Assessment of *Lactobacillus paracasei* F₂I₂ as a Possible Biopreservative for Raw Pork

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Abstract

Raw meats sold in the public market at ambient temperature (25 °C) are prone to contamination with foodborne pathogens. Lactic acid bacteria with antimicrobial properties can be used as an economical approach in preserving raw meat. This study aimed to evaluate the potential of *Lactobacillus paracasei* F₂I₂ (LP) as a possible biopreservative for raw pork under laboratory and typical public market conditions. Spraying, rinsing, and dipping were tested as means of applying the LP suspension, with spraying as the most efficient method. LP-sprayed and untreated meat were monitored for 6 hours (h) under the prevailing market conditions. Microbiological counts, cooking qualities, and physicochemical parameters were evaluated. Roasted pork samples were subjected to a preference ranking test. Results showed that the application of LP significantly (*p* < 0.05) reduced the rate of increase of staphylococci in raw pork after 8 h at laboratory conditions. The treatment also significantly (*p* < 0.05) retarded the growth of aerobic bacteria and coliforms after 3 and 6 h, respectively, under public market conditions. No negative effect on the meat cooking qualities and degree of preference was observed. However, due to the initially high levels of coliform (>3.29 log CFU/g) and staphylococcal (>3.48 log CFU/g) counts posing considerable threats to food safety, the effect on reduction was not sufficient to keep the meat within acceptable microbiological standards. Though results indicated that LP has been shown to have potential as biopreservative for raw pork, it cannot be used as a remedial intervention for poor microbiological quality.

*Keywords*: biopreservative, lactic acid bacteria, microbial inhibition, raw pork

1. Introduction

The presence of spoilage and pathogenic microorganisms in meat poses threats to meat safety and quality. Fresh meat, in particular, is prone to microbial contamination due to the amount of water, proteins, and essential
nutrients that favor the growth of undesirable microorganisms. The pathogenic bacteria usually present in meat include *Salmonella*, *Campylobacter jejuni*, *Escherichia coli* O157:H7, *Clostridium perfringens*, *Clostridium botulinum*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Bacillus cereus*, and *Yersinia enterocolitica* (Woraprayote et al., 2016). These pathogens can be found in pork products. Pork is reported to be the most consumed type of meat globally, therefore the presence of undesirable microorganisms such as *Salmonella*, *L. monocytogenes*, and *S. aureus* largely affects its safety and quality (Baer et al., 2013; Mansur et al., 2015). Pork products are also notably associated with the development of antibiotic-resistant pathogens (Mangal et al., 2018).

While refrigeration and application of chemical preservatives have been used to preserve meat products, the use of natural antimicrobials to extend shelf life can be a promising alternative for cost savings and prevention of adverse health effects and quality loss (Le et al., 2019). Consumer demand for minimally processed food products is also increasing, contributing to the trend of applying natural antimicrobials to preserve meat (Field et al., 2018). Several studies have investigated the role of lactic acid bacteria (LAB) and their natural products in biopreservation (Chakchouk-Mtibaa et al., 2017).

Lactic acid bacteria are gram-positive microorganisms that are generally recognized as safe due to their history in food fermentation (Shehata et al., 2016). LAB are known to have nutritional and therapeutic effects. In a recent study by Le et al. (2019), a *Lactobacillus plantarum* strain isolated from traditional fermented yogurt was found to possess biopreservative ability on pork. Other studies have demonstrated the biopreservative effect of LAB on various meat products (Albano et al., 2009; Woraprayote et al., 2016; Favaro and Todorov, 2017). The safety of meat sold at public markets can be achieved using LAB isolates with antimicrobial properties, which is a more economical approach.

Farnazo (2013) isolated LAB from *Nypa fruticans* (nipa), a mangrove found in many coastal areas in the Philippines, and screened them for antibacterial properties. The top three isolates that were shown to inhibit the growth of *E. coli* and *S. aureus* using co-culture method were F1I2, F2I2, and C2I4. Using the API 50 carbohydrates utilization kit, these were identified as *L. curvatus*, *L. paracasei*, and *L. delbrueckii*, respectively.

The general objective of the study was to evaluate the potential of *Lactobacillus paracasei* F2I2 (LP) F2I2 as biopreservative for raw pork under typical public market conditions in Mintal, Davao City, Philippines.
2. Methodology

2.1 Microorganism

The microorganism used in this study was pre-selected from those isolated from nipa inflorescence. Specifically, among eleven previously screened isolates, one potential LAB (F2I2) was chosen based on the results of Farnazo (2013). Based on the characteristics displayed in the API 50 kit (Sigma Aldrich), isolate F2I2 was identified as *Lactobacillus paracasei* (LP). LP was selected for the study because it was fast-growing.

LP was maintained in de Man, Rogosa, and Sharpe Agar (MRS) stab cultures at 4 °C and was sub-cultured every two weeks in MRS broth. The working culture was prepared by inoculating the refrigerated culture into 50 mL MRS broth and incubating at 35 ± 2 °C for 24 hours (h).

2.2 Microbial Analyses

Plate count agar (PCA), violet red bile agar (VRBA), mannitol salt agar (MSA), and MRS supplemented with CaCO₃ were prepared according to the methods recommended by Harrigan and McCance (1966). PCA was used for determining the total plate count (TPC), VRBA for coliform count, MSA for staphylococcal count, and MRS with CaCO₃ for LAB count. Aliquots were inoculated into the different media. After incubation at 37 °C for 48 h, Petri dishes with 25-250 colonies were counted.

Counts were converted to logarithm colony-forming units (CFU) increase or decrease computed as follows:

\[
\log \text{CFU increase or decrease} = \log \text{initial CFU} - \log \text{final CFU}
\]  

(1)

As such, a negative sign is indicative of a decrease in log CFU/g of sample.

2.3 Assessment under Laboratory Conditions

Randomly selected slices of pork *longissimus dorsi* (LD) muscle were purchased from Mintal Public Market (MPM), Mintal, Davao City, Philippines at 8:00 AM. The meat slices, each weighing 100 g, were placed in an icebox and brought to the laboratory for analysis. Meat muscle cut at about 2 cm thick was laid flat on a plate. Using a micropipette, five pours of LP of 1 mL each were applied on each of the two sides of the meat. Untreated meat
muscle served as the control. Initially and after 8 h of incubation at 25 °C, portions of the slices were randomly collected. A 25-g sample was added to 225 mL of 0.1% peptone water and serial dilutions were prepared. Microbiological analyses were conducted. Results for TPC, coliform count, staphylococcal count, and LAB count were expressed as log CFU increase or decrease.

2.4 Evaluation of Methods of Application

Four pieces of 250 g pork loins were bought from MPM, Mintal, Davao City, Philippines from 6:30 to 7:00 AM. These were placed in an icebox and brought to the laboratory. Pork loins were treated with the prepared bacterial suspension of LP (4.8x10² cell/mL suspension) by dipping, spraying, and rinsing. One piece of pork loin was left untreated to serve as the control.

2.4.1 Dipping

The pork loin was treated with LP by dipping into a pre-measured amount of the bacterial suspension enough to fully submerge the loin. The meat was allowed to be in contact with the suspension for about 10 min under ambient conditions before microbiological sampling and eventual cooking.

2.4.2 Spraying

The pork loin was sprayed with the bacterial suspension at five passes per side. The total volume of the sprayed bacterial suspension was computed. The treated pork loins were then kept under ambient conditions until microbiological sampling and eventual cooking.

2.4.3 Rinsing

A measured volume of the bacterial suspension was poured onto the pork loin. Drippings were collected using a clean and sanitized basin and then poured again onto the meat. The treated pork sample was kept under ambient conditions until microbiological sampling and eventual cooking.

After cooking, the treated pork loin samples were tested for drip loss and cooking loss. Roasted pork samples were also subjected to sensory evaluation by preference ranking to determine the application method that resulted in the most preferred cooked meat. Thirty untrained panelists were asked to rank the
four samples (dipped, sprayed, rinsed, and control) based on their preference using a score sheet with “1” as the most preferred and “4” as the least preferred.

2.5 Assessment under Public Market Conditions

A survey at MPM was conducted with market vendors as respondents. Information regarding the slaughterhouse, time of slaughter and delivery to the market, and the time it would take for the product to be sold were gathered. A visit to the slaughterhouse was also conducted.

For the pilot study, pork loins, each weighing 3 kg, were randomly purchased at 6:00 AM. The loin assigned to Treatment 1 served as the control and was not subjected to any application. The loin assigned to Treatment 2 was sprayed with sterile distilled water. This served as a blank in this set-up to account for the action of distilled water on meat. The loin assigned to Treatment 3 was also sprayed similarly except that LP suspension was used. Initial sampling was done at 6:00 AM and initial microbial and physicochemical data were obtained before the application of treatments. For the physicochemical analysis, pH was monitored using a digital pH meter. This was done by homogenizing 10 g meat samples with 90 mL distilled water. The total volatile base nitrogen (TVB-N) was measured based on the method described by the European Commission (1995). The treatments were applied, then the loins were hung in the market stalls to expose them to prevailing market conditions. Subsequent sampling was done after 3 h and 6 h. This experiment was replicated twice with three participating vendors.

2.6 Statistical Analysis

For assessment under laboratory conditions, independent t-test and Cohen's effect size were used to compare the log reductions at an alpha level of 0.05. In evaluating the three methods of application, a one-way analysis of variance (ANOVA) at an alpha level of 0.05 was used to compare data from triplicate experiments. Friedman's test was used for the preference ranking test. For the pilot study, one-way ANOVA and Fisher's least significant difference (LSD) at an alpha level of 0.05 were used following a completely randomized design to compare the mean microbial reduction or increase of the different treatments and the obtained pH and TVB-N mean values.
3. Results and Discussion

3.1 Assessment of Laboratory Conditions

The log increase data of the microorganisms in the raw pork LD muscle after 8 h of incubation under laboratory conditions are presented in Table 1. The microbiological counts of both the control and the meat applied with LP generally increased as indicated by the positive values.

Table 1. Increase in log count of microorganisms in the untreated and LP-treated raw pork LD muscle incubated for 8 h under laboratory conditions

<table>
<thead>
<tr>
<th></th>
<th>Initial log CFU/g of pork</th>
<th>Increase in log CFU/g of pork&lt;sup&gt;1,2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Untreated</td>
<td>Treated</td>
</tr>
<tr>
<td>Total plate count</td>
<td>5.24</td>
<td>5.25</td>
</tr>
<tr>
<td></td>
<td>+1.76 ± 0.71&lt;sup&gt;a&lt;/sup&gt;</td>
<td>+0.90 ± 1.87&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Coliform count</td>
<td>3.29</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td>+1.58 ± 0.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>+0.55 ± 0.53&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Staphylococcal count</td>
<td>5.13</td>
<td>4.82</td>
</tr>
<tr>
<td></td>
<td>+1.47 ± 0.70&lt;sup&gt;a&lt;/sup&gt;</td>
<td>+0.04 ± 0.14&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LAB count</td>
<td>3.57</td>
<td>6.00</td>
</tr>
<tr>
<td></td>
<td>+2.38 ± 0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>+2.02 ± 1.78&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>Positive sign indicates an increase in microbial count
<sup>2</sup>Five pours of LP of 1 mL each on each of the two sides of the meat. Estimated LP concentration = 9.47 log count per mL
<sup>3</sup_means within a row with similar letters are not significantly different (p > 0.05)

The aerobic plate count or TPC measures the level of aerobic microorganisms present in a food product (Maturin and Peeler, 2001). This parameter indicates general microbiological quality and was used to assess a hazard analysis critical control point system (Hong et al., 2008). In the United States, the TPC of freshly dressed pork carcasses usually ranges from 2 to 4 log CFU/cm² (National Research Council (US) Subcommittee on Microbiological Criteria, 1985). A study by Bohaychuk et al. (2011) reported aerobic counts of 3 log CFU/cm² of the pork carcass. According to the New Zealand Ministry of Health and US National Research Council (1995), the TPC of carcasses of pigs at 35 °C must not exceed 6.70 log CFU/g of food. Moreover, the National Meat Inspection Services (2008) of the Philippines prescribed a TPC limit of 6 log CFU/g of food. Given this threshold, the obtained initial TPC of the raw pork muscle was found to be acceptable. However, considering that the TPC of the meat at 8:00 AM was approaching the maximum limit, meat bought much later may already exceed the standard. Additionally, the increase in TPC in the untreated and LP-treated raw pork LD muscle was not statistically different. Still, a higher log increase was observed in the control, suggesting that LP was able to slow down the growth of aerobic microorganisms. Using the same standard set by the New Zealand Ministry of Health (1995), the obtained TPC of the raw pork after 8 h of incubation already failed to meet the
standard maximum value. This could signify that the initial count was already too large to begin with. However, TPC results must be accompanied by other microbial tests such as staphylococcal and coliform counts which are more specific.

The log increase values in coliform count in both untreated and treated pork were not significantly different. However, the mean value was higher in the control. Using the standard set by the New Zealand Ministry of Health (1995), the obtained initial coliform count exceeded the limit of 3.0 log CFU/g of food. Initially, the sample was already shown to contain fecal contamination. High levels of coliforms suggest the need to improve hygienic practices during meat processing and selling as they indicate potential contamination with undesirable microorganisms (Pond et al., 2016).

Results also showed that the untreated pork manifested a significantly greater increase in staphylococcal count compared to the treated meat. This suggests the effectiveness of LP in slowing down the growth of staphylococci in raw pork after incubation at ambient temperature (25 °C) for 8 h. This has important implications on food safety because enterotoxins produced by staphylococci are a major cause of foodborne diseases. *Staphylococcus aureus*, in particular, is a pathogen commonly involved in food intoxications. A study by Atanassova et al. (2001) described the prevalence of *S. aureus* in raw pork. Threshold levels for *S. aureus* enterotoxin expressed as the number of bacteria of 5 to 8 log CFU/g of food have been used. In this study, the staphylococcal count after 8 h of contact time reached 6.26 log CFU/g of pork for the untreated meat while the LP-treated meat had 4.86 log CFU/g of pork. This indicated that treatment with LP suspension reduced the possibility of enterotoxin production by staphylococci in the meat. Moreover, the obtained initial and final staphylococcal counts of the sample did not satisfy the limit of 3.0 log CFU/g of food set by the New Zealand Ministry of Health (1995). This signified that initially, the raw pork LD muscle had already been contaminated with staphylococci, suggesting that there was contamination during slaughter, transport, and display in the meat stalls.

Lastly, the LAB counts of the untreated and LP-treated raw pork LD muscle were not significantly different, though a higher increase was observed in the former. Overall, slaughter practices largely affect the incidence of pathogens in raw pork sold in the market. Unorganized retailers that do not follow standard practices and pollution in the slaughterhouse and meat shop can lead to high levels of undesirable microorganisms (Mangal et al., 2018). In this
study, the initial pathogen counts that did not satisfy the standards can be due to contact of the carcass with hides, feet, manure, and dirt during the slaughtering process, the equipment used, clothing and hands of the personnel, water used for washing carcasses and the equipment, and airborne microorganisms. Thus, intervention in previous steps in the processing line is necessary to reduce the initial microbial load of raw meat. In line with this, the National Meat Inspection Service of the Philippines has plans of constructing a food safety-compliant slaughterhouse in Calinan, Davao City.

3.2 Evaluation of Methods of Application

Dipping a kilogram of pork loin required about 1,300 mL of the bacterial suspension, spraying a kg needed about 6 mL, while rinsing the meat required approximately 300 mL LP suspension per kg of meat. The approximations of these volumes, however, were only true for the containers and sprayer used in this experiment. Variations are expected.

Table 2 shows that initially, the TPC of the meat applied with LP was still acceptable and the increase in log CFU was not significantly different across methods of application. On the other hand, the initial coliform counts of all samples failed to pass the standard. The treatments were able to slow down the rate of coliform increase, but there was no significant difference across methods of application (Figure 1).

<table>
<thead>
<tr>
<th>Log CFU/g of pork</th>
<th>Untreated</th>
<th>Spray(^1)</th>
<th>Rinse(^1)</th>
<th>Dip(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total plate count</td>
<td>5.02</td>
<td>5.01</td>
<td>5.12</td>
<td>5.22</td>
</tr>
<tr>
<td>Coliform count</td>
<td>3.63</td>
<td>3.98</td>
<td>3.99</td>
<td>3.89</td>
</tr>
<tr>
<td>Staphylococcal count</td>
<td>4.72</td>
<td>4.83</td>
<td>4.73</td>
<td>4.86</td>
</tr>
<tr>
<td>LAB count</td>
<td>4.56</td>
<td>4.56</td>
<td>4.53</td>
<td>4.55</td>
</tr>
</tbody>
</table>

\(^1\)Estimated cell count/mL of LP suspension = 4.8x10\(^2\) cell/mL
Means with different letters among treatments within the same incubation time are significantly different \((p < 0.05)\); and bars pointing down indicate a reduction in the microbial count; estimated cell count/mL of LP suspension \(= 4.8 \times 10^2 \text{ cell/mL}\).

Figure 1. Increase/decrease in log count of microorganisms in the untreated and LP-treated pork loins incubated for 4 h at 25 °C.

The initial staphylococcal counts exceeded the maximum acceptable limit (Figure 1). However, results showed that LP significantly retarded the growth of staphylococci. The log reduction was significantly higher in the treated samples compared to the control after 2 h and 4 h of exposure to ambient conditions, with no significant difference across methods of application. This describes the potential of the LP treatment in controlling the growth of staphylococci. The increase in LAB counts did not differ among all treatments.

Furthermore, LP had no adverse effects on the drip loss, cooking loss, and degree of preference of the roasted pork samples. According to Table 3, there was no significant difference in the roasted loins concerning the percent drip loss and percent cooking loss. Drip loss encompasses the fluid which can be expelled from meat. This includes water and protein (Fischer, 2007). On the other hand, cooking loss includes drippings and losses that affect meat flavor, so a high cooking loss signifies poor eating quality (Aaslyng et al., 2003). Results of the preference ranking test showed that meat sprayed with LP was the most preferred and the difference across methods of the application was not significant.
Table 3. Mean percent drip loss, percent cooking loss, and rank-sum scores of roasted untreated and LP-treated meat

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percent drip loss of meat (%)</th>
<th>Percent cooking loss of meat (%)</th>
<th>Rank sum&lt;sup&gt;2&lt;/sup&gt; (n=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>6.33</td>
<td>36.18</td>
<td>147</td>
</tr>
<tr>
<td>Spray</td>
<td>6.71</td>
<td>37.26</td>
<td>130</td>
</tr>
<tr>
<td>Rinse</td>
<td>6.14</td>
<td>32.04</td>
<td>156</td>
</tr>
<tr>
<td>Dip</td>
<td>5.05</td>
<td>32.03</td>
<td>163</td>
</tr>
</tbody>
</table>

<sup>1</sup>No significant differences (p > 0.05); <sup>2</sup>a lower rank-sum indicates a higher preference

Based on the results of the microbiological analysis and sensory evaluation, spraying the raw meat sample was the most efficient method of application as it used the least amount of bacterial suspension. This method was then employed for assessment under public market conditions.

3.3 Assessment under Public Market Conditions

According to the survey conducted, 80% of the stall vendors source the hogs slaughtered and sold in the market from farms while the remaining 20% source the hogs from backyard raisers. A Value Chain Analysis for swine in Iloilo conducted by the Department of Agriculture – Philippine Rural Development Program (2015) indicated that hogs sourced from farms are more preferred by traders because of good meat quality. Meats from farm-raised hogs are described as having more consistent and thinner back fat. This can be attributed to the use of upgraded breeds by farms compared to the use of traditional breeds by backyard raisers.

Several slaughterhouse conditions were observed to be non-compliant with Processing Hygiene set by the Food and Agriculture Organization (Skaarup, 1985). For instance, hogs were carried by hand without using hoists. In the slaughterhouse, there was no barrier between the skinning or scalding and the eviscerating area, violating the rules defined by FAO. The same set of knives was used for different operations and the facility did not have a designated handwashing area. Also, the personnel did not wear prescribed attire and protective gear. Proper waste disposal was not observed. In these instances, the strict application of safety regulations and inspections conducted by regulatory agencies is necessary to guarantee the safety of pork products and to prevent the transmission of foodborne pathogens (Pond et al., 2016). From the slaughterhouse, the meat is delivered to MPM using a refrigerated van at around 4:00 to 5:00 AM every day. It would take more than 12 h for the meat
delivered to be mostly, if not completely, sold from 4:00 AM earliest to 7:00 PM at the latest.

After 3 h and 6 h of exposure to public market conditions, the TPC of the meat samples generally increased as presented in Figure 2. The control had the highest increase for both sampling periods. It was observed that after 3 h, the mean log increase in TPC of the untreated meat was significantly higher.

![Figure 2. Increase/decrease in log count of microorganisms in the untreated and LP-treated pork after 6 h of exposure to public market conditions](image)

Using the international standards set by the New Zealand Ministry of Health (1995), the observed initial mean coliform log count exceeded 3.0 log CFU/g of meat, signifying that at 6:00 AM, meat sold at MPM already had a high coliform count (Table 4). However, after 6 h, there was a significantly lower rate of increase in the coliform count in the treated samples compared to the control. This slowing down of coliform growth by the LP spray could be attributed to the production of bacteriocins and the production of organic acids. Alakomi et al. (2000) explained that lactic acid produced by LAB can permeabilize the outer membrane of Gram-negative bacteria, thereby increasing the effectiveness of other antimicrobial substances against these microorganisms.
Table 4. Initial microbial counts of raw pork before spraying with sterile distilled water and LP suspension

<table>
<thead>
<tr>
<th></th>
<th>Untreated</th>
<th>Sterile distilled water</th>
<th>LP spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total plate count</td>
<td>5.66</td>
<td>5.76</td>
<td>5.63</td>
</tr>
<tr>
<td>Coliform count</td>
<td>3.30</td>
<td>3.96</td>
<td>3.65</td>
</tr>
<tr>
<td>Staphylococcal count</td>
<td>3.79</td>
<td>3.71</td>
<td>3.48</td>
</tr>
<tr>
<td>LAB count</td>
<td>4.89</td>
<td>4.85</td>
<td>4.80</td>
</tr>
</tbody>
</table>

1Estimated LP concentration = 2%

The initial staphylococcal count also exceeded the standard as listed in Table 4. At 2% LP concentration, the spray was not able to retard the growth of staphylococci under prevailing public market conditions (Figure 2). Considering that the initial mean log staphylococcal count exceeded the accepted limit (Table 4), applying the LP spray immediately after slaughter could reduce the initial log count of staphylococci since intervention is applied before the meat is distributed in the market. Furthermore, as stated in the market survey, meat is displayed in stalls for about 12 h at ambient temperature, providing more time for possible contact with contaminated equipment as well as vendors and customers with unhygienic practices. Thus, the application of the LP spray right after slaughter could lower the staphylococcal count of the meat.

Figure 3 shows that pH values were not significantly different among treatments and across sampling periods. These values were also within the standards set by FAO at 5.5 to 6.2 for fresh pork meat (Heinz and Hautzinger, 2007). Post-mortem pH of meat muscle and pH decline rate affect water holding capacity, which further determines drip loss and cooking loss as previously described. Measurement of pH is thus crucial in dictating meat quality (Kim et al., 2016). Based on the mean pH values recorded after 6 h, the meat is good for processing because it did not fall within the PSE meat classification (pH < 5.5) and DFD meat classification (pH > 6.1). This type of meat is considered to be of good quality based on non-microbiological parameters since the typical meat flavor is optimum at these pH values (Heinz and Hautzinger, 2007; Kim et al., 2016).
Figure 3. Change in pH of raw pork after 6 h of exposure to public market conditions.

The TVB-N values are illustrated in Figure 4. TVB-N accounts for all substances that are produced from the degradation of protein. These substances include ammonia, dimethylamines, trimethylamines, other amines from decarboxylation of amino acids, and other nitrogenous compounds that become volatile when subjected to alkaline conditions (Etienne, 2005). In pork, TVB-N compounds include ammonia, trimethylamine, and dimethylamine. The TVB-N content in pork is a vital index used to evaluate the freshness of pork meat (Cai et al., 2011). Based on Figure 4, the TVB-N levels for the treatments generally decreased after 6 h of treatment while for the control, TVB-N values increased after 6 h. The observed decrease after 3 h of treatment was not significantly different from the initial values obtained. The same trend was observed for the meat pH. Moreover, the initial pH and TVB-N values may be different across treatments with the LP spray resulting to meat with lowest initial pH and highest initial TVB-N (Figures 3 and 4); however, these values were not found to be significantly different across treatments.

Meat studies reported a direct relationship between pH and TVB-N (Abu Bakar et al., 2008; Kuswandi and Nurfawaidi, 2017). Based on the results of the current study, the TVB-N of meat sold at MPM was low, indicating that the pork was still fit for consumption following the standard of 4.0 to 15.0 mg per 100 g sample (Xiong et al., 2012). This observation coincided with the observed pH which was still under acidic conditions signifying that the meat was still of good quality. This acidic condition did not allow more TVB-N to be accounted for during analysis since the pH was not sufficient to liberate the volatile bases that require alkaline conditions.
4. Conclusion and Recommendations

LP F$_2$I$_2$ has shown some potential as biopreservative for raw pork under prevailing market conditions. However, it cannot be used as a remedial intervention for poor microbiological quality. As a precautionary measure, meat bought from Mintal Public Market should be washed thoroughly with water before cooking or storage at appropriate temperatures. Moreover, thorough cooking of meat should always be observed. Further study based on the use of LP F$_2$I$_2$ is necessary before it can be recommended for biopreservation of meat sold at ambient conditions (25 °C).

5. Acknowledgement

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6. References


