



Animal Health Research Journal

P-ISSN : 2356-7767 On Line-ISSN : 2535-1524
Journal Homepage: <https://animal.health.ahri.gov.eg/>

Research Paper

Effect of *Lactobacillus plantarum* on some food poisoning bacteria in fresh raw beef sausage

Ghada, A. Abd Elhameed* and Zeinab, A.M. Mahdy**

*Food Hygiene Department, Animal Health Research Institute (Shebin ElKoom Branch), Agriculture Research Center (ARC), Egypt.

**Bacteriology Department, Animal Health Research Institute (Benha Branch), Agriculture Research Center (ARC), Egypt.

Received in 2/10/2025
Received in revised from 5/11/2025
Accepted in 2/12/2025

Keywords:

L. plantarum,
beef sausage,
S. aureus,
E. coli.

Abstract

This study assessed the bioprotective efficacy of *Lactobacillus plantarum* (8 log₁₀CFU/mL) against some food poisoning bacteria, like *Staphylococcus aureus* (6 log₁₀CFU/mL) and *Escherichia coli* (4 log₁₀CFU/mL) in fresh raw beef sausage stored at 4°C. Disc diffusion assays revealed dose-dependent inhibition, with zones of inhibition increasing from 5 mm within concentration (5 log₁₀CFU/mL) to 26 mm within (8 log₁₀CFU/mL) against *S. aureus* and from undetectable to 23 mm against *E. coli*. In inoculated sausages, *L. plantarum* markedly reduced pathogen counts, *S. aureus* from 6.5 to 2.07 log CFU/g and *E. coli* from 4.32 log CFU/g to undetectable by day 15 versus increases to log 8.23 and 5.91 CFU/g, respectively, in controls. Physicochemical analyses showed sustained stability in *S. aureus* and *E. coli* treated samples (by day 6 pH declining to 4.52-4.58, TBARS 0.46 - 0.37 mg MDA/kg and TVB-N 11.32-11.2 mg/100 g), respectively up to 15 days, compared to spoilage (pH >6.21, TBARS >0.89 mg MDA/kg, TVB-N >17.5 mg/100 g) and rejection by day 6 in untreated groups. Sensory scores (color, odor, texture and acceptability) remained acceptable (>5.0) through day 15 of storage in *L. plantarum*-treated sausages, versus rapid decline and rejection in controls. These findings position *L. plantarum* as an effective "clean label" probiotic for enhancing meat safety, shelf life and quality.

Introduction

Population growth and an increase in the number of individuals, combined with a decline in per capita income, have significantly influenced individual food preferences and led to

the emergence of new food products, particularly diverse meat products. The surge in consumer needs for reliable supplies of diverse, safe, high-quality foods emphasizes products with extended shelf life that maintain organo-

Corresponding author: Ghada, A. Abd Elhameed, Food Hygiene Department, Shebin El-Koom Branch, Animal Health Research Institute (AHRI) Dokki, Nadi El-Seid Street, Dokki P.O., Giza 12618, Egypt. Agriculture Research Center (ARC), Giza, Egypt.

Email address: drdodi_201088@yahoo.com

leptic and nutritional properties from manufacture to end-use. Stringent requirements for safety, quality, and sensory attributes must be upheld throughout (Saltmarch and Insall, 2013).

Sausages represent one of the most palatable products that have a broad front of consumers. However, Sausages are a complex and emulsified meat-based product that is sensitive to chemical interactions and microbial degradation. Meat products are susceptible to contamination by various microorganisms, which can endanger human safety (Niyonzima *et al.*, 2015). Pathogenic organisms that have historically been associated with outbreaks from beef consumptions include *S. aureus*, *Salmonella* spp., *L. monocytogenes*, *E. coli*, *C. jejuni*, *B. cereus*, and *Y. enterocolitica*. These pathogens are recognized for causing serious illness in consumers such as Salmonellosis, gastrointestinal diarrhea and listeriosis (Castellano *et al.*, 2008 and Prasad and Vidyarthi, 2009).

Heat treatment may get rid of pathogens, but contamination may still occur during production and pose risks of foodborne bacteria (Zeraat Pisheh *et al.*, 2023). Consumer demand to minimize synthetic preservatives has prompted the meat sector to investigate natural options derived from plants, animals and bacteria (Hugo and Hugo, 2015 and Novais *et al.*, 2022).

Utilization of probiotics like lactic acid bacteria, one of most common beneficial bacteria that is used in meat industry, increased greatly and become acceptable by the consumers due to their benefits (Elsabagh *et al.*, 2021 and Wang *et al.*, 2022). Those bacteria help in inhibiting and minimizing the growth of pathogenic bacteria through their ability in reducing pH, preventing toxins, and producing several inhibitory compounds (Moradi *et al.*, 2020 and Kaveh *et al.*, 2023). Moreover, it significantly boosts sausage flavor and texture characteristics and prolongs product shelf life. (Lin and Pan, 2017).

Lactobacillus plantarum represents one prominent member of LAB family, which possesses potential employed in commercial fermented meat products besides the fact that it has a high antioxidant potential in fermenting sausage

(Ayyash *et al.*, 2019). In modern food biotechnology, LAB are key for meat processing and preservation due to their ability to generate organic acids, peptides and bacteriocins. These compounds inhibit harmful pathogens and spoilage bacteria, boosting food safety, prolonging shelf life, elevating sensory characteristics and supporting health making them excellent replacements for chemical additives (Sivamaruthi *et al.*, 2025).

The current study focuses on measuring the consequence of addition of *L. plantarum* on the shelf life, physicochemical and sensory properties of meat sausage stored in chilling condition for 15 days.

Material and Method

Bacterial strains

Referenced pathogenic bacterial strains, including *E. coli* (Lot No: 020090, Des: NCTC: 12241 and ATCC: 25922), and *S. aureus* (Lot No: 460074, Des: NCTC: 10788 and ATCC: 6538), were obtained from Media Unit, Food Hygiene Department, Animal Health Research Institute, Dokki, Giza, Egypt. *L. plantarum* recorded with accession number (PP788561) in gene bank.

Preparation and the lowest potent concentration of the used *L. plantarum* against pathogenic strains:

The antibacterial effect of the used *L. plantarum* against the examined pathogenic strains established by using disc diffusion method pronounced by Topisirovic *et al.* (2006) and Boulares *et al.* (2012).

Tested *L. plantarum* was prepared through culturing on de Man Rogosa sharp (MRS) broth (TM media, TM 147) and incubated at 37 °C for 24 h. Then Make four dilutions from the tested *L. plantarum* (5 log₁₀, 6 log₁₀, 7 log₁₀, 8 log₁₀ CFU/ml) then inoculate 50µl from each dilution into sterile disc and let it to slightly dry, then place it into Mueller Hinton agar medium (TM media) inoculated with pathogenic bacteria (*E. coli* and *S. aureus*) with a count of 4 log₁₀CFU mL⁻¹ and 6 log₁₀CFU mL⁻¹ respectively. The produced zone of inhibition was measured to determine the most effective dilution to be used. According to Detha

et al. (2018), inhibition zone diameters were graded as follows: weak (5 mm), moderate (5–10 mm), strong (10–20 mm), and very strong (20–30 mm).

Preparation of beef sausage

Local beef meat (2 kg) sourced from a nearby slaughterhouse served as the base. The sausage recipe followed *Mejri et al.* (2017) with modifications—75% (w/w) beef and 25% (w/w) fat in place of camel meat minced via Panasonic mincer (Osaka, Japan). Per kg of mince: 10 g garlic, 4 g sucrose, 25 g salt (NaCl), and 30 g spice mix.

Prior to the experiment, the meat was exposed to ultraviolet light (UV) for 15 minutes at a wavelength of 385 nm in order to reduce background microflora according to (*Morsy et al.*, 2018).

Experimental part

Following the division of the produced mixture into five groups, cultured bacteria adjusted at 6 log₁₀ for *S. aureus*, 4 log₁₀ for *E. coli* and 8 log₁₀ for *L. plantarum* were added. The first group, noted as control, was UV-treated but not inoculated (control –ve); the second group was inoculated with *S. aureus*; the third group had *S. aureus* + *L. plantarum*; the fourth group was made up of *E. coli*; and the fifth group was *E. coli* + *L. plantarum*. Following inoculation, samples were allowed to adhere to cells at room temperature (22°C) for 15 minutes before being placed into a sterile polyethylene sausage casing using a portable sausage filling machine. Remaining bacterial populations, physicochemical characteristics, and sensory attributes were assessed at the start of the study and every three days until deterioration. Samples were stored at 4 ± 1°C. Each group underwent three repetitions of the current experiment in order to collect mean data for statistical analysis.

Sensory evaluation

Seven skilled panelists from the Food Hygiene and Control Department of the Animal Health Research Institute, Shebin Elkom, Egypt conducted a sensory evaluation of prepared sausage (control and inoculation groups) stored at 4°C in refrigerator. The descriptive organoleptic assessment criteria (color, odor and texture) are rated on continuous and numerical scales from 0 (the lowest score for each attribute,

very bad) to 9 (the highest score for each attribute, very good) using the triangle test and the psychological rating system. The scale points were used according to (*ISO 13299: 2016*).

Microbiological assay

At each sampling day, samples were opened and then 10 g from each one of them was aseptically transferred into 90 mL of 0.1% buffered peptone water (BPW, Neogen) and stomached (model seaward 400, circulator) for 1 minute. Ten-fold serial dilutions were made in BPW (Neogen) and 1 ml was poured on Eosin methylene blue (EMB, Himedia) for *E. coli* (*ISO 7251:2005/Amd 1: 2023*) and Baird parker (Oxoid) for *S. aureus* (*ISO 6888-1: 2003*). Colonies were counted after 24 hours of incubation at 37°C and expressed as log₁₀ CFU/gm-1.

Physico-chemical evaluation

PH value: -

In order to measure the pH using a digital pH meter (Suntex TS-1, Taiwan) with a probe-type combination electrode (In gold), 10 grams of beef sausage were homogenized and completely mixed with 100 milliliters of distilled water. The electrode was then directly dissolved into the mixture at room temperature according to the method recommended by *AOAC (2002)*.

Thiobarbituric acid – Reactive substances (TBARS) measurement:

The TBARS of the beef sausage was determined according to the method described by *Egyptian Organization for Standardisation "EOS" 63/9 (2006)*. The TBA values were expressed as mg malonaldehyde/kg of sample.

Total volatile basic nitrogen (TVBN):

The TVBN of the beef sausage was determined by the method described by *Egyptian Organization for Standardisation "EOS" 63/10 (2006)*.

Statistical analysis

Statistical analysis utilized GraphPad Prism software; results are shown as mean ± SD values. Inter-group comparisons employed one-way ANOVA, with significance set at P < 0.05. All assays were run in triplicate (*Peacock and Peacock, 2020*).

Results

The results present in **table (1)** demonstrated the antimicrobial activity of *L. plantarum* at varying concentrations (5 log₁₀ to 8 log₁₀ CFU/mL) against *S. aureus* (inoculum 6 log₁₀ CFU/mL) and *E. coli* (inoculum 4 log₁₀ CFU/mL) via disc diffusion assay. The data reveals a clear dose-dependent antibacterial effect. For *S. aureus*, inhibition zones increase progressively from 5 mm at 5 log₁₀CFU/mL to 26 mm at 8 log₁₀CFU/mL, indicating stronger activity at higher probiotic densities. While *E. coli* shows no detectable inhibition (ND) at 5 log₁₀CFU/mL but escalates to 23 mm at 8 log₁₀CFU/mL.

The results established in **table (2) & figure (1)** showed the sensory attributes (color, odor, texture and overall acceptability) of sausage stored at 4°C in which their declined rapidly in control (-ve) and pathogen-inoculated groups over 15 days, while the groups treated with *L. plantarum* preserved quality longer. Where all untreated samples become spoiled and unacceptable on 6th day of storage, the treated groups sustained scores above 5 until day 15, confirming bioprotective benefits of *L. plantarum* in extended shelf-life and consumer appeal.

By examining the effect of *L. plantarum* with concentration 8 log₁₀CFU/mL against the inoculated pathogenic strains *S. aureus* (inoculum 6 log₁₀ CFU/gm) and *E. coli* (inoculum 4 log₁₀ CFU/gm) in the examined sausage results in **table (3)** showed the progressive increase in the count of both strains over the control group within the storage period where *S. aureus* increased from (log 6.52 in day zero to log 8.23 in the day 15th) and *E. coli* increased from (log 4.41 in day zero to log 5.91 in the day 15th). While the groups treated with *L. plantarum* exhibit marked reduction in the bacterial counts as *S. aureus* decreased from (log 6.5 in day zero to log 2.07 in the day 15th) and for *E. coli* counts reduced from (log 4.32 in the day zero to undetectable (ND) levels by day 15), with reduction percent reached by day 15 to 74.85% in *S. aureus* treated group and 100% in *E. coli* treated group highlighting potent inhibition against these pathogens this cleared in **figure (2&3)**.

The results in **table (4)** demonstrated that pH

values in control group and groups inoculated with pathogenic bacteria were significantly different ($p \leq 0.05$) with those treated with *L. plantarum*. At zero day of storage, the pH values of all groups are similar at approximately (5.59-5.69). Then, the pH values increased reached to 6.21 ± 0.06 , 6.53 ± 0.07 and 6.6 ± 0.04 in control, *Staph aureus* and *E.coli* inoculated groups, respectively, while *L. Plantarum* treated sausages showed a decrease in its values as reached to 4.52 ± 0.06 and 4.58 ± 0.04 in *Staph aureus* and *E.coli* inoculated groups and treated with *L. plantarum*. As time progressed, the pH values of the two *L. Plantarum* treated groups slightly fluctuated, but not significantly ($p > 0.05$) and reached 5.41 ± 0.03 and 5.38 ± 0.11 in *Staph aureus* and *E.coli* groups treated with *L. plantarum*.

The results in **table (5)** obtained that TBARS content at 6th day of storage reached to 0.89 ± 0.06 , 1.01 ± 0.03 and 0.99 ± 0.04 in control, *Staph aureus* and *E.coli* inoculated groups, respectively, but lower TBARS content in *L. plantarum* treated groups at the same day of storage and reached to 0.46 ± 0.03 and 0.37 ± 0.02 in *Staph aureus* and *E.coli* treated groups, respectively. While, results in **table (6)** cleared that TVBN values at 6th day of storage reached to 17.5 ± 0.54 , 21.03 ± 0.54 and 20.7 ± 0.53 in control, *Staph aureus* and *E.coli* inoculated groups, respectively. Contrasting the lower TVBN content in groups supplemented with *L. plantarum* where it recorded 11.32 ± 0.33 and 11.2 ± 0.22 for *Staph aureus* and *E.coli*, respectively. Evaluation of physico-chemical properties extended to 6 days of storage in groups inoculated with pathogenic bacteria. Conversely, *L. plantarum*-treated groups underwent assessment for 15 days at 4°C refrigerated storage, terminating upon spoilage detection on the 15th day where the TBARS content reached to 0.80 ± 0.07 and 0.77 ± 0.05 and TVBN content reached to 18.4 ± 0.46 and 17.8 ± 0.51 in *Staph aureus* and *E.coli* groups treated with *L. plantarum*.

Discussion

Meat products are primarily populated by specific spoilage organisms that drive deterioration and so the explore for an alternative way to preserve them and elevate their profitability

increased gradually. The incorporation of safe probiotic is the most preferable method in order to enhance their possible health impacts (Cavalheiro *et al.*, 2015). People around the world are becoming more conscious of the link between health and nutrition. The need for biological goods is going to expand rapidly over the coming years as consumers start using the terms probiotics and prebiotics (Cosme *et al.*, 2022).

The results tabulated in **table (1)** robust the antimicrobial effect of *L. plantarum* in inhibiting both *S. aureus* and *E. coli* by using disc diffusion assay. The data revealed a clear dose-dependent antibacterial effect. For *S. aureus*, inhibition zones increase progressively from 5 mm at 5 log₁₀ CFU/mL to 26 mm at 8 log₁₀ CFU/mL, indicating stronger activity at higher probiotic densities. While *E. coli* shows no detectable inhibition (ND) at 5 log₁₀ CFU/mL but escalates to 23 mm at 8 log₁₀ CFU/mL, suggesting a higher threshold for efficacy against the Gram-positive pathogen than Gram-negative ones. Such results came in line with the findings mentioned by **Elsabagh *et al.* (2021)**, who reported that the concentration 8 log₁₀ CFU/ml had the widest inhibitory zone against *S. aureus* and *E. coli*.

The sensory evaluation detected in **table (2) & figure (1)** confirmed the role of *L. plantarum* in extending shelf-life and enhancing consumer appeal through pathogen inhibition and antioxidant effects. This came in the agreement with the results mentioned by **Slima *et al.* (2017)** who assessed the improved quality and safety of beef sausages kept at 4°C for ten days using *L. plantarum*. And in harmony with **Elsabagh *et al.* (2021)** who revealed that *L. plantarum* enhanced the sensory attributes, physico-chemical and shelf life of fermented chicken sausage. Furthermore, the study by **Telmoudi *et al.* (2025)** showed that the sausage samples treated with the prospective probiotic strain *L. plantarum* CT28 showed superior sensory scores compared to the control. Probiotic strains could be employed as bioprotective inoculants to increase the shelf life of sausage samples. In addition, **Yingying *et al.* (2022)** noted that *L. plantarum* had a confident influence on the aroma, color and texture attributes of the sausages. This is elucidating how LABs have the ability to transform the

meat industry by meeting technology requirements and public health issues in a sustainable and natural manner through continuous multidisciplinary research that looks at customer perception, functionality and safety (Sivamaruthi *et al.*, 2025).

Based on the results tabulated in **table (3)**, the addition of *L. plantarum* at 8 log₁₀ CFU/mL effectively inhibited inoculated pathogenic strains (*S. aureus* at 6 log₁₀ CFU/mL and *E. coli* at 4 log₁₀ CFU/mL) in fresh sausage stored at 4°C. Declining bacterial counts might arise from *Lactobacillus* consuming carbohydrates for growth, while transforming proteins and carbohydrates into acids and alcohols (Yang *et al.*, 2020), converting pH to be acidic that affect directly inoculated bacteria or as a result of secretion of various metabolites by *L. plantarum* as fatty acids, organic acids, bacteriocins and exopolysaccharides which have antibacterial effects (Oleksy and Klewicka, 2018). This agrees with the results of **Yadav and Pipaliya (2017)** and **Elsabagh *et al.* (2021)**, who demonstrate the potent antibacterial activity of *L. plantarum* incorporated in the fermented chicken sausage. The effect of *L. plantarum* was more potent against *E. coli* than *S. aureus* this is mainly approved with the results of **Cavalheiro *et al.* (2019)**, who declared the effective dimension of the *Enterobacteriaceae* counts in chorizo sausages after incorporation of *L. plantarum*. This mainly exploits the unique outer membrane structure of these pathogens, that making inhibition more pronounced against Gram-negative bacteria than against Gram-positive ones (Ahmed and Abdullah, 2025). Probiotics' enzymatic activity can be a helpful tool for rapidly replicating the unique flavor of meat products. The sensory quality of a product may be enhanced by using carefully selected probiotic bacteria with lipolytic and/or proteolytic activity, which can generate strong aroma molecules (Rouhi *et al.*, 2013).

Because probiotics have the ability to quickly and effectively produce organic acid, determining the pH is a critical parameter that affects both product stability and meat quality. It also has a significant effect on the color, lipid oxidation and sensory quality of meat products (Holck *et al.*, 2017).

According to **table (4)**, all of the samples have

identical pH values at zero days of storage, which range from 5.59 to 5.69. Following this, the sausages supplemented with *L. plantarum* had lower pH values, whereas the groups not treated with *L. plantarum* had higher pH values. *L. plantarum* decreases the pH levels in sausage because lactic acid bacteria multiply and create lactic acid through glycometabolism (Karabacak and Bozkurt, 2008 and Slima et al., 2017). This acidification is a straightforward method of assessing a starter's performance. Organic acids are produced during fermentation, lowering pH and inhibiting the growth of microorganisms (Mataragas et al., 2015). Additionally, it enhances the flavor by enhancing the sense of aroma (Bonomo et al., 2009). As fibrillar proteins to coagulate it need a lower pH and the end product is more united, firmer and easier to slice, also rapid and adequate organic acid generation that lowers pH improve quality of sausage and inhibit pathogens and spoilage bacteria (Agüero et al., 2020). However, after nine days, the pH may have increased as a result of either a drop in *L. Plantarum* or an increase in the proteolytic activity of microorganisms, which produced free peptides and amino acids that buffer organic acids (Essid & Hassouna, 2013 and Chen et al., 2017). Our results correspond with earlier research that found sausages treated with *L. plantarum* had lower pH levels (Jatupornpipat and Keatikumjorn, 2007; Ba et al., 2016; Dominguez et al., 2016; Lorenzo et al., 2016; Elsabagh et al., 2021; Huiting et al., 2024; Telmoudi et al., 2025).

Thiobarbituric Acid Reactive Substances (TBARS), a common marker of rancidity in meat products, provide significant information on lipid oxidation (Tornuk et al., 2015). Lipid oxidation poses health risks and causes quality deterioration (Grun et al., 2006).

Results in table (5) cleared that TBA increased over prolonged storage at 4 °C gradually with significant difference ($p \leq 0.05$) between groups treated with *L. plantarum* and other groups not treated with *L. plantarum* due to the effect of oxidative action on fatty acids. These results were agree with those reported by Sun et al. (2016), who found that the samples treated with starter cultures had lower TBARS values than non-inoculated group. The *L. plantarum* had a significant antioxidant effect in cam-

el sausages (Ayyash et al., 2019) and in chicken sausages (Elsabagh et al., 2021; Yadav and Pipaliya, 2017).

TVBN content is formed up of ammonia, hydrogen sulfide and other compounds that are produced when spoilage microorganisms or endogenous enzymes break down proteins (Huang et al., 2014). As a result, the TVBN is typically utilized as an essential indicator of the microbiological quality and shelf life of meat-processed goods or the freshness of raw meats. The outcomes might be caused by the ability of organic acids (like lactic acid) or bacteriocin produced by the inoculated bacteria to neutralize TVBN content (Yin et al., 2002). Concerning TVB-N results in table (6) demonstrated that TVB-N increased during storage at 4°C gradually, with a significant difference ($p \leq 0.05$) between groups treated with *L. plantarum* and those inoculated with pathogenic bacteria due to bacterial or enzymatic actions on protein degradation. With longer storage times, TVB-N values increased in the pathogenic bacteria-inoculated groups but decreased in the *L. plantarum*-treated groups because *L. plantarum* preserves lipid oxidation in sausage (Slima et al., 2017). Nearly results also obtained by Elsabagh et al. (2021) and Huiting et al. (2024) who recorded that in sausage treated with *L. plantarum*, levels of lipid and protein oxidation were markedly reduced, signifying pronounced antioxidant activity exerted by LABs.

All pathogenic bacteria-inoculated groups' physico-chemical characteristics, such as pH, TBARS, and TVB-N, were evaluated until the sixth day of storage; however, groups treated with *L. plantarum* were assessed until the fifteenth day of refrigerated storage (4°C). Our results demonstrated that *L. plantarum* treated samples not only survive till 15 days but also continued to have extraordinary good physico-chemical properties.

Conclusion

The incorporation of *L. plantarum* emerged as a promising "clean label" bio-protectant, reducing reliance on synthetic preservatives in respond to increasing interest from consumers for beef products that are natural and healthy. This study demonstrates its potent antimicrobial activity against *S. aureus* and *E. coli* in fresh raw beef sausage, evidenced by dose-

dependent inhibition zones, significant pathogen count reductions and sustained physico-chemical stability including pH decline and lower TBARS and TVB-N levels throughout

15 days of storage at 4°C. Consequently, *L. plantarum* not only extended shelf life and inhibited spoilage but also enhanced sensory attributes.

Table (1). Antimicrobial evaluation of *L. plantarum* using the disc diffusion method against *S. aureus* and *E. coli*

| Foodborne pathogen | Concentration of <i>L. plantarum</i> | | | |
|--------------------|--------------------------------------|-----------------------------|-----------------------------|-----------------------------|
| | 5 log ₁₀ CFU/ ml | 6 log ₁₀ CFU/ ml | 7 log ₁₀ CFU/ ml | 8 log ₁₀ CFU/ ml |
| <i>S. aureus</i> | 5 ± 0.13mm | 9 ± 0.13mm | 15 ± 0.21mm | 26±0.12mm |
| <i>E. coli</i> | ND | 8± 0.21mm | 12±0.3mm | 23±0.21mm |

Table (2). Effect of *L. plantarum* on sensory attributes of fresh beef sausage stored at refrigerator temperature 4°C.

| Fresh sausage groups | Storage period | | | | | |
|-------------------------------|----------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| | Zero day | 3 rd day | 6 th day | 9 th day | 12 th day | 15 th day |
| Color | | | | | | |
| <i>Control (-ve)</i> | 9.3± 0.22 | 6.5± 0.14 ^a | 4.2± 0.06 ^a | R | R | R |
| <i>Control (+ve) S.aureus</i> | 9.1± 0.24 | 5.8± 0.19 ^b | 3.1± 0.08 ^b | R | R | R |
| <i>S.aureus + LP</i> | 9.4± 0.22 | 8.2± 0.13 ^c | 7.18± 0.33 ^c | 6.7± 0.34 ^a | 5.7± 0.23 ^a | 5.09± 0.21 ^a |
| <i>Control (+ve) E. coli</i> | 9.2± 0.34 | 5.9± 0.26 ^b | 3.6± 0.17 ^d | R | R | R |
| <i>E. coli + LP</i> | 9.4± 0.21 | 8.3± 0.22 ^c | 7.3± 0.03 ^c | 6.8± 0.13 ^a | 5.9± 0.26 ^a | 5.11± 0.15 ^a |
| Odor | | | | | | |
| <i>Control (-ve)</i> | 9.5± 0.32 | 5.5± 0.24 ^a | 3.8± 0.22 ^a | R | R | R |
| <i>Control (+ve) S.aureus</i> | 9.2± 0.25 | 5.2± 0.19 ^a | 3.2± 0.22 ^b | R | R | R |
| <i>S.aureus + LP</i> | 9.6± 0.14 | 8.5± 0.22 ^b | 7.1± 0.13 ^c | 6.7± 0.14 ^a | 5.9± 0.16 ^a | 5.2± 0.11 ^a |
| <i>Control (+ve) E. coli</i> | 9.3± 0.23 | 5.3± 0.25 ^a | 3.5± 0.15 ^{ab} | R | R | R |
| <i>E. coli + LP</i> | 9.6± 0.21 | 8.6± 0.18 ^b | 7.2± 0.33 ^c | 6.8± 0.28 ^a | 5.9± 0.24 ^a | 5.4± 0.16 ^a |
| Texture | | | | | | |
| <i>Control (-ve)</i> | 9.3± 0.21 | 5.9± 0.08 ^a | 3.9± 0.1 ^a | R | R | R |
| <i>Control (+ve) S.aureus</i> | 9.1± 0.24 | 4.7± 0.17 ^b | 3.4± 0.25 ^b | R | R | R |
| <i>S.aureus + LP</i> | 9.4± 0.22 | 8.2± 0.24 ^c | 7.5± 0.27 ^c | 6.51± 0.16 ^a | 5.66± 0.29 ^a | 5.02± 0.23 ^a |
| <i>Control (+ve) E. coli</i> | 9.1± 0.37 | 4.9± 0.22 ^b | 3.6± 0.04 ^{ab} | R | R | R |
| <i>E. coli + LP</i> | 9.4± 0.13 | 8.2± 0.23 ^c | 7.6± 0.41 ^c | 6.49± 0.18 ^a | 5.71± 0.27 ^a | 5.07± 0.22 ^a |
| Overall acceptability | | | | | | |
| <i>Control (-ve)</i> | 9.36± 0.25 | 5.97± 0.15 ^a | 3.96± 0.13 ^a | R | R | R |
| <i>Control (+ve) S.aureus</i> | 9.13± 0.24 | 5.2± 0.18 ^b | 3.23± 0.18 ^b | R | R | R |
| <i>S.aureus + LP</i> | 9.5± 0.19 | 8.3± 0.19 ^c | 7.26± 0.24 ^c | 6.6± 0.21 ^a | 5.7± 0.23 ^a | 5.1± 0.18 ^a |
| <i>Control (+ve) E. coli</i> | 9.2± 0.31 | 5.4± 0.24 ^b | 3.63± 0.12 ^a | R | R | R |
| <i>E. coli + LP</i> | 9.5± 0.18 | 8.4± 0.21 ^c | 7.5± 0.26 ^c | 6.69± 0.19 ^a | 5.8± 0.25 ^a | 5.19± 0.18 ^a |

Data are presented as (Mean ± S.D). S.D: Standard Deviation, R: Rejected depending on sensory evaluation. The mean values in the same column that have differ superscripts (small letters) differ significantly at *p* value < 0.05. LP: *L. plantarum*.

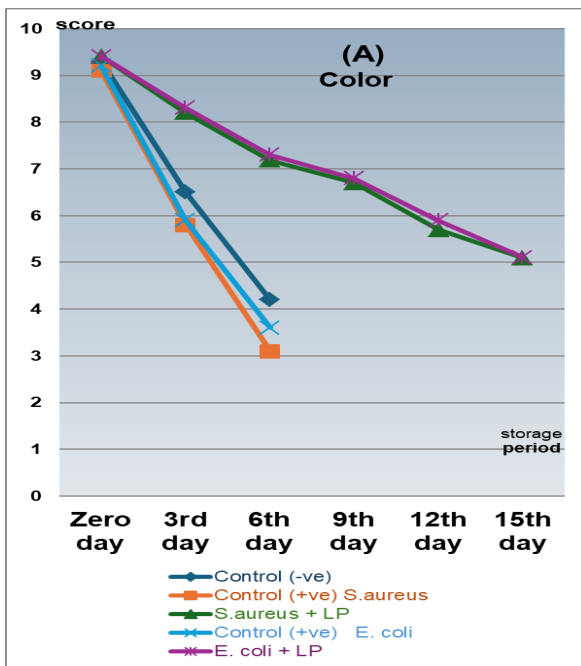


Figure (1, A). Effect of *L. plantarum* on color of fresh beef sausage stored at refrigerator temperature 4° C

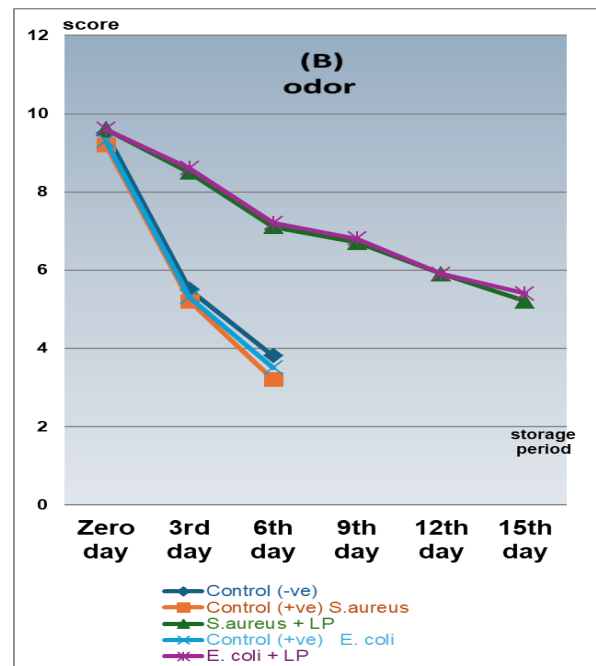


Figure (1, B). Effect of *L. plantarum* on odor of fresh beef sausage stored at refrigerator temperature 4° C

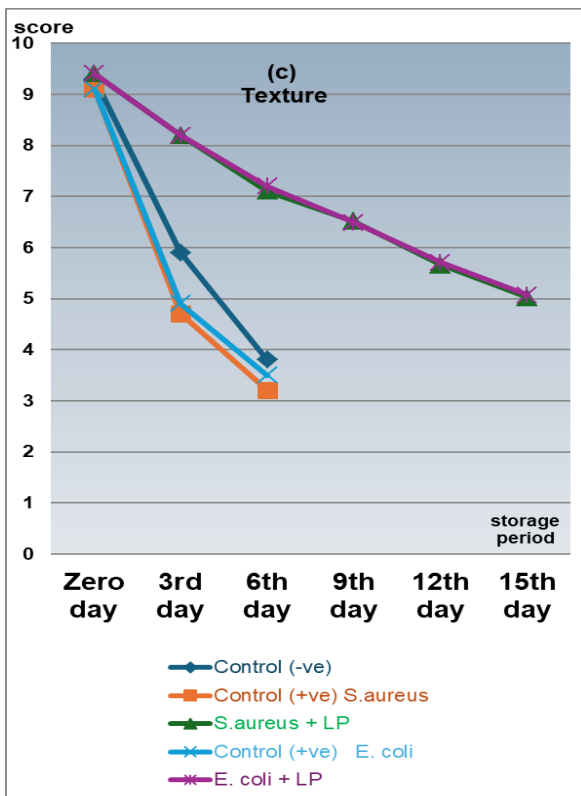


Figure (1, C). Effect of *L. plantarum* on texture of fresh beef sausage stored at refrigerator temperature 4° C

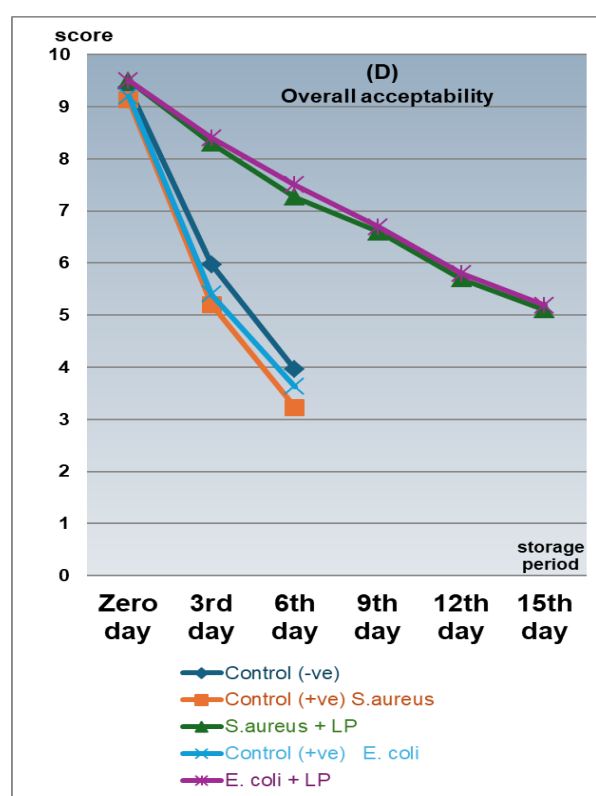


Figure (1, D). Effect of *L. plantarum* on over all acceptability of fresh beef sausage stored at refrigerator temperature 4° C

Figure (1). Effect of *L. plantarum* on sensory attributes of fresh beef sausage stored at refrigerator temperature 4° C (A, B, C and D).

Table (3). Effect of *L. plantarum* on different food poisoning bacteria (log CFU/gm.) inoculated in fresh beef sausage stored at refrigerator temperature 4°C.

| Fresh sausage groups | Storage period | | | | | | | | | | | |
|-------------------------------|----------------|------|------------------------|-------|------------------------|-------|------------------------|-------|------------------------|-------|------------------------|-------|
| | Zero day | | 3rd day | | 6th day | | 9th day | | 12th day | | 15th day | |
| | Count | R% | Count | R% | Count | R% | count | R% | count | R% | Count | R% |
| Control (-ve) | ND | ---- | ND | ---- | ND | ---- | ND | ---- | ND | ---- | ND | ---- |
| Control (+ve) <i>S.aureus</i> | 6.52±0.26 | ---- | 6.89±0.15 ^a | ---- | 6.97±0.21 ^a | ---- | 7.58±0.18 ^a | ---- | 7.89±0.23 ^a | ---- | 8.23±0.25 ^a | ---- |
| <i>S.aureus</i> + LP | 6.5±0.24 | 0.31 | 5.61±0.21 ^b | 18.58 | 5.08±0.22 ^b | 27.12 | 4.83±0.16 ^b | 36.27 | 4.38±0.23 ^b | 44.49 | 2.07±0.19 ^b | 74.85 |
| Control (+ve) <i>E. coli</i> | 4.41±0.23 | ---- | 4.91±0.27 ^c | ---- | 5.32±0.25 ^b | ---- | 5.56±0.24 ^c | ---- | 5.78±0.26 ^c | ---- | 5.91±0.24 ^c | ---- |
| <i>E. coli</i> + LP | 4.32±0.15 | 2.02 | 3.86±0.31 ^d | 21.38 | 3.39±0.26 ^c | 36.27 | 2.91±0.22 ^d | 47.66 | 1.9±0.11 ^d | 67.12 | ND | 100 |

Data are presented as (Mean ± S.D). S.D: Standard Deviation, The mean values in the same column that have differ superscripts (small letters) differ significantly at *p* value < 0.05. LP: *L. plantarum*, ND: not detected, R%: Reduction percent.

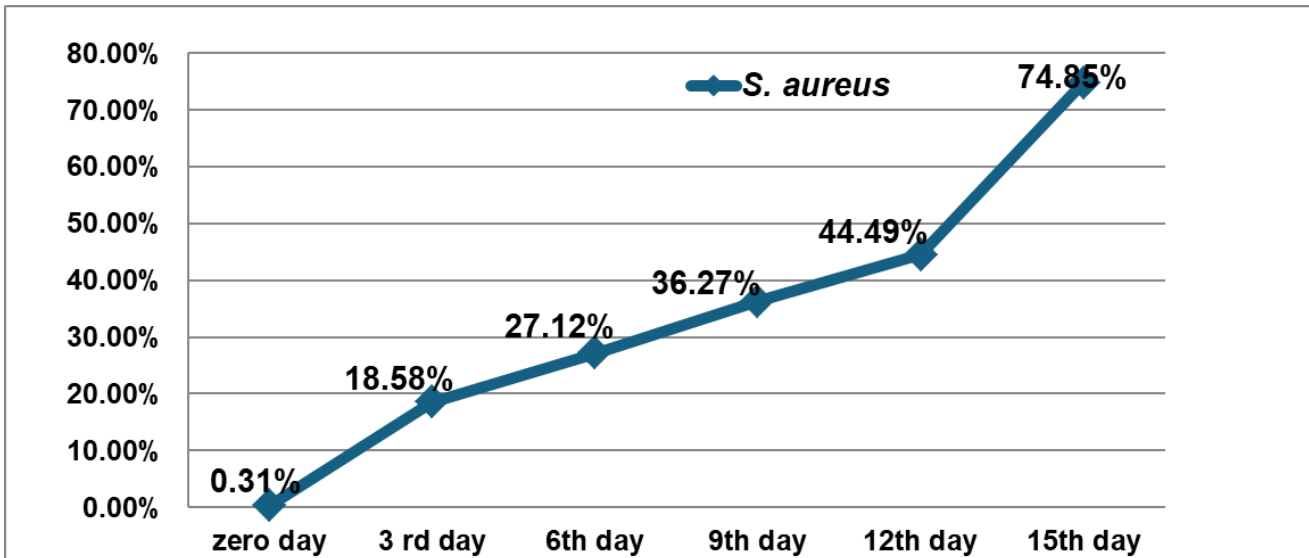


Figure (2). Reduction % of *S. aureus* (log10 CFU/gm) at fresh beef sausage treated by *L. plantarum* stored at 4°C compared with control (+ve) at the same day of storage.

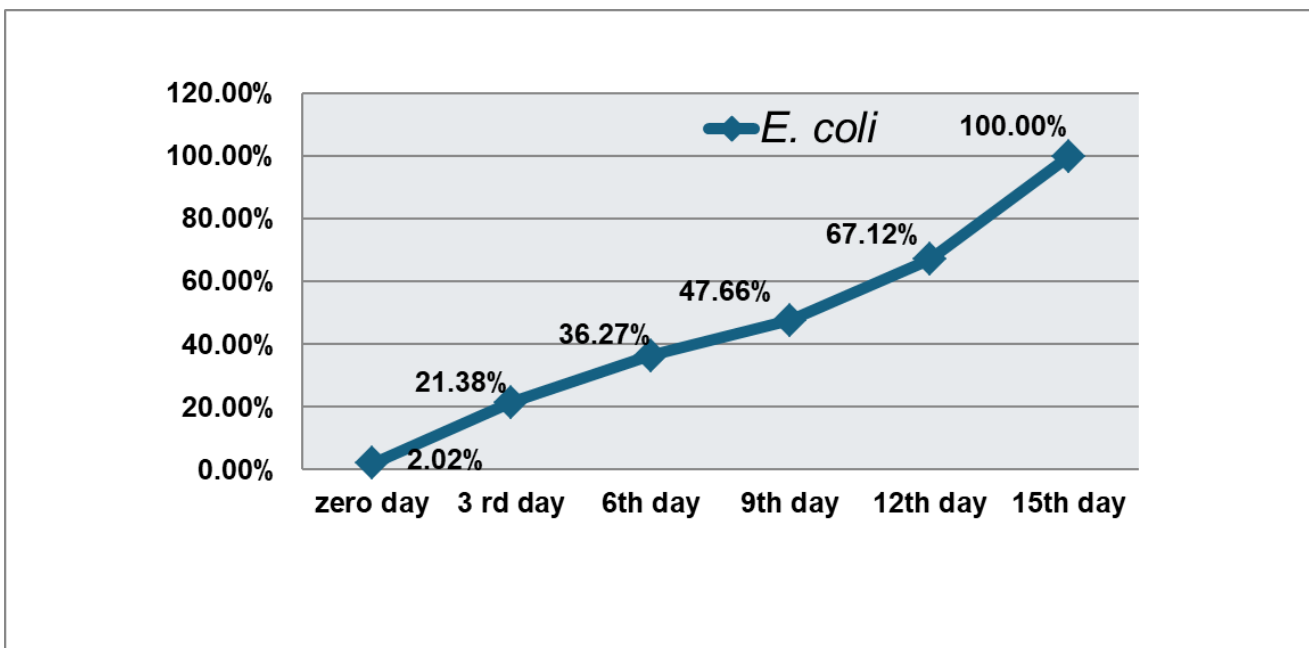


Figure (3). Reduction % of *E. coli* (log10 CFU/gm) at fresh beef sausage treated by *L. plantarum* stored at refrigerator temperature 4° C compared with control (+ve) at the same day of storage.

Table (4). Effect of *L. plantarum* on the pH of laboratory manufactured fresh beef sausage stored at refrigerator temperature 4°C.

| Fresh sausage groups | Storage period | | | | | |
|-------------------------------|----------------|-------------------------|------------------------|-------------------------|-------------------------|-------------------------|
| | Zero day | 3rd day | 6th day | 9th day | 12th day | 15th day |
| <i>Control (-ve)</i> | 5.62± 0.04 | 5.96± 0.05 ^a | 6.21±0.06 ^a | R | R | R |
| <i>Control (+ve) S.aureus</i> | 5.63± 0.12 | 6.41± 0.12 ^b | 6.53±0.07 ^b | R | R | R |
| <i>S.aureus + LP</i> | 5.61± 0.04 | 4.71± 0.05 ^c | 4.52±0.06 ^c | 4.37± 0.08 ^a | 4.81± 0.15 ^a | 5.41± 0.03 ^a |
| <i>Control (+ve) E. coli</i> | 5.69± 0.03 | 6.37± 0.06 ^b | 6.6±0.04 ^b | R | R | R |
| <i>E. coli + LP</i> | 5.59± 0.13 | 4.61± 0.05 ^c | 4.58±0.04 ^c | 4.26± 0.12 ^a | 4.62± 0.07 ^a | 5.38± 0.11 ^a |

Data are presented as (Mean ± S.D). S.D: Standard Deviation, R: Rejected depending on sensory evaluation. The mean values in the same column that have differ superscripts (small letters) differ significantly at p value < 0.05. LP: *L. plantarum*.

Table (5). Effect of *L. plantarum* on the TBARS of laboratory manufactured fresh beef sausage stored at refrigerator temperature 4°C.

| Fresh sausage groups | Storage period | | | | | |
|-------------------------------|----------------|--------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| | Zero day | 3rd day | 6th day | 9th day | 12th day | 15th day |
| <i>Control (-ve)</i> | 0.04± 0.001 | 0.59± 0.02 ^a | 0.89± 0.06 ^a | R | R | R |
| <i>Control (+ve) S.aureus</i> | 0.05± 0.003 | 0.92± 0.08 ^b | 1.01± 0.03 ^b | R | R | R |
| <i>S.aureus + LP</i> | 0.04± 0.002 | 0.25± 0.02 ^c | 0.46± 0.03 ^c | 0.54± 0.04 ^a | 0.67± 0.06 ^a | 0.80± 0.07 ^a |
| <i>Control (+ve) E. coli</i> | 0.04± 0.001 | 0.89± 0.05 ^b | 0.99± 0.04 ^b | R | R | R |
| <i>E. coli + LP</i> | 0.03± 0.001 | 0.23± 0.002 ^c | 0.37± 0.02 ^c | 0.49± 0.08 ^a | 0.61± 0.14 ^a | 0.77± 0.05 ^a |

Data are presented as (Mean ± S.D). S.D: Standard Deviation, R: Rejected depending on sensory evaluation. The mean values in the same column that have differ superscripts (small letters) differ significantly at p value < 0.05. LP: *L. plantarum*.

Table (6). Effect of *L. plantarum* on the TVB-N of laboratory manufactured fresh beef sausage stored at refrigerator temperature 4°C.

| Fresh sausage groups | Storage period | | | | | |
|-------------------------------|----------------|--------------------------|--------------------------|--------------------------|--------------------------|-------------------------|
| | Zero day | 3rd day | 6th day | 9th day | 12th day | 15th day |
| <i>Control (-ve)</i> | 4.92± 0.24 | 10.91± 0.31 ^a | 17.5± 0.54 ^a | R | R | R |
| <i>Control (+ve) S.aureus</i> | 5.08± 0.18 | 16.05± 0.51 ^b | 21.03± 0.54 ^b | R | R | R |
| <i>S.aureus + LP</i> | 4.96± 0.26 | 7.55± 0.24 ^c | 11.32± 0.33 ^c | 14.91± 0.42 ^a | 16.32± 0.23 ^a | 18.4± 0.46 ^a |
| <i>Control (+ve) E. coli</i> | 5.1± 0.15 | 15.93± 0.41 ^b | 20.7± 0.53 ^b | R | R | R |
| <i>E. coli + LP</i> | 4.93± 0.28 | 6.93± 0.23 ^c | 11.2± 0.22 ^c | 14.7± 0.34 ^a | 15.9± 0.34 ^a | 17.8± 0.51 ^a |

Data are presented as (Mean ± S.D). S.D: Standard Deviation, R: Rejected depending on sensory evaluation. The mean values in the same column that have differ superscripts (small letters) differ significantly at p value < 0.05. LP: *L. plantarum*.

References

- Agüero, N.D.L.; Frizzo, L.S.; Ouwehand, A.C.; Aleu, G. and Rosmini, M.R. (2020).** Technological characterisation of probiotic lactic acid bacteria as starter cultures for dry fermented sausages. *Foods*, 9(5), 596. <https://doi.org/10.3390/foods9050596>
- Ahmed, R.Z.T. and Abdullah, R.M. (2025).** Effect of probiotics on Gram-positive and Gram-negative bacteria that causes different clinical infections. *Journal of biotechnology research center*, 19 (2):85-95.
- Association of Official Agricultural Chemists (AOAC) (2002).** Official methods of analysis (17th ed.). Association of Official Analytical Chemists, Washington.
- Ayyash, M.; Shao-Quan, L.; Aysha, A.; Mouza, A.; Bakhita, R.; Anas, A.; Tareq, O. and Amin, O. (2019).** In vitro investigation of health promoting benefits of fermented camel sausage by novel probiotic *L. plantarum*: A comparative study with beef sausages. *LWT-Food Science and Technology*, 99: 346-354. DOI: <https://www.doi.org/10.1016/j.lwt.2018.09.084>
- Ba, H.V.; Seo, H.W.; Kim, J.H.; Cho, S.H.; Kim, Y.S.; Ham, J.S.; Park, B.Y.; Kim, H.W. and Seong, P.N. (2016).** The effects of starter culture types on the technological quality, lipid oxidation and biogenic amines in fermented sausages. *LWT-Food Sci, Technol.* 74:191-198.
- Bonomo, M.G.; Ricciardi, A.; Zotta, T.; Sico, M.A. and Salzano, G. (2009).** Technological and safety characterization of coagulase-negative staphylococci from traditionally fermented sausages of Basilicata Region (Southern Italy). *Meat Science*, 83: 15-23. DOI: <https://www.doi.org/10.1016/j.meatsci.2009.03.006>
- Boulares, M.; Aouadhi, C.; Mankai, M.; Ben, Moussa; Essid, O. and Mnasser, H. (2012).** Characterisation identification and technological properties of psychotropic lactic acid bacteria originating from Tunisian fresh fish. *Journal of Food Safety*, 32, 333–344.
- Castellano, P.; Belfiore, C.; Fadda, S. and Vignolo, G. (2008).** A review of bacteriocinogenic lactic acid bacteria used as bioprotective culture in fresh meat products in Argentina. *Meat science.*, 79(3), 483-499.
- Cavalheiro, C.P.; Ruiz-Capillas, C.; Herroero, A.M.; Jiménez-Colmenero, F.; Pintado, T.; de Menezes, C.R. and Fries, L.L.M. (2019).** Effect of different strategies of *L. plantarum* incorporation in chorizo sausages. *Journal of the Science of Food and Agri-*

- culture, 99(15), 6794–6803. <https://doi.org/10.1002/jsfa.9952>
- Cavalheiro, C.P.; Ruiz-Capillas, C.; Herreiro, A.M.; Jiménez-Colmenero, F.J.; Menezes, C.R. and Fries, L.L.M. (2015).** Application of probiotic delivery systems in meat products. *Trends Food Sci Technol.* 46:120–131.
- Chen, Q.; Kong, B.; Han, Q.; Xia, X. and Xu, L. (2017).** The role of bacterial fermentation in lipolysis and lipid oxidation in Harbin dry sausages and its flavor development. *LWT.*, 77: 389–396.
- Cosme, F.; Inês, A. and Vilela, A. (2022).** Consumer's acceptability and health consciousness of probiotic and prebiotic non-dairy products. *Food Res. Int.*, 151: 110842.
- Detha, A.; Datta, F.U. Beribe, E.; Foeh, N. and Ndaong, N. (2018).** Efektivitas bakteri asam laktat yang diisolasi dari susu kuda sumba terhadap kualitas silase jerami padi (effectiveness of lactic acid bacteria isolated from sumba horse milk on silase quality). *J Kaji Vet.* 6(1):31–7. <https://doi.org/10.35508/jkv.v6i1.1053>
- Dominguez, R.; Munekata, P.E.; Agregan, R. and Lorenzo, J.M. (2016).** Effect of commercial starter cultures on free amino acid, biogenic amine and free fatty acid contents in dry-cured foal sausage. *LWT-Food Sci Technol* 71:47-53.
- Elsabagh, R.; Nada, Sh.M. and Abd-Elaaty, E.M. (2021).** Controlling Food Poisoning Bacteria in Fermented Chicken Sausage Using *L. plantarum*. *World Vet. J.*, 11 (3): 462-468.
- Egyptian Organization for Standardization "EOS" 63/10. (2006).** Egypt. Organiz. For Standar. And quality control. Determination of Total Volatile Basic Nitrogen (TVB-N, mg%).
- Egyptian Organization for Standardization "EOS" 63/9. (2006).** Egypt. Organiz. For Standar. And quality control. Determination of Thiobarbituric Acid number (TBA, mg/Kg).
- Essid, I. and Hassouna, M. (2013).** Effect of inoculation of selected *S. xylosum* and *L. plantarum* strains on biochemical, microbiological and textural characteristics of a Tunisian dry fermented sausage. *Food Control* 32:707-714.
- Grun, I.; Ahn, J.; Clarke, A. and Lorenzen, C. (2006).** Reducing oxidation of meat. *Food Technol.*1:36-43.
- Holck, A.; Axelsson, L.; McLeod, A.; Rode, T.M. and Heir, E. (2017).** Health and safety considerations of fermented sausages. *Journal of Food Quality*, 2017, 1–24.
- Huang, L.; Zhao, J.; Chen, Q. and Zhang, Y. (2014).** Nondestructive measurement of total volatile basic nitrogen (TVB-N) in pork meat by integrating near infrared spectroscopy, computer vision and electronic nose techniques. *Food Chem* 145:228-236.
- Hugo, C.J. and Hugo, A. (2015).** Current trends in natural preservatives for fresh sausage products. *Trends in Food Science and Technology*, 45: 12-23.
- Huiting, L.; Mei, X. and Peijun, L. (2024).** Protective Effect of *L. plantarum* R2 and *L. sakei* B2 on Low-Salt Sliced Sausages Stored at 5°C. *Foods*, 13, 3960. <https://doi.org/10.3390/foods13233960>.
- International Organization for Standardization (ISO) 13299 (E) (2016).** Sensory analysis – Methodology - General guidance for establishing a sensory profile.
- International Organization for Standardization (ISO) 7251:2005/Amd 1: (2023).** Microbiology of food and animal feeding stuffs — Horizontal method for the detection and enumeration of presumptive *Escherichia coli* — Most probable number technique Amendment 1: Inclusion of performance testing of culture media and reagents. <https://www.iso.org/standard/83209.html>
- International Organization for Standardization (ISO) 6888-1 (2003).** Horizontal methods for the enumeration of coagulase-positive Staphylococci (*S. aureus* and other species), Technique using Baird-Parker medium. Available at: <http://www.oxid.com/pdf/iso-food-safety-brochure.pdf>
- Jatupornpipat, M. and Keatikumjorn, P. (2007).** The effect of Kefir starter on Thai fermented sausage product. *Songklanakarin, J. Sci. Technol.*, 29(4): 1145-1152.
- Karabacak, S. and Bozkurt, H. (2008).** Effects of *Urtica dioica* and *Hibiscus sabdariffa* on the quality and safety of sucuk (Turkish dryfermented sausage). *Meat Sci.* 78, 288–296.

- Kaveh, S.; Hashemi, S.M.B.; Abedi, E.; Amiri, M.J. and Conte, F.L. (2023).** Bio-preservation of meat and fermented meat products by lactic acid bacteria strains and their antibacterial metabolites. *Sustainability*, 15 (13), 10154.
- Lin, T.H. and Pan, T.M. (2017).** Characterization of an antimicrobial substance produced by *L. plantarum* NTU 102. *Journal of Microbiology, Immunology and Infection*, 52 (3): 409-417. DOI: <https://www.doi.org/10.1016/j.jmii.2017.08.003>
- Lorenzo, J.M.; Gomez, M.; Purrinos, L. and Fonseca, S. (2016).** Effect of commercial starter cultures on volatile compound profile and sensory characteristics of dry cured foal sausage. *J Sci Food Agric* 96:1194-1201.
- Mataragas, M.; Bellio, A.; Rovetto, F.; Astegiano, S.; Decastelli, L. and Cocolin, L. (2015).** Risk-based control of food-borne pathogens *L. monocytogenes* and *Salmonella enterica* in the Italian fermented sausages Cacciatore and Felino. *Meat Science*, 103: 39-45. DOI: <https://www.doi.org/10.1016/j.meatsci.2015.01.002>
- Mejri, L.; Ziadi, A.; El Adab, S.; Boulares, M.; Essid, I. and Hassouna, M. (2017).** Effect of commercial starter cultures on physicochemical, microbiological and textural characteristics of a traditional dry fermented sausage reformulated with camel meat and hump fat. *Journal of Food Measurement and Characterization*, 11(2): 758-767. <https://www.doi.org/10.1007/s11694-016-9445-6>
- Moradi, M.; Kousheh, S.A.; Almasi, H.; Alizadeh, A.; Guimarães, J.T.; Yilmaz, N. and Lotfi, A. (2020).** Postbiotics produced by lactic acid bacteria: The next frontier in food safety. *Compr Rev Food Sci Food Saf*. 19(6):3390-3415.
- Morsy, M.K.; Elsabagh, R. and Trinetta, V. (2018).** Evaluation of novel synergistic antimicrobial activity of nisin, lysozyme, EDTA nanoparticles, and/or Zn Oxide nanoparticles to control foodborne pathogens on minced beef. *Food Control*, 92: 249-254. DOI: <https://www.doi.org/10.1016/j.foodcont.2018.04.061>
- Niyonzima, E.; Ongol, M.P.; Kimonyo, A. and Sindic, M. (2015).** Risk Factors and Control Measures for Bacterial Contamination in the Bovine Meat Chain: A Review on *Salmonella* and Pathogenic *E. coli*. *Journal of Food Research*; 4 (5), 98-121.
- Novais, C.; Molina, A.K.; Abreu, R.M.V.; Santo-Buelga, C.; Ferreira, I.C.F.R.; Pereira, C. and Barros, L. (2022).** Natural Food Colorants and Preservatives: A Review, a Demand, and a Challenge. *J Agric Food Chem*. 70(9):2789-2805.
- Oleksy, M. and Klewicka, E. (2018).** Exopolysaccharides produced by *L. sp.*: Biosynthesis and applications. *Crit. Rev. Food Science and Nutrition*, 58: 450-462. DOI: <https://www.doi.org/10.1080/10408398.2016.1187112>
- Peacock, J.L. and Peacock, P.J. (2020).** Oxford handbook of medical statistics. Oxford University Press, 11.
- Prasad, D. and Vidyarthi, A. (2009).** DNA based methods used for characterization and detection of food borne bacterial pathogens with special consideration to recent rapid methods. *African Journal of Biotechnology*. 8(9), 1768-1775.
- Rouhi, M.; Sohrabvandi, S. and Mortazavian, A.M. (2013).** Probiotic fermented sausage: Viability of probiotic microorganisms and sensory characteristics. *Critical Reviews in Food Science and Nutrition*, 53(4), 331-348.
- Saltmarch, M. and Insall, L. (2013).** Food additives and why they are used. In M. Saltmarch (Ed.), *Essential guide to food additives* (pp. 1-13). <http://doi.org/10.1039/9781849734981-00001>.
- Sivamaruthi, B.S.; Kesika, P.; Rafeek, S.B.S.; Sivakumar, K.; Ramasamy, S.P.; Chaiyatsut, C.; Fukngoen, P. and Alagarsamy, K. (2025).** Lactic acid bacteria in the meat industry: flavor, function, and food safety. *Front. Microbiol.*, 16, 1703213.
- Slima, S.B.; Naourez, K.; Imen, T.; Mehdi, T.; Feki-Tounsi, M.; Hafedh, M.; Iskandar, M.; Ana, H.; Francisco, J. and Claudia, P. (2017).** Effect of partial replacement of nitrite with a novel probiotic *L. plantarum* TN8 on color, physico-chemical, texture and microbiological properties of beef sausages. *LWT-Food Science and Technology*, 86: 219-226. DOI: <https://www.doi.org/10.1016/j.lwt.2017.07.058>
- Sun, Q.; Chen, Q.; Li, F.; Zheng, D. and Kong, B. (2016).** Biogenic amine inhibition

- and quality protection of Harbin dry sausages by inoculation with *S. xylosum* and *L. plantarum*. *Food Control*, 68: 358-66. DOI: <https://www.doi.org/10.1016/j.foodcont.2016.04.021>.
- Telmoudi, A.; Imen, M.; Moncef, C. and Mnasser, H. (2025).** Development of novel fermented goat sausage inoculated with *L. plantarum* probiotic bacteria. *Acta Scientiarum. Technology*, 47, e70767.
- Topisirovic, L.; Kojic, M.; Fira, D.; Golic, N.; Strahinic, I. and Lozo, J. (2006).** Potential of lactic acid bacteria isolated from specific natural niches in food production and preservation. *International Journal of Food Microbiology*, 112 (3), 230–235.
- Tornuk, F.; Hancer, M.; Sagdic, O. and Yetim, H. (2015).** LLDPE based food packaging incorporated with nanoclays grafted with bioactive compounds to extend shelf life of some meat products. *LWT-Food Science and Technology*, 64: 540-546. <https://www.doi.org/10.1016/j.lwt.2015.06.030>
- Wang, J.; Hou, J.; Zhang, X.; Hu, J.; Yu, Z. and Zhu, Y. (2022).** Improving the Flavor of Fermented Sausage by Increasing Its Bacterial Quality via Inoculation with *L. plantarum* MSZ2 and *S. xylosum* YCC3. *Foods* 11, 736. <https://doi.org/10.3390/foods11050736>
- Yadav, A.S. and Pipaliya, G. (2017).** Antioxidant and antimicrobial profile of chicken sausages prepared after fermentation of minced chicken meat with *L. plantarum* and with additional dextrose and starch. *LWT-Food Science and Technology*, 77: 249-258. DOI: <https://www.doi.org/10.1016/j.lwt.2016.11.050>
- Yang, F.; Zhang, Q.; Liu, Y.; Li, J.; Wang, L. and Chen, J. (2020).** Lactic acid biosynthesis pathways and important genes of *L. panis* L7 isolated from the Chinese liquor brewing microbiome, *Food Biosci.* 36, 100627. <http://doi.org/10.1016/j.fbio.2020.100627>.
- Yin, L.R.; Pan, C.L. and Jiang, S.T. (2002).** Effect of lactic acid bacterial fermentation on the characteristics of minced mackerel. *J Food Sci* 67:786-792.
- Yingying, Hu; Yongjie, Li; Xiang-ao, Li; Hongwei, Zhang; Qian, C. and Baohua, K. (2022).** Application of lactic acid bacteria for improving the quality of reduced-salt dry fermented sausage: Texture, color, and flavor profiles. *LWT - Food Science and Technology* 154, 112723.
- Zeraat Pisheh, F.; Falah, F.; Sanaei, F.; Vassiee, A.; Zanganeh, H.; Tabatabaee, Yazdi, F. and Ibrahim, S.A. (2023).** The Effect of Plasma-Activated Water Combined with Rosemary Extract (*Rosmarinus officinalis* L.) on the Physicochemical Properties of Frankfurter Sausage during Storage. *Foods*. 12 (21):4022.