71st ICoMST
GIRONA - CATALONIA - SPAIN
3rd-8th August - 2025

# EFFECT OF HEATING TIME AND SODIUM NITRITE CONCENTRATION ON THE FORMATION OF N-NITROSAMINES

Jeong-Uk Eom[1], Han-Sul Yang[1,2*]

[1] Division of Applied Life Science (BK21 Four), Gyeongsang National University, Jinjudaero, 501 Jinju, Gyeongnam 52828, Republic of Korea

[2] Institute of Agriculture and Life Science, Gyeongsang National University, Jinjudaero, 501 Jinju, Gyeongnam 52828, Republic of Korea

*Corresponding author email: hsyang@gnu.ac.kr

## I. INTRODUCTION

Nitrite has been widely used in processed meat products due to its multifunctional roles, including color development, flavor enhancement, and inhibition of microbial growth. However, despite these functional benefits, nitrite poses a significant food safety concern due to its potential to form N-nitrosamines through reactions with secondary amines [1]. Various factors, including heating temperature, nitrite concentration, pH, and gastrointestinal conditions, influence these compounds' formation [2]. While numerous studies have focused on the effects of these key variables, relatively few have addressed nitrosamine formation under realistic thermal processing conditions commonly used in the meat industry. One such method is Low Temperature Long Time (LTLT) heating, which involves maintaining a relatively low temperature (approximately 80°C) for an extended period (30–90 min). Unlike high-temperature, short-time processes that aim to raise the core temperature rapidly, LTLT gradually transfers heat while keeping the product at a constant surface temperature [3]. This method is known to improve tenderness, preserve nutrients, and maintain overall product quality, and is commonly applied in the production of fully cooked meat products such as pressed ham. Nevertheless, the formation characteristics of nitrosamines under low-temperature, long-time (LTLT) heating conditions combined with varying nitrite concentrations have not yet been elucidated. Furthermore, each nitrosamine exhibits distinct chemical properties, leading to different reactivity and formation patterns; thus, their concentrations may vary even under identical processing conditions. Therefore, this study aimed to investigate the effects of heating time (30, 60, and 90 min) and sodium nitrite concentration (0, 200, and 400 ppm) at a constant temperature of 80 °C on the formation of four major volatile nitrosamines, N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA), N-nitrosopiperidine (NPIP), and N-nitrosopyrrolidine (NPYR), and to compare their compound-specific generation trends under LTLT conditions.

## II. MATERIALS AND METHODS

Pressed hams were prepared with ground meat (75%), fat (10%), water (10%), salt (1.2%), phosphate (0.2%), sugar (0.5%), and sodium nitrite (0, 100, or 200 ppm). Samples were cooked at 80 °C for 30, 60, or 90 min using a convection steam oven (RCO-050E, KOSTEM, Korea). Sausages were produced across three independent batches (days), with nine samples per treatment. Nitrosamines were analyzed using a GC-MS system (7890B/5975C, Agilent Technologies, USA) equipped with a PAL RSI autosampler and HP-INNOWAX column (30 m × 0.25 mm, 0.25 μm). The oven program ranged from 50 °C to 240 °C through staged ramping. Injections (1 μL, splitless) were performed at 220 °C, with the ion source and quadrupole set at 230 °C and 150 °C, respectively. Statistical analysis was conducted using a randomized complete block design with batch as a random effect. Nitrite concentration and heating time interaction were treated as fixed effects. Data were analyzed using the MIXED procedure in SAS 9.4 (SAS Institute Inc., Cary, NC, USA), and least squares means were compared by Tukey's test at $p < 0.05$. Results are presented as mean ± standard error.

## III. RESULTS AND DISCUSSION

The analysis of four volatile nitrosamines revealed that NDMA, NDEA, and NPIP showed significant differences in concentration depending on treatment conditions (Figure 1). NDMA was consistently detected at the highest levels, with its formation significantly increasing as nitrite concentration increased ($p < 0.05$). The highest concentrations were observed at 400 ppm, while prolonged heating gradually reduced NDMA levels, likely due to its volatility and thermal instability. NDEA was detected at 30 and 90 minutes but not at 60 minutes, showing a V-shaped pattern. This suggests temporary decomposition during intermediate heating, followed by re-formation at 90 minutes, as additional protein-derived precursors were released during extended heating. NPIP peaked at 60 minutes under the 400 ppm condition and declined sharply at 90 minutes, indicating formation from short-lived precursors that degrade

over time. Small amounts of NPIP were also detected at 200 ppm, but were absent under 0 ppm. In contrast, NPYR was detected only at low levels with no significant differences. NPIP and NPYR are formed from protein-derived precursors typically released during high-temperature protein degradation. Under the relatively low-temperature condition used in this study (80 °C), limited precursor release likely contributed to the low levels of these compounds.

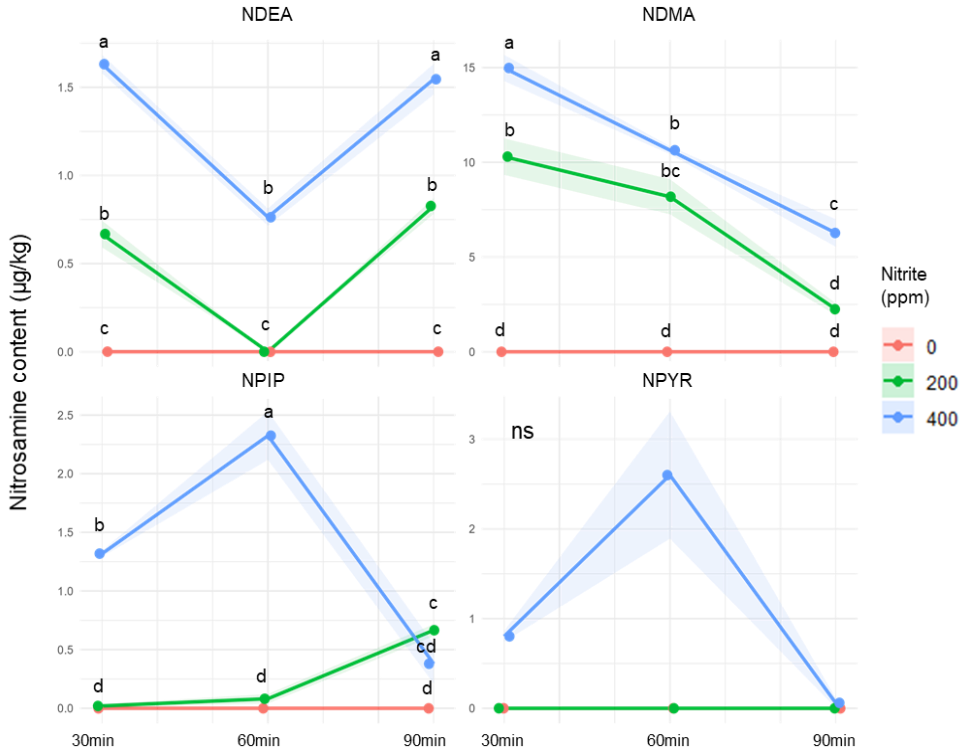



Figure 1. Effect of heating time and nitrite concentration on the formation of four nitrosamines (NDMA, NDEA, NPIP, and NPYR) in pressed ham. Different superscript letters indicate significant differences between treatments at $p < 0.05$. Values are expressed as mean ± SE ($n = 3$).

## IV. CONCLUSION

This study confirmed that the formation patterns of volatile nitrosamines at a constant temperature of 80 °C varied with heating time and nitrite concentration. NDMA, NPIP, and NPYR showed decreasing trends over time, while NDEA exhibited a reformation pattern, increasing with prolonged heating. These results indicate that the formation characteristics differ among nitrosamines and that each compound responds differently to heating duration due to its unique chemical properties and thermal reactivity. While previous research has focused mainly on nitrite levels, temperature, and pH, this study provides empirical evidence that heating duration is also a relevant variable. Effective mitigation of nitrosamine formation in complex meat processing systems requires a compound-specific approach, with heating time appropriately considered part of a comprehensive risk management strategy.

## ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science, and Technology (Project No. 2022R1A2C1013013116138211653010 1).

## REFERENCES

1. Gushgari, A.J.; Halden, R.U. (2018) Critical review of major sources of human exposure to N-nitrosamines. Chemosphere, 210: 1124-1136.
2. Xie, Y.; Geng, Y.; Yao, J.; Ji, J.; Chen, F.; Xiao, J.; Hu, X.; Ma, L. (2023) N-nitrosamines in processed meats: Exposure, formation and mitigation strategies. Journal of Agriculture and Food Research 13: 100645.
3. Dominguez-Hernandez, E.; Salaseviciene, A.; Ertbjerg, P. (2018) Low-temperature long-time cooking of meat: Eating quality and underlying mechanisms. Meat Science, 143: 104-113.