Pigs and Environs: A Cross-sectional Study. IPS Journal of Public Health, 1(2), 9-12. https://doi.org/10.54117/ijph.v1i2.4.

Iheukwumere, I.H. and Iheukwumere, M.C. (2022g). Cross-sectional Study of Multiple Antibiotic-resistant Streptococcus suis in Pigs and Environments. IPS Interdisciplinary Journal of Biological Sciences, 1(1), 19–21. https://doi.org/10.54117/iijbs.v1i1.4

Iheukwumere, I.H., Dimejesi, S.A.,Iheukwumere, C.M., Chude, C.O., Nwaolisa, C.N.,Ukoha, C.C., Nwakoby,N.E., Egbuna, C. and Egbe, P.A. (2020) Diversity and molecular characterization of keratinophilic fungi from soil samples. *International Journal of Research Publication* 50(1); 1047 - 1062.

Iheukwumere, I.H., Iheukwumere, M.C. and Nwakoby, N.E. (2022b). Synergistic Effects of Probiotics and Autogenous Bacterin against Salmonella enterica Serovar Typhimurium Strain U288. IPS Journal of Nutrition and Food Science, 1(1), 1–5. https://doi.org/10.54117/ijnfs.v1i1.3.

Iheukwumere, I.H., Nwike, M. I., Iheukwumere, C.M., Ike, V.E., Obianom, A.O., Ihenatuoha, U.A., Igboanugo, E.U., Ekesiobi, A.O., Okereke, F.O., Obiefuna, O. H. Nnadozie, C.H., Agbaugo, C.F., Oduoye, O.T., Nwakoby, N.E., Ilechukwu, C. C.,, Ochibulu, S. C. and Ejike, C. E. (2025l). Extraction and Elucidation of Antibiotics from the Mycelia of Aspergillus niger Isolated from Poultry Farm against Enteric Bacterial Pathogens. *IPS Journal of Advanced and Applied Biochemistry*, 1(1), 1–10. https://doi.org/10.54117/ijaab.v1i1.58.

Iheukwumere,I.H., Iheukwumere,C.M., Chude, C.O., Nwaolisa,C.N. and Egbe, P.A. (2020a). Comparative study of different clinical samples used for the diagnosis of staphylococcal systemic infections in appearent healthy students. *International Journal of Research Publications* 49(1): 1 – 10

Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025a). Prevalence of Bacillus cereus in Powdered Soybean Sold in Uli Community, Anambra State: A Cross-Sectional Study. *IPS Journal of Basic and Clinical Medicine*, *2*(3), 108–114. https://doi.org/10.54117/ijbcm.v2i3.18

Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025b). *Bacillus cereus in Uli's cornflour: A prevalence study*. *IPS Journal of Nutrition and Food Science*, *4*(3), 544–548. https://doi.org/10.54117/8btte840

Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025c). Pathogenic Profile Analysis: In Vitro Screening of Enteric Bacteria from University Dusters. *IPS Journal of Applied Microbiology and Biotechnology*, *4*(3), 187–191. https://doi.org/10.54117/ijamb.v4i3.76

Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025d). Frozen Fish Pathogens: Antimicrobial Resistance and Public Health Implications. *IPS Interdisciplinary Journal of Biological Sciences*, *4*(4), 138–143. https://doi.org/10.54117/iijbs.v4i4.77

Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025e). Stream water quality assessment: Antibiotic resistance of Lac-positive enteric bacterial isolates. *Journal of Pollution Monitoring, Evaluation Studies and Control*, *4*(2), 120–125. https://doi.org/10.54117/jpmesc.v4i2.21.2025

Karthikeyan, R., Balaji, S., and Rajendran, R. (2019). Microbial keratinases and their prospective applications: An overview. *Applied Microbiology and Biotechnology*, 103(15), 6015–6036. https://doi.org/10.1007/s00253-019-09956-4

Li, Y., Guo, B., Wu, Z., Wang, W., Li, C., Liu, G., & Cai, H. (2020). Effects of Fermented Soybean Meal Supplementation on the Growth Performance and Cecal Microbiota Community of Broiler Chickens. *Animals*, *10*(6), 1098. https://doi.org/10.3390/ani10061098

Manasseh, C.O., Logan, C.S.P., Ikeyi, A.P., Ede, K.K., Iheukwumere, I.H., Iheukwumere, C.M. and Ejike, C.E. (2025). Investigating the Effects of the Covid-19 Pandemic and Climate Risks on Trade Balance in Emerging Markets. *The Nigerian Health Journal* 25(2): 1-27. https://doi.org/10.71637/tnhj.v25i2.914

Mannan, S. J., Rezwan, R., Rahman, M. S., & Begum, K. (2017). Isolation and biochemical characterization of Lactobacillus species from yogurt and cheese samples in Dhaka metropolitan area. *Bangladesh Pharmaceutical Journal*, *20*(1), 27-33.

Nwike, M.I., Iheukwumere, I.H. and Uneze, B.C. (2017). Effect of Spices, pH and Temperature on the Survival and Multiplication of Staphylococcus aureus in Locally Made Soya Milk Drink. *Journal of Natural Sciences Research* 7(4).

Obianom, A.O. , Iheukwumere, I.H. , Iheukwumere, C.M. , Ochibulu, S.C., Nnadozie, H. C. and Ifenetu, F. C. (2024). Supersizing the inhibitory activity of Xylopia aethiopica extract

against Vibrio cholerae using doxycycline. *Tropical Journal of Applied Natural Sciences* 2(2).

Okeke, C. E. Iheukwumere, I. H. Ejike, C.E. (2017). Pathogenicity Study of Dematiaceous Fungi Isolated from Chicken Feeds on Immunoincompetent Chickens. *J. Biol. Agriculture. Healthcare* 7(4).

Patel, R. M., Shah, N. P., and Prajapati, J. B. (2018). Impact of probiotics on cholesterol metabolism: A review. *Critical Reviews in Food Science and Nutrition*, 58(14), 2496–2514. https://doi.org/10.1080/10408398.2017.1322553

Safari, H., Mohit, A., & Mohiti-Asli, M. (2024). Fermented feather meal improves the antioxidant status, meat quality, and immune response of broilers. *Iran J Vet Med*, 1-43.

Safari, H., Mohit, A., & Mohiti-Asli, M. (2024). In vitro and in vivo evaluation of the nutritional value of various hydrolyzed feather meals and comparison of their effect on performance and carcass characteristics of broilers. *Heliyon*, *10*(21).

Sjofjan, O., Adli, D. N., Harahap, R. P., Jayanegara, A., Utama, D. T., & Seruni, A. P. (2021). The effects of lactic acid bacteria and yeasts as probiotics on the growth performance, relative organ weight, blood parameters, and immune responses of broiler: A meta-analysis. *F1000Research*, *10*, 183.

Sugiharto, S. (2016). Role of nutraceuticals in gut health and growth performance of poultry. *Journal of the Saudi Society of Agricultural Sciences*, 15(2), 99–111. https://doi.org/10.1016/j.jssas.2014.06.001

Tesfaye, T., Sithole, B., Ramjugernath, D., and Chunilall, V. (2017). Valorisation of chicken feathers: Characterisation of physical properties and morphological structure. *Journal of Cleaner Production*, 149, 349–365. https://doi.org/10.1016/j.jclepro.2017.02.083

Tufail, M., Hussain, S., Malik, F., Mirza, T., Parveen, G., Shafaat, S., ... & Sadiq, A. (2011). Isolation and evaluation of antibacterial activity of bacteriocin produced by Lactobacillus bulgaricus from yogurt. *African Journal of Microbiology Research*, *5*(22), 3842-3847.

Ugwu, C. H., Iheukwumere, I. H., Iheukwumere, C. M., Ike, V. E., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025a). Maternal health and antibiotic resistance: *Klebsiella pneumoniae* isolates analysis. *IPS Journal of Public Health*, *5*(3), 290–295. https://doi.org/10.54117/s3tx6v26

Ugwu, C. H., Iheukwumere, I. H., Iheukwumere, C. M., Ike, V. E., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025b). Ocimum gratissimum Extract's Effectiveness against Vibrio cholerae from Uli Streams. *IPS Journal of Phytochemistry and Medicinal Plant Research*, *1*(2), 15–19. https://doi.org/10.54117/ijpmpr.v1i2.38

Yu, L., Zhihui, C., Hongzhi, W., Fengjie, J., Yang, L., Jianing, L., ... & Liangmei, X. (2024). Effects of Fermented Puffed Feather Meal on Growth Performance, Serum Biochemical Indices, Meat Quality, and Intestinal Microbiota in Broilers. *Journal of Northeast Agricultural University*, *31*(3).

Zhu, F., Zhang, B., Li, J., & Zhu, L. (2020). Effects of fermented feed on growth performance, immune response, and antioxidant capacity in laying hen chicks and the underlying molecular mechanism involving nuclear factor-κB. *Poultry science*, *99*(5), 2573-2580.