

Acidification alternatives for elaborating “salchichon” (Spanish dry fermented sausage)

¹Soto-Aguilar, A., ²Soto-Simental, S., ¹Islas-Pelcastre, M., ¹Pérez-Soto, E. and ^{1,*}González-Tenorio, R.

¹*Agroindustria Sustentable, Instituto de Ciencias Agropecuarias, Universidad Autónoma del Estado de Hidalgo, Código postal 43600, Tulancingo, Hidalgo, México*

²*Biología Veterinaria, Instituto de Ciencias Agropecuarias, Universidad Autónoma del Estado de Hidalgo, CP. 43600, Tulancingo, Hidalgo, México*

Article history:

Received: 1 November 2023

Received in revised form: 23 January 2024

Accepted: 5 November 2024

Available Online: 9

December 2024

Keywords:

Lactic acid bacteria,
Glucono delta lactone,
Apple cider,
Acidification,
Salchichon

DOI:

[https://doi.org/10.26656/fr.2017.8\(6\).354](https://doi.org/10.26656/fr.2017.8(6).354)

Abstract

The acidification technique is widely used in the meat industry to increase meat product security and quality. The most popular acidified and fermented meat product is salchichon. The objective of this study was to determine the effect of alternatives to lactic acid bacteria for elaborating salchichon. Three treatments were prepared to acidify the meat product: glucono delta lactone (GDL), apple cider (SID) and a commercial starter (BAL) as control. When the meat product reached a weight loss of 35%, physicochemical parameters, microbial groups and sensory analyses were evaluated. Results indicated that pH decreased most in GDL and SID resulted in greater weight loss, while GDL showed the lowest pH value at the end of the fermentation process. There were also statistical differences in cohesiveness and resilience. Moreover, there was no presence of *Salmonella* or *Listeria monocytogenes* in any of the treatments. The sensory analysis indicated that the treatment added with apple cider scored the highest for color, while both SID and BAL were the most accepted in terms of taste. It was concluded that apple cider and glucono delta lactone can be used for acidification during the elaboration of the salchichon, as pH levels decline quickly, thereby reducing the processing time without affecting the quality of the final product.

1. Introduction

The acidification procedure is widely used in the meat industry to ensure the quality of meat products. The salchichon is a dry fermented sausage elaborated with a blend of pork fat and meat, spices as well as other ingredients (Bejarano, 2001) and is one of the most popular acidified meat products. The original acidification process was based on native bacterial flora which was favored during the pre-salting, mixing, and sausage stuffing processes as well as for the climatic conditions during ripening. However, the process was not always successful and sometimes the sausages did not ferment with a sufficiently high pH value, thereby developing harmful bacteria and foodborne microorganisms (Fadda *et al.*, 2020).

The use of lactic acid bacteria (LAB) lowers the pH due to the lactic acid produced during the fermentation process. When the pH falls to 5.1 (the protein isoelectric point), a quicker drying process of the sausages is achieved. Then, during ripening, the characteristic

flavors and textures associated with this product are developed brought about by several physicochemical and enzymatic changes (Jurado *et al.*, 2007; Seleshe *et al.*, 2021). In the same way, it is essential that there is a reduction in water activity (aw) which, in combination with the lower pH values, results in sausages with high stability and can be kept without refrigeration (Vignolo *et al.*, 2010).

For the meat industry, the quality assurance and safety of the sausages is important, as well as the processing time and cost of the product. Generally, the processing time for the salchichon can vary between 20 to 30 d depending on the diameter and casing type (Luzón and Bejarano, 2001). However, smaller businesses that elaborate this type of product in an artisanal manner use uncontrolled maturation or drying processes, in which uncontrolled spontaneous fermentation can occur as these LAB are not widely used. This is in part due to a lack of knowledge of the technological fermentation processes as well as the

*Corresponding author.

Email: rtenorio@uaeh.edu.mx

availability and cost of meat starters.

An alternative to using meat starter is adding organic acids such as acetic, malic or lactic directly to meat products which allows the acidification process to occur quickly. This leads to a low pH and speeds up the drying process, thereby decreasing the processing time for a dry fermented sausage (Solignat, 2002). However, some acidulants could have a detrimental effect on the final meat product due to a decrease in pH.

Glucono delta lactone is a neutral cyclic ester which is hydrolyzed to produce gluconic acid, thereby emulating the mild acidification performed by lactic acid-producing bacteria. This additive is usually used to accelerate the lowering of pH values in dry-matured products, as unlike the starter cultures that acidify raw sausages within days, this particular additive can complete the process in hours. This helps to decrease the water activity values, lower the risk of pathogens present in the sausage, as well as benefit the yield of the final product (Juárez, 2020). This additive can also be used to control the pH and encourage the fermentation of the desired microorganisms which are responsible for the characteristic texture, flavor and aroma. In addition, it can help prevent the growth of unwanted bacteria and help maintain product quality and safety. This effect can also be achieved with other additives or ingredients that manage to control the pH and help with the fermentation of the sausage. According to Linares (2022), cider is a fermented natural beverage obtained from the pressing and fermentation of apples and has a high content of vitamins A and C, thereby giving this beverage high antioxidant properties. Apart from water, other components of cider are organic acids, sugars, alcohols and phenolic compounds. Due to its low pH of 3.7, apple cider can be used as a natural acidifying agent and as a source of nutrients by allowing the meat mass to rapidly lower the pH and begin the maturation process. GDL and apple cider can be used as an alternative to meat starters to decrease ripening time and the cost of the fermentation process without adverse effects on the sensory quality of the sausage. According to above

mentioned, it is important to evaluate the effectiveness of different acidification methods to determine which is the most suitable for the production of salchichon. The objective of this research was to analyze the use of GDL and apple cider as an alternative to the use of LAB and to determine its effect on the physicochemical, textural, microbiological, and sensory characteristics.

2. Materials and methods

2.1 Elaboration and acidification of meat batter

The meat components were grounded in a Torrey grinder model M-32HP (Torrey, Mexico) using a 5.6 mm sieve. Then meat and fat were homogenized and divided to make three treatments as described in Table 1. The control treatment (BAL) contained the SafePro Flora Italia meat starter 0.03% (Chr. Hansen, Denmark), while the second treatment contained Glucono Delta Lactone (GDL) (FABPSA®, Mexico), and the third treatment contained apple cider (SID) (Moment's Suprema® Zacatlán, Mexico). After adding an acidifier or meat starter, the meat batter was homogenized for 5 mins and was then stuffed.

2.2 Salchichon ripening

The meat batter was stuffed in portions of 500 g using 90 gauge collagen casing with a model VF 608 vacuum filler (Handtmann group, Biberach, Germany). The sausages were subjected to fermentation, ripening and drying under controlled conditions as described in Table 2. During this period, several parameters were measured to evaluate the sausages' characteristics (weight loss, pH, water activity and color). Once the sausages reached 40% weight loss, the salchichon products were vacuum packed and kept in refrigeration

Table 2. Conditions used during the fermentation process, ripening and drying time.

| Parameter | Temperature | Relative humidity | Time |
|--------------|-------------|-------------------|--------|
| Fermentation | 24 - 26°C | 90 - 95% | 24 hrs |
| Ripening | 14 - 16°C | 80 - 85% | 32 d |
| Drying | 22 - 24°C | 55 - 65% | 48 hrs |

Table 1. Formulations used to elaborate salchichon with three different acidification methods.

| Component | Quantity (kg) | Percentage | | |
|---------------------------|---------------|------------|-------|-------|
| | | BAL | GDL | SID |
| Meat | 3.600 | 67.87 | 67.01 | 66.02 |
| Dorsal fat | 1.400 | 26.40 | 26.06 | 25.68 |
| Additives and species mix | 0.220 | 4.15 | 4.09 | 4.03 |
| Apple cider | 0.150 | - | - | 2.75 |
| Glucono delta lactone | 0.070 | - | 1.30 | - |
| Meat starter | 0.0013 | 0.03 | - | - |
| Salt | 0.050 | 0.94 | 0.93 | 0.92 |
| Dextrose | 0.020 | 0.38 | 0.37 | 0.37 |
| Cured salt | 0.013 | 0.24 | 0.23 | 0.23 |

BAL: Control (SafePro Flora 0.03%, Italy), GDL: Glucono Delta Lactone, SID: Apple cider.

(4 to 6°C) for 15 days, after which microbiological, texture profile and sensory analyses were performed.

2.3 Microbiological analysis

To determine the presence of pathogenic bacteria to warranty the safety of salchichon, *Listeria monocytogenes* and *Salmonella* spp. were monitored.

2.3.1 Detection of *Listeria monocytogenes*

To detect the presence of *L. monocytogenes* in the samples of salchichon, a rapid method was used (VIP Gold™) following the manufacturer's instructions (BioControl Systems, Inc., Bellevue, WA, USA). Briefly, samples were enriched for 24 hrs using modified Frazer broth + LiCl, after that samples were inactivated at 100°C for 5 mins and read in 10 mins. A negative result is when only one band appears on VIP Gold device.

2.3.2 Detection of *Salmonella* spp.

The presence of *Salmonella* spp. was detected using a rapid method (VIP Gold™ for *Salmonella*) according to the manufacturer's instructions (BioControl Systems, Inc., Bellevue, WA, USA). Briefly, 25 g of the sample was enriched with Rappaport-Vassiliadis R10 Broth for 24 hrs at 41.5°C. Then samples were inactivated and placed the tubes in hot water for 10 min. Subsequently, 0.1 mL of the inactivated sample was transferred to the device and incubated for 10 min and read it. One band in the device indicates a negative result.

2.4 Physicochemical analysis

Weight loss during the elaboration of the meat products was determined by identifying the difference in weight of the sausage every five days through fermentation, maturation and drying processes until reaching a loss of 40%. The pH was determined using an insertion electrode adapted to a Hanna HI99163 pH meter (Hanna Instruments, Cluj-Napoca, Romania). To determine water activity, an Aqualab Decagon Device Series 3 TE (Aqualab, Pullman, WA, USA) was used. The color of the salchichon was measured using a Minolta CM-508-d colorimeter (Konica-Minolta, Japan) using the CIEL*a*b* color space. The equipment was configured with a D65 illuminant, an aperture size of 8 mm and an observer angle of 10°.

The texture profile analysis was performed with a Stable MicroSystems TA-XT Plus texture analyzer (Surrey, United Kingdom). The samples were cut into cubes measuring 1 cm on each side. The texture analyzer was configured to 1 mm.s⁻¹ using a cylinder probe with a 2.56 cm diameter. Specialized software was used to obtain the following parameters from the graphics:

hardness, springiness, chewiness, cohesiveness and resilience.

2.5 Sensory analysis

A preference test was conducted to evaluate the sensory analysis with 151 consumers taking part, 38.8% of whom were male and 61.2% of whom were female with an age range of 19 to 60 years. The sensorial attributes evaluated were general appearance, color, odor, and taste of the salchichon. A 7-point scale was used (1= I dislike much, and 7= I like much).

2.6 Statistical analysis

This study was analyzed under a randomly completed design using the addition of GDL, CID or BAL as a fixed factor. Moreover, the variables measured during ripening (weight loss, pH, a_w and color) were analyzed over time. After performing an analysis of variance, a Tukey's mean comparison test was performed with a significance of P<0.05 if differences were observed between the treatments or time periods. All procedures were performed with the statistical software Minitab 20 (Minitab Inc., USA). The models used were the following:

$$Y_{ij} = \mu + \beta_i + \varepsilon_{ij},$$

Where, Y_{ij} = dependent variable, μ = population mean, β_i = treatment effect, and ε_{ij} = experimental error.

$$Y_{ijk} = \mu + \beta_i + \tau_j + \beta_i(\tau_j) + \varepsilon_{ijk},$$

Where, Y_{ijk} = dependent variable, μ = population mean, β_i = treatment effect, τ_j = ripening time, $\beta_i(\tau_j)$ = treatment effect through the ripening time, and ε_{ijk} = experimental error.

3. Results and discussion

3.1 Physicochemical characteristics of salchichon

The ripening time between the fermentation and drying of the salchichon was 35 days (Table 3). This period was necessary to reach the required water activity of 0.90 in order to obtain the desired characteristics of firmness and pH values for the sausage to be considered a stable dry meat product (Lücke, 1998). At the end of the drying process, the SID treatment (38.99%) recorded the greatest weight loss (P<0.05), followed by the BAL treatment (37.20%) while the GDL treatment had the lowest weight loss values (36.48%). These results are similar to those found by Santos *et al.* (2021) who characterized chorizo and salchichon for 25 and 30 d of ripening and drying, obtaining a loss of between 35 to 40%. In another study, Cavalheiro *et al.* (2021) reported a weight loss of 42.5% in a dry meat product during the

Table 3. Weight loss, pH and water activity during the fermentation process, ripening and drying time of the salchichon.

| Day | Weight loss (%) | | | pH | | | Water activity (a_w) | | |
|-----|--------------------|--------------------|--------------------|---------------------|-----------------------|-----------------------|--------------------------|-----------------------|------------------------|
| | BAL | GDL | SID | BAL | GDL | SID | BAL | GDL | SID |
| 0 | 0 | 0 | 0 | 5.52 ^a | 5.19 ^b | 5.50 ^a | 0.953 ^{ab} | 0.951 ^{abc} | 0.950 ^{abc} |
| 5 | 2.95 ^t | 3.15 ^s | 2.86 ^u | 4.76 ^{efg} | 4.48 ^{ij} | 4.55 ^{ghij} | 0.950 ^{abc} | 0.955 ^a | 0.950 ^{abc} |
| 10 | 10.43 ^q | 9.66 ^r | 11.94 ^p | 4.73 ^{efg} | 4.39 ^j | 4.56 ^{fghij} | 0.944 ^{abcd} | 0.946 ^{abcd} | 0.944 ^{abcd} |
| 15 | 19.69 ^o | 20.31 ⁿ | 20.43 ^m | 4.97 ^c | 4.53 ^{hij} | 4.63 ^{efghi} | 0.936 ^{abcde} | 0.932 ^{cdef} | 0.934 ^{bcdef} |
| 20 | 25.39 ^l | 25.64 ^k | 26.75 ^j | 5.09 ^c | 4.19 ^k | 5.05 ^{bc} | 0.920 ^{efgh} | 0.927 ^{defg} | 0.936 ^{abcde} |
| 25 | 30.31 ⁱ | 30.37 ^h | 32.08 ^g | 5.08 ^{bc} | 4.68 ^{efgh} | 5.11 ^{bc} | 0.918 ^{efgh} | 0.919 ^{efgh} | 0.922 ^{efgh} |
| 30 | 34.06 ^e | 33.90 ^f | 36.03 ^d | 5.01 ^{bc} | 4.60 ^{efghi} | 4.95 ^{cd} | 0.910 ^{hi} | 0.910 ^{ghi} | 0.914 ^{fghi} |
| 35 | 37.20 ^b | 36.48 ^c | 38.99 ^a | 5.03 ^{bc} | 4.75 ^{cf} | 5.01 ^{bc} | 0.908 ^{ghi} | 0.897 ⁱ | 0.907 ^{ghi} |
| SEM | 2.77 | 2.75 | 2.91 | 0.05 | 0.06 | 0.06 | 0.004 | 0.004 | 0.003 |

Values are presented as mean. Values with different superscripts within the same row of the same parameter are statistically significantly different, using Tukey's test ($P < 0.05$). SEM: Standard error of the mean.

ripening process over 20 d. Furthermore, Škrlep *et al.* (2022) recorded a weight loss of 42.3% in a ripening sausage. Generally, differences between ripening and drying days depend on several factors such as sausage diameter, fat content, speed of airflow during drying time, and the use of acidifying agents, among other factors. As previously mentioned, the salchichon acidified with GDL underwent less weight loss than other treatments ($P < 0.05$). The addition of GDL led to a low pH value (5.1), and this behavior was even noted during the ripening and drying time, leading to values far removed from the range of the protein isoelectric point. This effect reduces humidity loss and consequently imparts different characteristics to other treatments.

The pH value in meat batter was different ($P < 0.05$) among the treatments (Table 3). GDL treatment had the lowest pH, and such an acidity value would mean less microbial growth. During the ripening-drying process, a decrease in pH values occurred with differences among the treatments ($P < 0.05$). Initial pH values in meat batter were between 5.19 and 5.72, which then quickly decreased during ripening caused mainly by lactic acid produced by BAL during the fermentation process and the use of GDL and SID. However, GDL treatment showed the lowest pH value ($P < 0.05$), with a pH of 4.19 on day 20 of ripening, but then it increased at the end of the drying period (4.75) which was probably due to a proteolytic change. Similar behavior in pH values was found by Joshevska *et al.* (2021) using GDL in a fermented sausage, and it is for this reason that Ducic *et al.* (2018) indicated that GDL can be used in the preparation of fermented sausage. It is also important to indicate that a rapid drop in pH inhibits enterobacteria growth and undesirable microorganisms at the beginning of ripening, especially when water activity is high. According to Incze (1998), a sausage can be classified as having high levels of acidity when a product has a pH value of less than 5.3.

Water activity decreased during the ripening process

(Table 3), although no differences ($P > 0.05$) were observed either at the beginning or at the end of the ripening stages between the treatments, with values ranging between 0.95 and 0.90 until the end of the drying process. Other studies by Gonzalez-Mohino *et al.* (2020) and Millan *et al.* (2018) reported lower water activity values than those reported in this work. However, according to Holck *et al.* (2017), the salchichon can be classified as a dry sausage when the water activity is equal to or less than 0.90.

The results obtained for the color of the salchichon are shown in Table 4, and there was no difference among the treatments during the ripening process. However, during the drying process, the L^* value after 35 d for the SID treatment had the most luminosity ($P < 0.05$) compared with the other treatments (46.6 vs 39.3 and 41.5 for SID, BAL and GDL, respectively). The redness index decreased during ripening and it is at its highest at the end of the drying process. Pérez-Álvarez *et al.* (1999) indicate that the loss of redness in fermented sausages is due to the effect of lactic acid on different myoglobin redox states. Finally, the b^* value was different among the treatments ($P < 0.05$), with the salchichon made with apple cider having the highest b^* value after 35 d.

The results for the texture profile analysis (TPA) can be observed in Table 5, and there was no difference ($P > 0.05$) for hardness, springiness and chewiness between treatments. Seleshe *et al.* (2021) carried out a TPA on salchichon added with different meat starters and reported hardness values of between 24 and 30 N, slightly lower than those presented in this study. The cohesiveness was different among treatments ($P < 0.05$), and the salchichon prepared with GDL had the lowest value (0.36) compared to BAL (0.55) and SID (0.50). However, these values are similar to those found in sausages sold commercially in Spain, with Herrero *et al.* (2007) reporting cohesiveness values of about 0.45 in these commercial products.

Table 4. Color parameters during the ripening and drying processes.

| Day | Weight loss (%) | | | pH | | | Water activity (a _w) | | |
|-----|-----------------------|----------------------|----------------------|-----------------------|-----------------------|-----------------------|----------------------------------|-------------------------|-------------------------|
| | BAL | GDL | SID | BAL | GDL | SID | BAL | GDL | SID |
| 0 | 36.77 ^h | 39.44 ^{gh} | 36.77 ^h | 30.59 | 30.86 | 31.02 | 42.00 ^{ab} | 42.11 ^{ab} | 44.12 ^a |
| 5 | 51.33 ^{ab} | 48.31 ^{bcd} | 48.54 ^{bcd} | 23.88 ^{defg} | 26.69 ^{bcd} | 27.94 ^{ab} | 35.95 ^{bcd} | 30.84 ^{efgh} | 26.93 ^{gh} |
| 10 | 49.31 ^{abcd} | 51.80 ^{ab} | 41.80 ^{bcd} | 27.65 ^{abc} | 25.95 ^{bcd} | 26.94 ^{bcd} | 28.11 ^{gh} | 33.00 ^{cdefgh} | 29.53 ^{fgh} |
| 15 | 49.24 ^{abcd} | 50.34 ^{abc} | 47.85 ^{bcd} | 24.40 ^{cdef} | 23.98 ^{defg} | 26.56 ^{bcd} | 35.99 ^{bcd} | 32.27 ^{cdefgh} | 31.13 ^{efgh} |
| 20 | 48.03 ^{bcd} | 53.32 ^a | 49.77 ^{abc} | 21.32 ^{efgh} | 21.13 ^{fgh} | 21.72 ^{efgh} | 27.82 ^{gh} | 30.70 ^{efgh} | 31.61 ^{defgh} |
| 25 | 45.93 ^{cde} | 42.33 ^{efg} | 47.95 ^{bcd} | 25.60 ^{bcd} | 24.58 ^{bcd} | 20.12 ^{hi} | 37.80 ^{abcde} | 39.15 ^{abc} | 32.31 ^{cdefgh} |
| 30 | 46.03 ^{cde} | 50.80 ^{ab} | 45.35 ^{def} | 18.91 ^{hi} | 20.96 ^{gh} | 21.64 ^{efgh} | 31.04 ^{efgh} | 27.90 ^{gh} | 34.20 ^{cdefg} |
| 35 | 39.27 ^{gh} | 41.50 ^{fg} | 46.31 ^{cde} | 19.88 ^{hi} | 22.03 ^{efgh} | 17.33 ⁱ | 38.00 ^{abcde} | 39.03 ^{abcd} | 26.38 ^h |
| SEM | 1.04 | 1.06 | 0.85 | 0.8 | 0.65 | 0.91 | 1.05 | 1.05 | 1.19 |

Values are presented as mean. Values with different superscripts within the same row of the same parameter are statistically significantly different, using Tukey's test ($P < 0.05$). SEM: Standard error of the mean.

Table 5. Texture profile analysis of salchichon prepared with meat starter or chemical acidifiers.

| | Treatments | | |
|--------------|-------------------------|------------------------|-------------------------|
| | BAL | GDL | SID |
| Hardness (N) | 28.52±11.13 | 33.14±9.15 | 31.52±10.04 |
| Springiness | 0.58±0.07 | 0.56±0.05 | 0.59±0.01 |
| Chewiness | 9.15±4.0 | 6.63±1.98 | 9.51±3.69 |
| Cohesiveness | 0.55±0.05 ^a | 0.36±0.05 ^b | 0.50±0.06 ^a |
| Resilience | 15.58±1.77 ^a | 9.25±1.20 ^c | 13.10±2.24 ^b |

Values are presented as mean. Values with different superscripts within the same row are statistically significantly different, using Tukey's test ($P < 0.05$). SEM: Standard error of the mean.

3.2 Salchichon microbiological quality

Table 6 shows the results obtained for the microbiological analysis of salchichon, and there was no presence of *L. monocytogenes* in any of the treatments. Martín *et al.* (2022) demonstrated that meat starter including *Lactobacillus casei* and *Lactobacillus sakei* performs an antimicrobial action on *L. monocytogenes*, while Rocha (2021) mentioned that fermented sausages have a low presence of pathogen bacteria due to a low water activity during drying the process. Certain *Salmonella* species can grow in these conditions, but pH and water activity contribute to the inactivation of foodborne pathogens in the final product (Hwang *et al.*, 2009). The use of LAB to acidify meat has been demonstrated to inhibit foodborne pathogens and also increase quality and food safety in fermented sausages

Table 6. Detection of *Listeria monocytogenes* and *Salmonella* in salchichon elaborated with a meat starter or chemical acidifiers.

| Pathogen Bacteria | Treatments | | |
|-------------------------|------------|----------|----------|
| | BAL | GDL | SID |
| <i>L. monocytogenes</i> | Negative | Negative | Negative |
| <i>Salmonella</i> | Negative | Negative | Negative |

(Ruiz *et al.*, 2017). It is possible that BAL, SID and GDL all have the capacity to inhibit bacterial growth, which explains why there was no trace of these two foodborne bacteria in this study.

3.3 Sensory analysis

The results of the sensory analysis for the salchichon are shown in Table 7, where it can be observed that the general appearance for all salchichon products was similar ($P > 0.05$). However, the color attribute with the highest acceptance among the panelists ($P < 0.05$) was the SID treatment, while the salchichon prepared with BAL and GDL had similar acceptance levels ($P > 0.05$). Regarding odor, the GDL treatment had the lowest value (4.66) compared with SID and BAL (5.14 and 5.17, respectively), with these last two treatments showing no differences ($P > 0.05$). For the taste attribute, the sausage with the highest acceptance were BAL and SID (5.6 and 5.3, respectively). Fermented sausages have a strong and acidic taste due to the fermented and ripening processes where lactic acid is accumulated due to carbohydrate fermentation. This results in a lower pH in the meat thereby developing a texture and acidic taste which is characteristic of fermented sausages (Fadda *et al.*, 2020). During glycolysis, acetic and lactic acids are produced and contribute to the bitter taste of the sausages, while

Table 7. Sensory analysis of salchichon elaborated with meat starter or chemical acidifiers.

| Attribute | Treatment | | | |
|--------------------|-------------------|-------------------|--------------------|------|
| | BAL | GDL | SID | MEE |
| General appearance | 5.54 | 5.39 | 5.57 | 0.03 |
| Color | 5.27 ^a | 5.65 ^a | 5.68 ^b | 0.1 |
| Odor | 5.17 ^a | 4.66 ^b | 5.14 ^a | 0.12 |
| Taste | 5.60 ^a | 5.15 ^b | 5.35 ^{ab} | 0.12 |

Values are presented as mean. Values with different superscripts within the same row are statistically significantly different, using Tukey's test ($P < 0.05$). SEM: Standard error of the mean.

the lipolysis of fatty acids interacts with amino acids to develop important compounds to produce the characteristic taste and aroma. In fermented sausages, the use of LAB leads to a lower pH, yet excessive acid production results in an unpleasant taste (Flores and Olivares, 2014). In addition, GDL used as a chemical acidifier can reduce the pH in sausages and produce an unpleasant taste.

4. Conclusion

In general, the results obtained in this study suggest that meat batter acidification with glucono delta lactone and apple cider can be an alternative to using lactic acid bacteria. Acidifier accelerates a reduction in pH to initialize the drying process without the need for fermentation. However, a decrease in pH leads to increased weight loss in sausages, but it does not affect water activity. The physicochemical characteristics such as pH and water activity were similar among the treatments, although the highest weight loss occurred in the elaborate with apple cider. This same treatment produced the highest L* value and lowest b* value which increased acceptability in the sensory analysis. Consequently, the use of a chemical acidifier such as apple cider and glucono delta lactone could be a potential substitute for meat starters in order to elaborate salchichon due to the shorter processing time which does not affect the physicochemical and sensorial analyses. However, if glucono delta lactone is used in high quantities, it can be detected in a sensory analysis.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors acknowledge to the company "Forrajes y Carnes de Santiago Tulantepec SPR de RL" (Carnex), for the use of its facilities during the manufacturing and analysis of the sausages. To Cristopher Shackley for revising the English translation.

References

- Bejarano, M.S. (2001). Enciclopedia de la carne y productos cárnicos. Vol. II. Plasencia, Spain: Martín y Macías. [In Spanish].
- Cavalheiro, C.P., Ruiz-Capillas, C., Herrero, A.M. and Pintado, T. (2021). Dry-fermented sausages inoculated with *Enterococcus faecium* CECT 410 as free cells or in alginate beads. *LWT*, 139, 110561. <https://doi.org/10.1016/j.lwt.2020.110561>.
- Ducic, M., Vranic, D. and Baltic, M. (2018). Selected

physico-chemical properties of Serbian dry fermented sausages in different meat industries. *Meat Technology*, 59(2), 120-126. <https://doi.org/10.18485/meattech.2018.59.2.7>.

- Fadda, S., López, C. and Vignolo, G. (2020). Embutidos fermentados cárnicos: contribución de bacterias lácticas en la calidad global. In Alejandro Ferrari, A., Vinderola, G. and Weill, R. (Eds.) *Alimentos fermentados. Microbiología, nutrición, salud y cultura*. 1st ed. Buenos Aires, Argentina: Instituto Danone del Cono Sur. [In Spanish].
- Flores, M. and Olivares, A. (2014). Flavor. In Toldrá, F., Hui, Y.H., Astiazarán, I., Sebranek, J.G. and Talon, R. (Eds.). *Handbook of Fermented Meat and Poultry*, p. 217-225. New Jersey, USA: Wiley. <https://doi.org/10.1002/9781118522653.ch25>
- Gonzalez-Mohino, A., Pérez Palacios, T., Antequera, T., Ruiz Carrascal, J., Souza Olegario, L. and Grassi, S. (2020). Monitoring the Processing of Dry Fermented Sausages with a Portable NIRS Device. *Foods*, 9(9), 1294. <https://doi.org/10.3390/foods9091294>.
- Herrero, A.M., Ordóñez, J.A., de Ávila, R., Herranz, B., De la Hoz, L. and Cambero, M.I. (2007). Breaking strength of dry fermented sausages and their correlation with texture profile analysis (TPA) and physico-chemical characteristics. *Meat Science*, 77 (3), 331-338. <https://doi.org/10.1016/j.meatsci.2007.03.022>.
- 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, 9753894. <https://doi.org/10.1155/2017/9753894>.
- Hwang, C.A., Porto-Fett, A.C., Juneja, V.K., Ingham, S.C., Ingham, B.H. and Luchansky, J.B. (2009). Modeling the survival of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* Typhimurium during fermentation, drying, and storage of soudjouk-style fermented sausage. *International Journal of Food Microbiology*, 129(3), 244-252. Retrieved from <https://doi.org/10.1016/j.ijfoodmicro.2008.12.003>
- Incze, K. (1998). Dry fermented sausages. *Meat Science*, 49, S169-S177. [https://doi.org/10.1016/S0309-1740\(98\)90046-8](https://doi.org/10.1016/S0309-1740(98)90046-8).
- Joshevaska, E., Kuzelov, A., Kalevska, T., Dimitrovska, G. and Makarijoski, B. (2021). The Impact of glucono delta lactone (GDL) and starter cultures over the chemical composition in fermented sausages. *International Journal of Research and Review*, 8(3), 148-154.
- Juárez, C. (2020). Glucono delta lactona: acidificación rápida para cárnicos. Retrieved from The Food Tech

- Website: <https://thefoodtech.com/ingredientes-y-aditivos-alimentarios/glucono-delta-lactona-adificacion-rapida-para-carnicos> [In Spanish].
- Jurado, A., García, C., Timón, M.L. and Carrapiso A.I. (2007). Maduración del jamón ibérico: evolución de índices basados en compuestos volátiles. *Ciencia y Tecnología Alimentaria*, 5(4), 278-286. [In Spanish].
- Linares García, J.A. (2022). Contribución de la manzana y la sidra al consumo de antioxidantes y su relación con biomarcadores del estado de salud. Retrieved from https://digibuo.uniovi.es/dspace/bitstream/handle/10651/64132/TFM_JuanAlfonsoLinaresGarcia.pdf?sequence=4. [In Spanish].
- Lücke, F. (1998). Fermented sausages. In Wood, B.J. (2012). *Microbiology of Fermented Foods*. Springer Science and Business Media. 442-483. https://doi.org/10.1007/978-1-4613-0309-1_14
- Martín, I., Rodríguez, A., Alía, A., Martínez, R. and Córdoba, J.J. (2022). Selection and characterization of lactic acid bacteria with activity against *Listeria monocytogenes* from traditional RTE ripened foods. *LWT*, 163, 113579. <https://doi.org/10.1016/j.lwt.2022.113579>.
- Millan, P., Núñez de González, M., Aguilar, C., Palazón Fernández, J. and Núñez, M. (2018). Composición proximal y características fisicoquímicas del salchichón tipo Nápoles producido en Venezuela. *Revista Agrollanía*, 15, 18-24. [In Spanish].
- Pérez-Álvarez, J.A., Sayas-Barberá, M.E., Fernández-López, J. and Aranda-Catalá, V. (1999). Physicochemical characteristics of Spanish-type dry-cured sausage. *Food Research International*, 32(9), 599-607. [https://doi.org/10.1016/S0963-9969\(99\)00104-0](https://doi.org/10.1016/S0963-9969(99)00104-0).
- Rocha, A.E. (2021). Cómo asegurar una producción inocua de embutidos fermentados. *Revista CarneTec*, 30(1), 101825. [In Spanish].
- Ruiz, M.J., Colello, R., Padola, N.L. and Etcheverría, A.I. (2017). Efecto inhibitorio de *Lactobacillus* spp. sobre bacterias implicadas en enfermedades transmitidas por alimentos. *Revista Argentina de Microbiología*, 49(2) 174-177. <https://doi.org/10.1016/j.ram.2016.10.005> [In Spanish].
- Santos, R., Ramos, M., Beldarraín, T., Guerra, M.A., Rodríguez, F. and Pérez, J. (2021). Características de un chorizo y un salchichón crudo curado/ Characteristics of dry-cured sausage <<chorizo>> and <<salchichon>>. *Ciencia y Tecnología de los Alimentos*, 31(3), 18-27. [In Spanish].
- Seleshe, S., Ameer, A. and Kang, S.N. (2021). Incorporation of Selected Strains of *Pediococcus* spp. on quality characteristics of dry fermented sausage during fermentation and ripening. *Food Science of Animal Resources*, 41(6), 1078. <https://doi.org/10.5851/kosfa.2021.e60>.
- Škrlep, M., Ozmec, M. and Čandek-Potokar, M. (2022). Reduced use of nitrites and phosphates in dry-fermented sausages. *Proceses*, 10(5), 821. <https://doi.org/10.3390/pr10050821>.
- Solignat, G. (2002). Secado-maduración. In Durand, P. (Ed.). *Tecnología de los productos de la charcutería y salazones*, p. 293-326. Spain: Editorial Acirbia, Zaragoza, España. [In Spanish].
- Vignolo, G., Fontana, C. and Fadda, S. (2010). Semidry and dry fermented sausages. In Toldra, F. (Ed) *Handbook of meat processing*. p. 379-398. New Jersey, USA: Wiley. <https://doi.org/10.1002/9780813820897>