

Influence of brine NaCl concentration and brining time on the physicochemical, microbiological and sensory properties of pork

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ABSTRACT: Brining is an important meat-processing technique that can modify moisture distribution, technological properties, microbial stability and sensory quality. This study evaluated the effects of NaCl concentration and brining time on the physicochemical, microbiological and sensory properties of pork. Fresh pork was subjected to a 3 × 2 factorial arrangement involving 30, 60 and 90 min brining periods and 10 and 15% NaCl concentrations. Brining time increased salt uptake but was associated with greater drip loss and reduced water-holding capacity. The higher NaCl concentration promoted greater brine uptake but also increased drip loss and shear force. Brining markedly reduced the loads of *Staphylococcus*, *Escherichia* and *Salmonella*, with the strongest reductions generally occurring at longer exposure periods. Sensory evaluation showed improved colour, tenderness, flavour, juiciness and overall acceptability at 60 and 90 min compared with 30 min. The responses indicate that brining time and NaCl concentration should be considered jointly because greater salt uptake did not necessarily correspond with improved technological properties. Under the conditions of the present study, 15% NaCl for 60 min provided a favourable compromise between physicochemical characteristics, microbial suppression and sensory acceptability.

Keywords: Curing, meat quality, microbial stability, sensory evaluation, Sodium chloride.

INTRODUCTION

Pork is an important source of animal protein and is widely consumed globally, with global pig-meat consumption projected to approach approximately 130 million tonnes, expressed in carcass-weight equivalent, by 2034 (FAO, 2025). Its nutritional value, versatility and relative affordability have contributed to its importance in human diets, while increasing consumer expectations have created greater demand for safe, nutritious and high quality meat (Ekpo et al., 2018; Adediran et al., 2025; Christopher et al., 2024; Sam et al., 2026a). Genetic improvement has contributed substantially to modern meat production through selection (Udo et al., 2025b) for rapid lean growth and production efficiency (Sam et al., 2020;

Essien et al., 2023; Udo et al., 2025a), although such selection may also influence meat-quality characteristics (Lonergan et al., 2001; Yu et al., 2020; Udo et al., 2025a; Udo et al., 2025b; Assam et al., 2026a). Consequently, nutritional and post-harvest processing interventions are increasingly important for maintaining desirable meat quality (Xu et al., 2019; Assam et al., 2026b; Essien and Sam, 2018; Alphonsus et al., 2010; Alphonsus et al., 2012).

Meat quality is determined by physicochemical, microbiological and sensory characteristics, including pH, moisture content, water holding capacity (WHC), cooking loss, colour, tenderness, juiciness, flavour and microbial stability (Udoudo et al., 2025; Ekpo et al., 2008). Brining is

an established meat-processing and preservation technique involving the exposure of meat to sodium chloride (NaCl) solution. During brining, salt diffuses from the surrounding solution into muscle tissue, where it interacts with myofibrillar proteins, influences water binding and contributes to flavour and preservation (Desmond, 2006; Inguglia *et al.*, 2017). Salt penetration is driven primarily by the concentration gradient between the brine and meat, resulting in relatively rapid uptake during the early stages of processing followed by progressively slower diffusion as the gradient decreases. In pork, salt penetration can alter myofibrillar proteins, particularly myosin, and consequently affect water binding properties and meat structure (Visy *et al.*, 2021a; Rahman, 2023).

Brine concentration is therefore a major determinant of salt uptake and pork quality. Increasing NaCl concentration increases the concentration gradient and can enhance salt transfer into muscle. At appropriate concentrations, NaCl promotes myofibrillar protein solubilisation and can improve water binding, moisture retention and tenderness; excessive concentrations, however, may cause undesirable moisture movement, excessive saltiness and changes in texture (Desmond, 2006; Inguglia *et al.*, 2017). Previous studies have shown that brine concentration affects NaCl diffusion, moisture characteristics, water activity, shear force, microstructure and lipid oxidation in pork products (Ozuna *et al.*, 2013; Yang *et al.*, 2012; Lu *et al.*, 2024). Thus, an appropriate concentration is required to obtain desirable technological and sensory properties without excessive salt accumulation or deterioration of product quality.

Brining time is another critical factor because it determines the period available for salt diffusion and interaction between NaCl and muscle proteins. Salt uptake is generally greater during the early stages of processing and decreases as the concentration gradient becomes smaller (Visy *et al.*, 2021b). Prolonged brining may therefore increase salt uptake without producing proportional improvements in quality and may contribute to excessive salinity or undesirable changes in moisture and texture. Conversely, inadequate processing time may result in insufficient salt penetration and limited improvement in product characteristics. Brining conditions may also influence microbial stability because sodium chloride reduces water availability and creates osmotic stress, although its antimicrobial effect depends on factors such as temperature, pH, moisture availability and processing hygiene (Inguglia *et al.*, 2017; Khayrullin *et al.*, 2021). Sensory characteristics, including flavour, saltiness, tenderness and juiciness, are likewise influenced by the concentration and duration of brining (Yang *et al.*, 2012; Gil *et al.*, 2025).

Previous research therefore demonstrates that pork quality during brining is influenced by the interaction between NaCl concentration and processing time, with effects on salt diffusion, protein functionality, moisture distribution, WHC, cooking loss, texture, oxidative stability, microbial characteristics and sensory acceptability

(Desmond, 2006; Inguglia *et al.*, 2017; Ozuna *et al.*, 2013; Visy *et al.*, 2021a). However, there remains a need for systematic evaluation of these two major processing variables under defined conditions to establish their combined effects on pork quality. The present study consequently evaluates the effects of selected brining concentrations and brining times on the physicochemical, microbiological and sensory properties of pork, with the aim of identifying practical conditions that achieve an appropriate balance among salt uptake, moisture retention, technological quality, microbial stability and sensory acceptability.

MATERIALS AND METHODS

Experimental location

The study was conducted using two laboratory facilities. The physicochemical analyses of the pork samples, including pH, water-holding capacity, cooking loss, thermal shortening, drip loss, brine uptake, brine yield, chilling loss and shear force, were carried out at the Animal Science Laboratory, Department of Animal Science, Faculty of Agriculture, Akwa Ibom State University, Obio Akpa Campus. Brining treatments involving different concentrations of sodium chloride, rosemary and brining durations were conducted under controlled laboratory conditions. Microbiological analyses were performed at the Microbiology Laboratory, University of Uyo, using standard aseptic procedures and microbiological techniques.

Sample collection and preparation

Fresh pork samples were obtained from a licensed abattoir in Abak Local Government Area, Akwa Ibom State. Samples were collected immediately after slaughter and inspected to ensure that they were free from visible defects and signs of spoilage. The samples were placed in clean, insulated ice-packed containers and transported to the Animal Science Laboratory at approximately $4\pm1^{\circ}\text{C}$ to minimise microbial proliferation and maintain sample quality prior to processing.

At the laboratory, visible excess fat and connective tissues were removed, and the pork was cut into uniform portions of approximately equal size and weight. Uniformity of sample size was maintained to minimise variation in brine penetration and ensure comparability among treatments. Commercially available rosemary spice was purchased from a dealer in Abak town, Akwa Ibom State, sun-dried, milled into powder and stored in clean, airtight polyethene bags until required.

Preparation of brine solutions

Two brine concentrations, 10% and 15% (w/v), were

evaluated. Each brine solution contained sodium chloride (NaCl), sugar and ground rosemary spice. For the 10% brine treatment, 10 g of NaCl, 5 g of sugar and 2.5 g of ground rosemary were weighed accurately, dissolved in distilled water and made up to a final volume of 100 mL. For the 15% brine treatment, 15 g of NaCl, 7.5 g of sugar and 3.7 g of ground rosemary were weighed and made up to 100 mL. Each solution was thoroughly mixed to ensure uniform distribution of the ingredients before use. The inclusion of sugar and rosemary was kept constant in relation to the respective NaCl concentration so that the principal experimental factor remained NaCl concentration. Rosemary was included as a flavouring and plant-derived antioxidant ingredient, consistent with the increasing use of natural ingredients in meat marination (Siroli *et al.*, 2020; Rahman *et al.*, 2023).

Brining procedure and duration

Individual pork portions were weighed individually before brining and randomly assigned to the experimental treatments. Each portion was immersed completely in the appropriate brine solution and held for 30, 60 or 90 min.

Following the designated brining period, samples were removed and allowed to drain for a standardised period before weighing and subsequent analyses. Samples intended for microbiological analysis were handled aseptically and transferred promptly to the microbiology laboratory.

Determination of physicochemical properties

The physicochemical properties evaluated were pH, brine uptake, brine yield, drip loss, cooking loss, chilling loss, thermal shortening, shear force and water-holding capacity (WHC).

Determination of pH

The pH of the pork samples was determined using a glass-electrode pH meter (HI-9125, Hanna Instruments, Cluj-Napoca, Romania), following the procedure described by Gamage (2017) with slight modifications. Approximately 1 g of each pork sample was finely chopped using a mortar and pestle and homogenised with distilled water at a ratio of 1:5 (w/v). The pH electrode was calibrated according to the manufacturer's instructions, after which the electrode was immersed in the homogenate and the stable reading recorded.

Although pH was measured, it was excluded from the results tables because the original dataset supplied for this revised manuscript did not contain the corresponding pH results. Consequently, no pH-based interpretation is made in the Results and Discussion.

Determination of drip loss

Approximately 20 g of each pre-weighed pork sample was placed in a clean polyethylene bag and suspended without direct contact with the bag surface. The samples were stored at 4°C for 48 h. After storage, each sample was removed, gently blotted to eliminate surface moisture and reweighed. Drip loss was expressed as a percentage of the initial sample weight:

$$\text{Drip loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Determination of shear force

Warner–Bratzler shear force was determined using a Warner–Bratzler meat shear device (Model 240, Instron, USA). Cooked samples were prepared under standardised conditions and cut into uniform cores with the muscle fibres oriented consistently. Each core was sheared perpendicular to the direction of the muscle fibres, and the maximum force required to shear the sample was recorded as the Warner–Bratzler shear force value. Lower shear-force values indicated greater tenderness.

Determination of brine uptake

Each pork portion was weighed before and immediately after brining. Brine uptake was calculated as follows:

$$\text{Brine uptake (\%)} = \frac{\text{Weight after brining} - \text{Weight before brining}}{\text{Weight before brining}} \times 100$$

Determination of cooking loss

Cooking loss was determined according to the procedure described by Honikel (1998) with modifications. Pre-weighed pork samples were individually placed in heat-resistant polyethylene bags and immersed in a water bath maintained at 80 °C for 20 min. Following cooking, the samples were removed from the bags and allowed to equilibrate to room temperature before being reweighed. Cooking loss was calculated as:

$$\text{Cooking loss (\%)} = \frac{\text{Weight before cooking} - \text{Weight after cooking}}{\text{Weight before cooking}} \times 100$$

Honikel (1998) provides internationally recognised reference procedures for evaluating physical characteristics of meat, including water-holding capacity and related quality attributes.

Determination of chilling loss

Chilling loss was determined following the procedure described by Fokolade *et al.* (2018) and Awosanya and Okubanjo (1993). Samples were weighed before chilling and subsequently stored under refrigerated conditions for 24 h. After chilling, the samples were removed, gently blotted and reweighed. Chilling loss was expressed as the percentage difference between the initial and chilled weights:

$$\text{Chilling loss (\%)} = \frac{\text{Initial weight} - \text{Chilled weight}}{\text{Initial weight}} \times 100$$

Determination of water-holding capacity

Water-holding capacity was determined using the filter-paper press method as modified from Suzuki *et al.* (1991). A representative meat sample was weighed and placed between two equal-sized sheets of filter paper measuring approximately 10.1 × 10.1 cm. The sample was placed between two Plexiglas plates and subjected to pressure using a vice for 1 min. After pressing, the sample was removed and the areas occupied by the meat and expressed moisture on the filter paper were determined using a compensating planimeter. The water-holding capacity was calculated according to the procedure of Suzuki *et al.* (1991):

$$\text{WHC} = 100 - \frac{(\text{Ar} - \text{Am}) \times 9.49 \times 100}{\text{Wm} \times \text{Mo}}$$

Where: Ar = area of water released from the meat (cm²); Am = area occupied by the meat sample (cm²); Wm = weight of the meat sample (mg); and Mo = moisture content of the meat (%).

The constant 9.49 was applied as specified in the modified method.

Determination of thermal shortening

Thermal shortening was determined using the procedure described by Malgorzata *et al.* (2005) with modifications. The length of each pork sample was measured before cooking. The samples were then individually placed in heat-resistant polyethylene bags and cooked in a water bath at 80 °C for 20 min. After cooking, the samples were cooled to room temperature and their lengths were measured again. Thermal shortening was expressed as the percentage reduction in sample length:

$$\text{Thermal shortening (\%)} = \frac{\text{Initial length} - \text{Final length}}{\text{Initial length}} \times 100$$

Determination of brine yield

Brine yield was determined from the change in sample

weight following brining. The weight of each pork portion was recorded before and after brining. Brine yield was calculated as:

$$\text{Brine yield (\%)} = \frac{\text{Weight after brining} - \text{Weight before brining}}{\text{Weight before brining}} \times 100$$

This value represented the percentage increase in sample weight attributable to brine uptake.

Microbiological analysis

Samples were collected aseptically and homogenised in sterile diluent. Serial dilutions were prepared and inoculated onto appropriate culture media. Total viable bacterial counts and counts of the target bacterial groups were determined using standard microbiological procedures. Colonies were counted after incubation and expressed as colony-forming units per gram (CFU/g). For presentation in Tables 2 and 3, microbial counts were expressed in 10⁴ CFU/g. Representative colonies were subjected to further identification using standard microbiological procedures.

Storage conditions for microbiological evaluation

Following brining, samples designated for storage evaluation were placed in sterile, labelled containers and maintained under refrigerated conditions at approximately 4 ± 1 °C. Microbiological assessments were conducted at 0, 12 and 24 h. Samples were handled aseptically at each sampling point to minimise cross-contamination. The storage period was deliberately limited to 24 h because the objective was to examine the short-term microbiological response to brining rather than to establish a commercial shelf-life.

Sensory evaluation

Sensory evaluation was conducted using ten trained panellists familiar with meat-product evaluation. Panellists were recruited from personnel and postgraduate/undergraduate students within the Faculty of Agriculture and related food-science disciplines who indicated willingness to participate and had previous experience evaluating food products.

The panellists received orientation and training on recognition of colour, aroma, flavour, tenderness and juiciness and on consistent use of the sensory scale. Training was conducted before formal evaluation to reduce variation among panellists.

A 9-point hedonic scale was used, where 1 = dislike extremely and 9 = like extremely. The evaluated attributes were colour, tenderness, flavour, juiciness and overall

acceptability.

For sensory evaluation, samples were cooked using the designated preparation method, coded with randomly assigned three-digit numbers and presented in a randomised order. Drinking water was provided for palate cleansing between samples. Evaluation was conducted under controlled conditions to minimise environmental and order effects.

The sensory scores were subjected to analysis of variance using the same factorial statistical model applied to the physicochemical data. Where significant differences occurred, means were separated using Duncan's Multiple Range Test at the 5% probability level.

Experimental design

The experiment was arranged as a 3×2 factorial experiment in a completely randomised design (CRD). The factors were:

- Brining duration: 30, 60 and 90 min.
- NaCl concentration: 10 and 15%.

The treatment combinations were:

- T1 = 10% brine $\times$ 30 min
- T2 = 10% brine $\times$ 60 min
- T3 = 10% brine $\times$ 90 min
- T4 = 15% brine $\times$ 30 min
- T5 = 15% brine $\times$ 60 min
- T6 = 15% brine $\times$ 90 min

Each treatment combination had two replicates, giving 12 experimental units.

Statistical analysis

Data were analysed using analysis of variance (ANOVA) appropriate for a 3×2 factorial arrangement. The model included the main effects of NaCl concentration, brining duration and their interaction. Where significant treatment effects were detected, treatment means were separated using Duncan's Multiple Range Test (DMRT) at $p < 0.05$. DMRT was selected because it permits pairwise separation of treatment means following a significant ANOVA while maintaining a structured comparison among the multiple treatment means. The 5% probability level was selected as the conventional threshold for statistical significance in agricultural and food-science experiments.

RESULTS AND DISCUSSION

Physicochemical properties of brined pork

Table 1 presents the effects of brine concentration and

brining time on the physicochemical properties of pork. Results showed that brining time and concentration influenced several quality attributes, including cooking loss, chilling loss, brine yield, brine uptake, drip loss, water-holding capacity (WHC) and shear force. Thermal loss increased progressively with brining time, from 5.47% at 30 min to 6.96% at 90 min, whereas brine uptake increased from 5.00 to 12.00% over the same period. Drip loss also increased from 3.71 to 7.23%, while WHC declined from 96.29 to 92.78%. Shear force increased from 22.50 to 25.15 N as brining time increased. The result agrees with the established principle that increasing processing time provides greater opportunity for diffusion of salt and other marinade constituents into meat. Recent research has similarly demonstrated that brining modifies physicochemical properties and salt distribution in pork muscle (Visy *et al.*, 2021a; Jin *et al.*, 2023). Rahman *et al.* (2023) further noted that marinade composition and processing duration are important determinants of salt penetration and subsequent changes in meat quality.

Brine concentration also affected the measured physicochemical characteristics. Pork treated with 15% brine had greater brine uptake (10.00%) and shear force (24.70 N) than pork treated with 10% brine (7.33% and 22.73 N, respectively). Conversely, WHC was higher at 10% brine (95.76%) than at 15% brine (93.44%), while drip loss was lower at 10% (4.24%) than at 15% brine (6.56%). The greater uptake at the higher concentration is consistent with the role of the concentration gradient in promoting salt movement into muscle. Ozuna *et al.* (2013) similarly demonstrated that NaCl concentration influences mass transfer and structural properties in brined pork. More recent work by Jin *et al.* (2023) also showed that modifications in the physicochemical structure of pork during brining are associated with changes in salt and moisture transfer.

However, the accompanying increase in drip loss and reduction in WHC suggest that excessive salt exposure may alter protein–water interactions and promote subsequent moisture release. Salt is known to modify myofibrillar proteins and their ability to bind water, with the magnitude and direction of the response depending on salt concentration and processing conditions (Desmond, 2006; Inguglia *et al.*, 2017).

The increase in shear force from 22.50 N at 30 min to 25.15 N at 90 min indicates that prolonged brining under the conditions used in this study did not improve instrumental tenderness. This result contrasts with the expectation that increased salt uptake always improves water retention, demonstrating that salt uptake and WHC are not necessarily linearly related. Siroli *et al.* (2020) reported improved WHC in marinated pork under their specific marinade conditions, whereas the present study showed declining WHC as brining duration increased. The difference may be related to the acidic oil/beer/lemon marinade used by Siroli *et al.* (2020), which differed substantially from the NaCl-sugar-rosemary brine used in

Table 1. Effect of brining concentration and brining time on physicochemical properties of pork.

Physicochemical Parameter	Concentration (%)					Main Effects		Holding Time Effects			
	Concentration (%)	T ₁ (30 min)	T ₂ (60 min)	T ₃ (90 min)	SEM	10% mean	15% mean	30 min mean	60 min mean	90 min mean	SEM
Thermal Loss (%)	10	5.97 ^b	5.97 ^b	6.95 ^a	0.33						
	15	4.97 ^b	6.97 ^a	6.97 ^a	0.67	6.30	6.30	5.47 ^c	6.47 ^b	6.96 ^a	0.33
Cooking Loss (%)	10	21.83 ^c	22.84 ^b	23.84 ^a	0.58						
	15	33.85 ^a	22.81 ^b	22.83 ^b	3.85	22.84	26.16	27.84 ^a	22.33 ^c	23.34 ^b	0.58
Chilling Loss (%)	10	26.08 ^a	26.08 ^a	25.00 ^b	0.36						
	15	26.08 ^a	20.83 ^b	20.83 ^b	1.75	25.70	22.58	26.08 ^a	23.46 ^b	22.92 ^c	0.36
Brine Yield (%)	10	46.15 ^a	42.59 ^b	40.00 ^c	1.78						
	15	43.39 ^a	40.00 ^b	38.18 ^a	1.53	42.91	40.52	44.77 ^a	41.29 ^b	39.09 ^c	1.78
Brine Uptake (%)	10	4.00 ^c	8.00 ^b	10.00 ^a	1.76						
	15	6.00 ^c	10.00 ^b	14.00 ^a	2.31	7.33	10.00	5.00 ^c	9.00 ^b	12.00 ^a	1.76
Drip Loss (%)	10	2.17 ^b	3.31 ^b	7.23 ^a	1.53						
	15	5.26 ^b	7.19 ^a	7.22 ^a	0.65	4.24	6.56	3.71 ^c	5.25 ^b	7.23 ^a	1.53
WHC (%)	10	97.83 ^a	96.69 ^a	92.77 ^b	1.53						
	15	94.74 ^a	92.81 ^b	92.78 ^b	0.65	95.76	93.44	96.29 ^a	94.75 ^b	92.78 ^c	1.53
Share Force (N)	10	21.0 ^c	22.0 ^b	25.2 ^a	1.27						
	15	24.0 ^b	25.0 ^a	25.1 ^a	0.35	22.73	24.70	22.50 ^c	23.50 ^b	25.15 ^a	1.27

^{abc} Means on the same row bearing different superscripts are significantly different. WHC = Water Holding Capacity.

the present experiment.

Cooking loss declined from 27.84% at 30 min to 22.33% at 60 min before increasing slightly to 23.34% at 90 min. The relatively high cooking loss at 30 min, particularly the 33.85% recorded for 15% NaCl, may indicate that the shorter brining period did not provide sufficient time for salt-mediated modification of the muscle proteins. The subsequent reduction at 60 min suggests improved moisture retention during cooking. Similar effects of marination on cooking loss have been reported in pork. Zapata *et al.* (2024) reported reduced cooking losses following spiced brine treatment of pork, although the precise response differed according to marinade formulation and application method.

The highest value was observed in pork treated with 15% brine for 90 min (25.10 N). This finding is important because salt can have complex effects on meat texture depending on concentration, exposure time, muscle type and subsequent processing conditions. Therefore, increased salt uptake should not automatically be interpreted as improved tenderness.

The reduction in WHC and simultaneous increase in drip loss with increasing brining time suggest that prolonged treatment may have exceeded the conditions required for optimum water retention. Thus, although 15% brine promoted greater brine uptake, the 10% treatment provided better WHC and lower drip loss. These results indicate that brine concentration and

processing duration should be considered jointly when determining suitable conditions for pork processing.

Microbiological quality of brined pork

Table 2 presents the effects of brine concentration and brining time on the bacteriological load of pork. Results showed that the loads of *Staphylococcus*, *Escherichia* and *Salmonella* generally declined markedly as brining time increased. The most pronounced reductions occurred between 30 and 60 min, after which bacterial counts remained very low through 90 min. For *Staphylococcus*, the mean count decreased from 2.90 at 10% brine to 1.83 at

Table 2. Effect of Brine concentration and time on Bacteriological load of Pork

Microorganisms	Concentration (%)	T1 (30 min)	T2 (60 min)	T3 (90 min)	SEM	Main effects	
						Concentration mean values (10%)	Brining time mean values (15%)
<i>Staphylococcus</i>	10	9.0 ^a	0.03 ^b	0.02 ^b	0.05	2.90	1.83
	15	3.0 ^a	0.02 ^b	0.03 ^b	0.05		
<i>Escherichia</i>	10	0.02 ^{ab}	0.02 ^{ab}	0.03 ^c	0.005	0.021	0.022
	15	0.03 ^a	0.02 ^b	0.02 ^b	0.005		
<i>Salmonella</i>	10	7.0 ^a	0.03 ^b	0.02 ^b	0.04	1.57	0.69
	15	2.0 ^a	0.03 ^b	0.03 ^b	0.04		

^{abc} Means on the same row bearing different superscripts are significantly different. CFU/g = colony-forming units per gram.

15% brine, while the corresponding mean *Salmonella* counts decreased from 1.57 to 0.69. In contrast, *Escherichia* counts were low across both concentrations, with mean values of 0.021 and 0.022, respectively.

The pronounced reduction in bacterial counts with increased brining time can be attributed partly to the inhibitory effect of sodium chloride on microbial growth. Salt reduces water activity and imposes osmotic stress, thereby creating conditions that are less favourable for the survival and multiplication of many microorganisms. However, the antimicrobial effectiveness of salt depends on salt concentration, exposure time, temperature, pH and the characteristics of the microorganism. Consequently, the observed reduction should be interpreted as an effect of the combined treatment conditions rather than salt concentration alone (Desmond, 2006; Inguglia *et al.*, 2017).

The stronger microbial suppression at 15% NaCl is consistent with the expected greater osmotic pressure at higher salt concentration. Siroli *et al.* (2020) reported that marinated pork had lower microbial loads and improved microbiological safety compared with untreated meat. Their study also reported inhibition of *Salmonella* enteritidis

and *Staphylococcus aureus*. Similarly, Jeong *et al.* (2018) observed substantial changes in microbial counts following pork ham marination and reported that marinade treatment improved microbiological characteristics.

The present findings are also consistent with Li *et al.* (2024), who reported that pickling materials inhibited microbial growth and improved the storage quality of pork. Their study further demonstrated that marination influenced water distribution and flavour characteristics. The agreement across these studies supports the role of marination as a useful hurdle for microbial control, although the degree of inhibition depends on the composition and application of the marinade.

Microbial changes during storage

Table 3 presents the effects of brine concentration and brining time on the bacteriological quality of pork during storage. Results showed that microbial counts generally declined during the 24-h storage period, with the lowest values mostly observed in samples subjected to longer brining times. *Staphylococcus* counts at 30 min declined from 9.0 × 10⁴ CFU/g at 0 h to 3.0 × 10⁴ CFU/g at 24 h in the

10% brine treatment, while the corresponding 15% treatment declined from 3.0 to 1.0 × 10⁴ CFU/g. Samples treated for 60 and 90 min maintained substantially lower counts throughout storage.

A similar pattern was observed for *Salmonella*. At 10% brine and 30 min, the count decreased from 7.0 × 10⁴ CFU/g at 0 h to 1.0 × 10⁴ CFU/g after 24 h. At 15% brine, the corresponding count decreased from 2.0 to 0.02 × 10⁴ CFU/g. The reductions observed during refrigerated storage are consistent with the combined effects of salt stress and low temperature. Sodium chloride decreases water availability, while refrigeration further restricts the growth of many bacteria. Siroli *et al.* (2020) reported that marinated pork had reduced microbial loads during refrigerated storage, while Li *et al.* (2024) found that pickling treatments suppressed microbial growth and improved pork storage quality.

The present results should nevertheless be interpreted cautiously because microbial counts do not necessarily decline under all storage conditions. The outcome depends on initial contamination, microbial species, storage temperature, oxygen availability and marinade composition. Jeong *et al.* (2018) similarly demonstrated that marination conditions influence microbial characteristics of

Table 3. Effect of brine concentration and time on storage of Pork

Duration	Microorganisms	Concentration/time	30 min	60 min	90 min	SEM
0 hours	<i>Staphylococcus</i>	10	9.0 ^a	0.03 ^b	0.02 ^b	0.05
		15	3.0 ^a	0.02 ^b	0.03 ^b	0.05
	<i>Escherichia</i>	10	0.02 ^{ab}	0.02 ^{ab}	0.3a	0.005
		15	0.03 ^a	0.02 ^{ab}	0.02 ^{ab}	0.005
	<i>Salmonella</i>	10	7.0 ^a	0.03 ^b	0.02 ^b	0.04
		15	2.0 ^a	0.03 ^b	0.03b	0.04
12 hours	<i>Staphylococcus</i>	10	5.0 ^a	0.025 ^b	0.015 ^b	0.05
		15	2.0 ^a	0.02 ^b	0.025 ^b	0.05
	<i>Escherichia</i>	10	0.015	0.02 ^b	0.025 ^a	0.005
		15	0.02 ^{ab}	0.015 ^a	0.02	0.005
	<i>Salmonella</i>	10	3.5 ^a	0.025 ^b	0.01 ^b	0.04
		15	1.0 ^a	0.025 ^b	0.02 ^b	0.04
24 hours	<i>Staphylococcus</i>	10	3.0 ^a	0.02 ^a	0.01 ^b	0.05
		15	1.0 ^a	0.015 ^c	0.02 ^b	0.05
	<i>Escherichia</i>	10	0.01 ^c	0.01 ^a	0.02 ^b	0.005
		15	0.01 ^b	0.02 ^a	0.015 ^a	0.005
	<i>Salmonella</i>	10	1.0 ^a	0.02 ^b	0.01 ^b	0.04
		15	0.02	0.015	0.02	0.04

^{abc} Means on the same row bearing different superscripts are significantly different. Values are expressed as $\times 10^4$ CFU/g

Table 4. Effect of brining time and brining concentration on sensory properties of grilled pork

Sensory Parameters	Concentration (%)	T ₁ 30 min	T ₂ 60 min	T ₃ 90 min	SEM
Colour	10	6.80 ^c	7.20 ^a	7.00 ^b	0.12
	15	7.10 ^b	7.40 ^a	7.30 ^a	0.15
Tenderness	10	6.50 ^c	7.30 ^a	7.00 ^b	0.18
	15	6.80 ^b	7.80 ^a	7.60 ^a	0.20
Flavour	10	7.00 ^b	7.60 ^a	7.50 ^a	0.14
	15	7.20 ^b	8.00 ^a	7.90 ^a	0.16
Juiciness	10	6.40 ^b	7.00 ^a	6.80 ^a	0.19
	15	6.50 ^b	7.20 ^a	7.10 ^a	0.17
Overall acceptability	10	6.80 ^b	7.40 ^a	7.20 ^a	0.20
	15	7.00 ^b	7.90 ^a	7.70 ^a	0.22

^{abc} Means on the same row bearing different superscripts are significantly different. Scores were based on a 9-point hedonic scale

pork and emphasised the importance of processing and storage conditions.

The relatively low *Escherichia* counts throughout the storage period suggest that the organism was strongly suppressed under the experimental conditions.

Sensory properties of grilled pork

Table 4 presents the effects of brine concentration and brining time on the sensory properties of grilled pork.

Results showed that brining concentration and duration significantly influenced the sensory attributes evaluated, including colour, tenderness, flavour, juiciness and overall acceptability. Sensory scores generally increased from 30 to 60 min and remained high at 90 min. At 10% brine, flavour increased from 7.00 at 30 min to 7.60 at 60 min and 7.50 at 90 min, while the corresponding values for 15% brine were 7.20, 8.00 and 7.90. This indicates that moderate to prolonged brining improved flavour perception, probably because of more effective distribution of salt and rosemary within the meat.

Table 5. Effect of brining time and brining concentration on sensory properties of oven dried pork

Sensory Parameters	Concentration (%)	T ₁ 30 Min	T ₂ 60 Min	T ₃ 90 Min	SEM
Colour	10	6.60 ^c	7.00 ^a	6.90 ^b	0.13
	15	6.90 ^b	7.20 ^a	7.10 ^a	0.14
Tenderness	10	6.40 ^b	7.20 ^a	7.20 ^a	0.17
	15	6.70 ^b	7.60 ^a	7.70 ^a	0.18
Flavour	10	6.80 ^c	7.40 ^a	7.20 ^b	0.12
	15	7.00 ^c	7.90 ^a	7.70 ^b	0.15
Juiciness	10	6.80 ^b	7.40 ^a	7.20 ^a	0.18
	15	6.90 ^b	7.60 ^a	7.50 ^a	0.17
Overall acceptability	10	6.90 ^b	7.50 ^a	7.30 ^a	0.21
	15	7.00 ^b	7.80 ^a	7.70 ^a	0.22

^{abc} Means on the same row bearing different superscripts are significantly different. Scores were based on a 9-point hedonic scale

Tenderness scores also increased with brining time. At 10% brine, the score increased from 6.50 at 30 min to 7.30 at 60 min, while the 15% treatment increased from 6.80 to 7.80. Juiciness followed a similar pattern, with the highest scores generally occurring after 60 or 90 min. Salt can influence myofibrillar protein functionality and water distribution, which may affect the sensory perception of tenderness and juiciness (Desmond, 2006; Inguglia *et al.*, 2017).

Flavour increased from 7.00 to 7.60 at 10% NaCl and from 7.20 to 8.00 at 15% NaCl between 30 and 60 min. The increase may be related to greater penetration and distribution of salt, sugar and rosemary during the longer treatment. Rahman *et al.* (2023) noted that marination can substantially influence flavour development, while Gil *et al.* (2025) reported that marinade type and duration affect sensory characteristics of pork.

Juiciness and overall acceptability also improved mainly between 30 and 60 min. Overall acceptability increased from 6.80 to 7.40 at 10% NaCl and from 7.00 to 7.90 at 15% NaCl. The relatively small difference between 60 and 90 min suggests that extending brining beyond 60 min may provide limited additional sensory benefit. This observation is consistent with the principle that an optimum marination period may exist beyond which additional treatment provides little improvement in sensory quality (Rahman *et al.*, 2023).

Sensory properties of oven-dried pork

Table 5 presents the effects of brine concentration and brining time on the sensory properties of oven-dried pork. Results showed that sensory scores generally improved with increasing brining time and concentration. Colour scores increased from 6.60 at 10% brine for 30 min to 7.00 and 6.90 at 60 and 90 min, respectively. At 15% brine, the corresponding scores were 6.90, 7.20 and 7.10. These results indicate that both brining concentration and duration influenced the appearance of the oven-dried pork.

Tenderness showed a particularly clear improvement with prolonged brining. At 10% concentration, tenderness increased from 6.40 at 30 min to 7.20 at both 60 and 90 min. At 15%, the score increased from 6.70 to 7.60 and 7.70, respectively. Flavour and juiciness also improved, with the highest scores generally recorded at 60 or 90 min. The improvement in these attributes may be associated with greater penetration and distribution of salt and seasoning before drying.

Overall acceptability increased from 6.90 at 10% brine for 30 min to 7.50 at 60 min and 7.30 at 90 min. At 15% brine, the corresponding values were 7.00, 7.80 and 7.70. The close scores between 60 and 90 min indicate that extending treatment to 90 min did not produce a substantial additional improvement in consumer acceptability. Therefore, 60 min at 15% brine produced the highest overall acceptability among the treatments evaluated for oven-dried pork.

The sensory results are broadly consistent with recent research demonstrating that marination can improve flavour, tenderness and acceptability of pork products. Rahman *et al.* (2023) identified sensory improvement as one of the major technological benefits of marination, while Gil *et al.* (2025) showed that both marinade formulation and duration influence sensory characteristics of pork tenderloin.

Conclusion

NaCl concentration and brining duration significantly influenced the physicochemical, microbiological and sensory characteristics of pork. Increasing brining duration enhanced brine uptake but was accompanied by greater drip loss, lower WHC and increased shear force. The 15% NaCl treatment promoted greater brine uptake and stronger microbial suppression but also produced greater drip loss and shear force than 10% NaCl. Sensory characteristics generally improved between 30 and 60 min,

with comparatively limited additional benefit at 90 min.

Under the conditions of this study, 15% NaCl for 60 min provided a favourable balance among brine uptake, microbial reduction and sensory acceptability. However, the recommendation is specific to the brine formulation, pork samples, processing conditions and short storage period evaluated and should not be generalised to all pork-processing systems.

CONFLICT OF INTEREST

The author declares that they have no conflict of interest.

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