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Nitrite to nitrate degradation pattern in dry cooked salami. Effect of packaging and cooking mode

Patrón de degradación de nitrito a nitrato en salami cocida en seco. Efecto del empaque y modo de cocción

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Abstract

Nitrite is a multifunctional additive in meat products, but its residual content is still under strict legislation. The aim of this paper is to evaluate the nitrite degradation pattern while observing its eventual conversion to nitrate in dry cooked salami. The influence of storage condition, packaging and cooking mode on their residual contents was studied. UV-Vis SF analytical method and Minitab 21 Software was used. The results confirmed the residual nitrite well below the limit and a low and steady nitrate presence. Whereas nitrite showed a noticeable depletion at a similar trend for all packages, nitrate showed quite a different pattern confirming the influence of packaging media. Effect of boiling compared to frying and grilling is also studied showing a nitrite decrease at 57% and noticeable increased nitrate content. Grilling presented a similar pattern to boiling, while frying showed a nitrite decrease at 58% but no considerable increase of nitrate resulted. The sum of both nitrite and nitrate residuals for boiling and grilling was 95% and 91.6% respectively compared to the initial nitrite contents, while frying showed a considerable reduction at about 71% leading to the conclusion that other potential harmful nitrite degradation compounds may have been formed.

Keywords: dry cooked salami, time depletion, packaging mode, cooking, nitrite to nitrate conversion.

Resumen

El nitrito es un aditivo multifuncional en productos cárnicos, pero su contenido residual aún está bajo estricta legislación. El objetivo de este estudio es evaluar el patrón de degradación del nitrito mientras se observa su eventual conversión a nitrato en salchichón cocido seco. Se estudió la influencia de las condiciones de almacenamiento, el empaque y el modo de cocción en sus contenidos residuales. Se utilizó el método analítico UV-Vis SF y el software Minitab 21. Los resultados confirmaron que el nitrito residual estaba muy por debajo del límite y una presencia baja y constante de nitrato. Mientras que el nitrito mostró un agotamiento notable con una tendencia similar para todos los empaques, el nitrato mostró un patrón bastante diferente, confirmando la influencia del medio de empaque. También se estudió el efecto de hervir en comparación con freír y asar, mostrando una disminución del nitrito en un 57% y un aumento notable del contenido de nitrato. La parrilla presentó un patrón similar al hervir, mientras que freír mostró una disminución del nitrito en un 58%, pero no se observó un aumento considerable del nitrato. La suma de los residuos de nitrito y nitrato para hervir y asar fue del 95% y 91.6%, respectivamente, en comparación con los contenidos iniciales de nitrito, mientras que freír mostró una reducción considerable de aproximadamente el 71%, lo que lleva a la conclusión de que pueden haberse formado otros compuestos potencialmente dañinos durante la degradación del nitrito.

Palabras clave: salami cocido en seco, disminución en el tiempo, modo de empaquetado, cocción, conversión de nitrito.

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1 Introduction

The need to preserve food has been dictated since ancient ages to guarantee safe and continuous food supply independent of time, season, marketing place or way of living. Meat and meat products are the main food subjected to preservation as they are important sources of protein available to humans. Meat proteins are of great nutritional value and are directly involved in the chemical processes essential for life (Flores-Silva *et al.,* 2022). Except for using natural preservative compounds such as salt, or drying and smoking as traditional artisanal practices, where art was mixed with infantile science from experience, an increasing number of chemicals have been in use since then.

These chemicals are the mostly used additives in meat products which are considered as concentrated nutrient sources including proteins, lipids, vitamins (A, B, etc.), minerals (iron, zinc, etc.) and some other bioactive compounds (Akcan *et al.,* 2023).

The majority of these chemicals have always been under continuous investigation and monitoring for their presence in ready to eat food products mostly because of their potential adverse effect in organism often related to not quite well understood degradation pathways, their eventual synergic action, other exogenous routes of entering in organism, etc (Shen *et al.,* 2023).

Their time depletion and degradation products monitoring remain a topic widely discussed and studied by different researchers (Merino *et al*., 2016; Iammarino *et al*., 2023; Pegg and Honikel, 2015) who have been focused on time dependence of these chemicals degradation by optimizing condition leading to some ultimate derived compounds which do not pose any considerable risk to the organisms. In this context nitrite and nitrate are between the mostly studied and investigated additives in meat products, because of their multifunctional uses and because of their biochemical interchangeable reactions with complex meat matrices and other additives added. Since 1995, nitrate and nitrite have been listed as officially accepted preservatives in European Union Legislation (OJ L 354, 2008).

Albania has also regulated the use of additives, nitrite and nitrate included by the Guide Nr.16 dated on 29.08.2011 and Guide No.18, dated on September 9th, 2022 "On Food Additives" according to EU Regulation "On Food Additives" (OJ L 354, 2008).

Though their use in meat products is scientifically approved but, in any case, regulated by law, they still pose a great concern.

Nitrite and nitrate both are quite different from other additives in their behavior in meat matrices. Studies have confirmed their residual amount show a strong dependence of storage time, heat treatment, pH, redox state inducing partially oxidation of nitrite to nitrate under specific condition (Peg and Honikel, 2015; Merino, 2009; Shen *et al*., 2023), making nitrite plays a role as an antioxidant during meat products preservation. By this and other complex chemical reactions with biomolecules, the concentration of nitrite is reduced to less than half of its ingoing quantity in a ready- to- eat product (Pegg and Honikel, 2015).

The low nitrite concentration just after thermal processing and the relatively high pH value (5-6.5) usual for cooked meat products such as cooked sausages and cooked hams, decrease the possibility to form carcinogenic N-nitrosamines due to the very low levels of secondary amines at almost zero in fresh meat (Pegg and Honikel, 2015; Feiner, 2006). Lately EFSA (European Food Safety Agency) has published a report on nitrite/nitrate use in meat products considered under a new prospective. EFSA experts have concluded that when nitrites are used at approved levels, their contribution to overall exposure to nitrosamines is of low concern for health (Mortensen *et al.*, 2017). Considering nitrite/nitrate from another point of view, emerging studies have strengthened the new understanding of their role in the human body, motivating revision of the long-held opinion that these ions pose a health risk. Research has shown that there are indisputable benefits of nitrite and nitrate in promoting human health, suggesting that NO_2 and NO_3 ions could be considered indispensable dietary components and even used as possible therapeutic agents (Merino, 2009). It is also worth mentioning that recent studies seem to demonstrate that high intakes of nitrate can improve cardiometabolic health and exercise performance pointing to the fact that because of its fourfold positive effect, nitrite presence in cooked meat products is much better than its absence (Feiner, 2006). Thus, the food safety topic "nitrite-nitrate in food" should be addressed in a more comprehensive view, such as the "Risk-benefit analysis (Iammarino *et al*., 2023).

Our intake of nitrate as food additives in meat processing industry is not the only source for their entering in organism. They also derive from two other main sources:

Vegetables are the most important source of nitrates in the human diet. Vegetables are the most important source of nitrate exposure in the human diet and contribute to the intake of more than 80% of nitrates (Salehzadeh *et al.,* 2020).

Drinking water, because nitrite is easily oxidized to nitrate, nitrate is the compound predominantly found in groundwater and surface waters. Contamination with nitrogen containing fertilizers or animal or human organic wastes, can raise the concentration of nitrate in water (European

Environmental Agency, 2023).

Among them, vegetables are generally the major source (75–91%), yet in some areas drinking water can account for the major contribution (European Commission Scientific Committee for Food, 1997).

Considering these facts, it should be noted that relating to the statistical data, Albanian consumers consume meat products at about 5.8 % of their daily consumption. The average volume per person in the Processed Meat segment is expected to amount to 35.67kg in 2023 (Meat Albania, Statista 2023), Vegetables direct suppliers of nitrate at about 118.9 kg, Dairy and Eggs 121.10kg, Bread & Bakery Products segment is expected to amount to 135.30kg, while Fruits and Nuts segment is expected to amount to 64.50kg in 2023 (Food Albania, Statista, 2023).

These data are supported from the household budget study of an Albanian family (Verçuni & Zhllima, 2008), where it has been clearly stated that fruit and vegetables constitute the most considerable part of the Albanian daily diet at about 10.24kg/capita, consequently the most important contributor in supplying organism with nitrate, following by dairy products 8.29kg/capita per month, while meat +fish 1.81kg/capita month (Verçuni and Zhllima, 2008).

This fact shows that other contributors to nitrate and thus nitrite after nitrate conversion are responsible for the total body burden of these two chemicals, being fruit, vegetables, and water other important contributors. Studies have already been carried out obtaining scientifically and statistically based results for population risk assessment according to each age group (Salehzadeh *et al.*, 2020), (Iammarino *et al.*, 2023), (Merino *et al.*, 2016). It is the time, basing on accurate and reliable scientific models to undertake an overall risk assessment towards total nitrate entering to organism for the Albanian consumers as well, especially to the most susceptible group age, young children.

Meat processing companies in Albania use sodium nitrite in their cooked meat products. Its residual amount has resulted much lower than the limit (Boci *et al.*, 2014) decreasing this way the possibility to form N-nitrosamines minimising the risk of nitrite/nitrate entering to organism from meat products additives (Pegg & Honikel, 2015).

This paper aims to evaluate nitrite and nitrate intake from meat products either from exogenous routes of entering in food chain or because of nitrite added followed by its oxidation to nitrate in meat matrices during storage in different condition. Though nitrite has resulted lower than the limit since from the first day after production, a considerable nitrate amount was detected in meat products as well, even if no nitrate was added. What is more the nitrate presented fluctuation in amount during time showing no consistent data. Such findings raised concern and debate between meat producers pretending for not using nitrate in their products and state officials who pretended undeclared use of nitrate pointing the finger to Albanian meat producers. Such a considerable content of nitrate could be explained by monitoring nitrate evolution during meat products storage and its potential entering by water, ice or spices used in meat processing or meat itself. To exclude these direct nitrate contributors as an anthropogenic contaminant from environment, the authors regularly tested technologic water of processing plant, meat, ice cubes and spices used but no considerable amount of nitrate was found to explain its relevant presence in meat products. From the other side no nitrate was found in some raw products such as raw sausages where no nitrite was added. As redox reactions may occur depending on the product condition, monitoring of their residual content in meat products is of utmost importance (Honikel, 2007). That is why the sum of both compounds is important to be determined for the human organism. This was the sparkle to investigate this dualism of nitrite/nitrate amount compared to ingoing nitrite content during meat products storage in different packaging after excluding all the other potential culprits for nitrate contamination of meat products.

2 Materials and method

The meat processed samples analyzed as a routine official control, presented a considerable nitrate content, except for nitrite (though both well below their MRLs). The repetition of analyses from the same lab confirmed the nitrate presence but at somewhat lower level (well below the MRL). Another accredited foreign lab confirmed nitrate presence. As all the meat producers in Albania sustained not to have used nitrate in their products, we followed this case. We analyzed the same products in our lab and confirmed the presence of nitrate at a lower level comparable to nitrite content but still considerable. We analyzed raw sausages with neither nitrite nor nitrate added and no nitrate had been found by analysis.

These findings excluded nitrate presence from any casual cross contamination or exogenous factor; consequently, we had to focus on nitrite time degradation pattern and nitrate formation by oxidation in different storage condition.

2.1 Sampling

The samples taken for analysis were traditional dry cooked salami, a massively consumed product in the domestic market. The samples were analyzed for nitrite and nitrate content even though no nitrate was added. The only additives used were preservative *E*

a) b) c)

Figure 1. Samples a) unpackaged (TO), b) packaged in vacuum (TAV), c) packaged in modified atmosphere (TAAM).

251(sodium nitrite) and antioxidant *E 301* (sodium ascorbate). The samples were analyzed during five weeks of storage starting from the first day of production. As the literature confirms, the fate of nitrate and nitrite is complex especially in meat processed matrices (Honikel, 2007), we studied the same product during storage in three different kinds of packaging: unpackaged (TO), vacuumed (TAV) (2 months shelf life), and modified atmosphere (N_2+CO_2) packaging (TAAM) (1 month shelf life).

All the sample units were packaged in separate packages on the same day and were stored in refrigerator at 4ºC. Each week we analyzed three separate units for each product sample.

2.2 *Analytical method*

We used the SF UV-Vis analytical method presented and validated by Merino (2009) and described in detail in Food Analytical Methods (Merino, 2009).

The general procedure is based on the determination of nitrite before and after nitrate reduction in alkaline condition followed by diazotization coupling Griess reaction forming an intensive-colored complex, whose absorbance is measured at λ = 540 nm. This method proposes Zn for nitrate reduction to nitrite instead of using toxic Cd as described in oficial ISO method (ISO 3091-1975).

The samples portions were prepared by water homogenization in magnetic stirrer followed by clarification with *Carrez I* and *Carrez II* reagents. After centrifugation, a portion of the test solution was treated with ammonia buffer (pH=11) followed by color development with coloring reagents and measurement. Another portion of the test solution was mixed with ammonia buffer and was vigorously shaken in presence of Zn to reduce nitrate. The same procedure was followed for nitrite determination.

Three portions of the unpackaged sample were analyzed in the same first day after cooking in three different ways: boiling at 90°C for 10', frying in presence of sunflower oil and grilling on a hot plate. The samples after drying by kitchen paper were analyzed for nitrite and nitrate content by the same procedure as described above. Three parallel samples for each cooking procedure have been analyzed. Results of all the analysis are shown in Table 1 and Table 4.

2.3 *Data analysis*

The analytical data obtained for nitrite and nitrate content, were statistically analyzed using MINITAB 21 Software. To check the variability of both parameters and stability of nitrites, the data were analyzed by descriptive statistics. Anderson-Darling test and probability plot diagram were used to check the normality on data distribution which is confirmed at $p > 0.05$. The variability of the data was checked by time series diagram. The co-existence and correlation of nitrite and nitrate in the targeted products is analyzed by correlation analysis which is confirmed by linear regression graphs.

3 Results and discussion

The average values of NO_2^- and NO_3^- ions for three parallel samples of products under different packaging modes are shown in Table 1.

3.1 *Statistical analysis*

The data of Table 1 were evaluated by Anderson-Darling test (Figure 2) to monitor for their normal distribution (P>0.05).

Table 1. Results of analysis for NO_2^- and NO_3^- during storage (in mg/kg).

Sampling	NO_2^- TO	NO_3^- TO	NO_2^- TAV	NO_3^- TAV	NO_2^- TAAM	NO_3^- TAAM
Production Day	66.78	3.27	66.78	3.27	66.78	3.27
1st day	58.64	2.97	50.64	5.97	45.19	4.03
8th day	39.15	15.46	39.3	6.39	32.09	4.19
15th	36.95	22.52	22.88	8.54	24.07	7.22
22nd day	12.2	21.1	11.53	10.46	9.15	14.58
29th day	6.98	18.4	6.15	19.11	3.41	1.6
50th day			4.12	15.34		

Table 2. Descriptive Statistics: NO_2^--TO, NO_3.-T.O., NO_2^--TAV, NO_3^--TAV, NO_2^--TAAM, NO_3^{-}—TAAM.

Variable	Mean	SD	CV	Minimum	Q1	Median	Q3	Maximum
NO_2^--TO	36.78	23.98	65.20	6.98	10.89	38.05	60.68	66.78
NO_3^--TO	13.95	8.73	62.58	2.97	3.20	16.93	21.46	22.52
NO_2^--TAV	32.88	23.56	71.66	6.15	10.18	31.09	54.68	66.78
NO_3^--TAV	8.96	5.54	61.84	3.27	5.29	7.46	12.62	19.11
NO_2^--TAAM	30.11	23.51	78.08	3.41	7.72	28.08	50.59	66.78
NO_3^--TAAMV	5.82	4.67	80.25	1.60	2.85	4.11	9.06	14.58

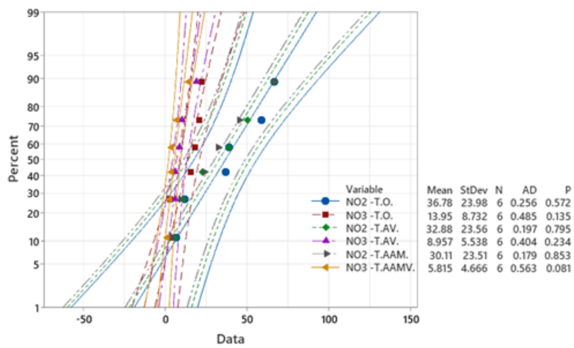

Figure 2. Probability Plot of NO_2^--TO, NO_3^--TO, NO_2^--TAV, NO_3^- -TAV, NO_2^--TAAM, NO_3^--TAAM.

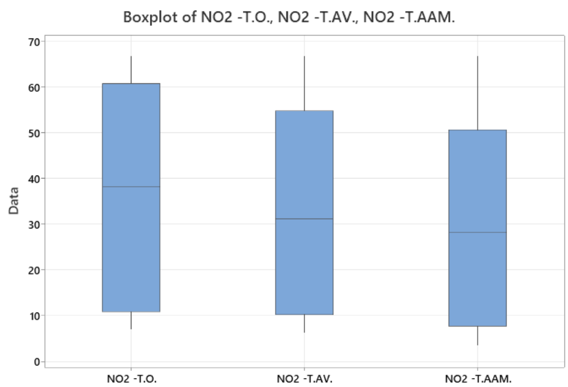

Figure 3.a. Boxplot NO_2^- analysis for the three sample types

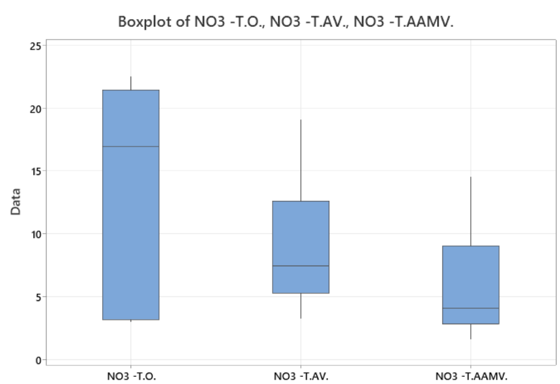

Figure 3.b. Boxplot NO_3^- analysis for the three sample types.

According to the values given in Table 2, it results that all the data obey to normal distribution.

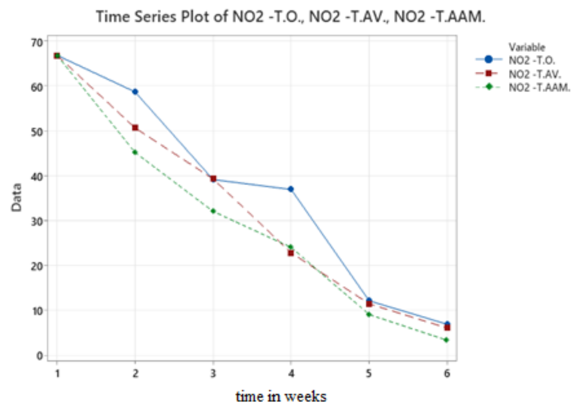

Figure 4. Time Series Plot of NO_2^- -TO, NO_2^- -TAV, NO_2^- –TAAM.

Descriptive statistical analysis was used to evaluate the concentration level of the parameters to be tested and their variability (Table 2). Average value and median are quite near to each other for each parameter as well as from the values of Coefficient of Variance (CV %) which resulted <75% except for modified atmosphere packaged product with CV%=78-80%. This fact may be explained by the influence of modified atmosphere in nitrite red-ox reactions. The variability of the data was visualized by boxplot diagram (Figure 3. a and Figure 3. b). Boxplot analysis for NO_2^- is shown in Figure 3a. Boxplot analysis for NO_3^- is shown in Figure 3b.

The values shown for NO_2^- resulted in a minimum-maximum distribution and interquartile range very near to each other. This may be correlated to the similar NO_2^- degradation pattern for all the three products showing almost the same degradation trend to the packaging mode.

The values shown for NO_3^- resulted in high differences between minimum and maximum and interquartile range. The figure shows that NO_2^- to NO_3^- conversion is more apparent for unpackaged products (TO) which is to be expected by direct contact with air. Unfavorable conditions for NO_2^- conversion to NO_3^- showed the modified atmosphere packaged product TAAM. This may be explained because nitrite to nitrate conversion is induced by a higher pH. The pH value of the TAAM presented a lower pH compared to TO and TAV respectively 5.87 in TAAM against 6.09 in TAV and 6.14 in TO.

Table 3. Linear regress equation for NO_2 time degradation pattern for the three products.

Variables	Equation	R^2
NO_2^- *vs*. time (TO)	-2.01x+61.9	0.952
NO_2^- *vs*. time (TAV)	-1.957x+57.3	0.935
NO_2^- *vs*. time (TAAM)	-1.912x+54.0	0.896

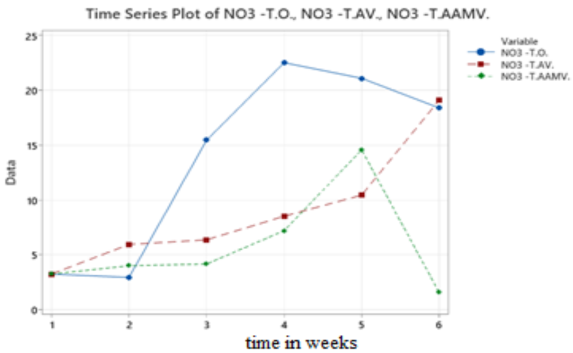

Figure 5. Time Series Plot of NO_3^- –TO, NO_3^- –TAV, NO_3^- –TAAM.

3.2 *Nitrite time degradation pattern and its conversion to nitrate depending of packaging mode*

To observe the NO_2^- time degradation pattern for the three products during storage, the Time Series Plot was constructed (Figure 4).

Residual nitrite content showed a sharp decrease during the first week of storage especially for TAAM, followed by TAV and a smoother decrease for TO, which showed a rapid decrease during the second week induced from the direct contact with the air. This result is consistent with other findings (Merino *et al*., 2016). Although regarding NO_2^- (Figure 4) very similar trend was observed for the three products until the recommended use-by date. To verify this trend, linear regress has been tested between the parameters in the study (Table 3).

To observe the NO_3^- time degradation pattern for the three products during storage, the Time Series Plot was constructed (Figure 5).

The data obtained for nitrite to nitrate conversion (Figure 5) did not show any similar trend, which supports the previous findings about the fluctuating and non-consistent values for nitrate derived spontaneously from nitrite oxidation. Time dependence of NO_3^- concentration quite interestingly, showed a maximum peak after 15 days for TO and 22 days for TAAM, while TAV showed a steady increase of nitrate until 29th day of storage. The shelf life of TAV (vacuum packaged product) is longer (2 months) than the two other products TO and TAAM (1 month), that is why the maximum peak for TAV is observed later during storage.

3.3 *Influence of cooking mode to nitrite degradation*

Some other factors were investigated regarding the stability of NO_2^- and its conversion to NO_3^-. We studied the effect of cooking mode on this oxidation reaction. The data shown in Table 4 are the average of three replicates for each cooking mode. It results that the impact of oxidation is higher by boiling followed by grilling on a hot plate.

Comparing the data presented in the Table 1 with the data in the Table 4, it is obviously noticed that boiling reduced the initial nitrite at 57% by converting it to nitrate. The sum of both these chemicals (expressed as $NaNO_2$ + $NaNO_3$) is more or less the same, leading to a possible conclusion that no other degradation chemical from nitrite may be formed by boiling. On the contrary frying resulted also with a nitrite decrease at 58% but no considerable increase of nitrate resulted compared to the initial amount of the reference unpackaged product. The sum of both chemicals ($NaNO_2$ + $NaNO_3$) showed a reduction at 70% of the initial nitrite and nitrate content. Frying may have stimulated some other degradation chemicals. This fact should be further monitored, and the derivative substances should be accurately identified and quantified. Grilling on hot plate showed similar pattern to frying but with a higher conversion of nitrite to nitrate, whereas their total sum is comparable to boiling. These findings are somewhat different from the results obtained by Iammarino *et al*. (2023), where boiling showed a high reduction of nitrite and nitrate. In our study nitrite showed the highest decrease in boiling compared to frying and grilling on hot plate, while nitrate showed a sharp increase suggesting that boiling may be more acceptable cooking mode regarding some other potential harmful end N-compounds.

Table 4. Effect of cooking on nitrite / nitrate content (in mg/kg) 150mg/kg sodium nitrite added.

Sample	NO_2^-	NO_3^-	Sum expressed as $NaNO_2$+$NaNO_3$
Unpackaged product (TO), 1st day	58.64	2.97	92.03
Unpackaged product (TO) boiling 10’ at 90°C, 1st day	25.66	33.86	84.9
Unpackaged product (TO) frying in sunflower oil, 1st day	34.07	9.99	64.8
Unpackaged product (TO) grilling on hot plate, 1st day	37.11	19.33	82.7

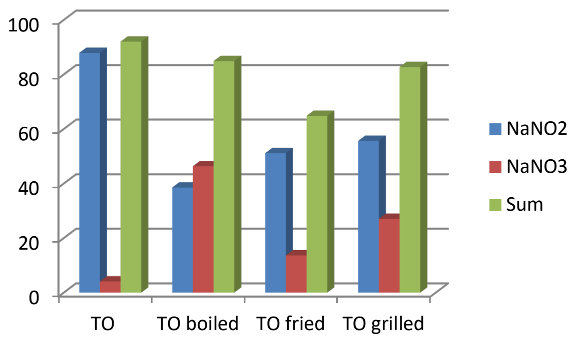

Figure 6. NO_2, NO_3 ions and their total sum (expressed in mg/kg) in the products analyzed after different cooking modes.

These tests can be used only to show the influence of cooking mode to nitrite to nitrate conversion in a type of dry cooked salami, in which the water content is relatively lower compared to sausages while NaCl content is higher. This fact and pH value at 6.05-6.1 at the finished product may have an influence on the chemical background of nitrite degradation and its conversion to nitrate. The results obtained should be further investigated to have more confirmative data especially relating to final degradation compounds. Feiner (2006) has shown that temperatures above 140°C (grilling) are required to form nitrosamines and only if heavily fried under high temperatures for a prolonged period of time. As this matter is highly sensitive to the consumers for safety reasons, more detailed analysis should be made for the degradation compounds of N-moiety under different temperatures and cooking media.

Conclusion

Nitrite added or derived from nitrate from meat products is the least contributor of nitrite in the organism considering the legal content and the remarkable instability of nitrite in product. However, nitrite use is a balance between risks and benefits. The proper question in this case would be: *What is the risk of having meat products with no nitrite added?* While a nitrite free product increases the risk of *Clostridium botulinum* toxin, products with added nitrite should be evaluated in a new scientifically based according to risk and benefits point of view. A total diet study for Albanian consumers should be performed to evaluate all the potential routes of nitrite formation or nitrate entering in organism. Factors such as type of product, storage duration, packaging mode, products pH, cooking mode should be all considered to conclude on nitrite stability, nitrate formation or potential other N-compound. The most important result from the study is the apparent decrease of nitrite content since the first day after production at about 67% of the initial added sodium nitrite amount.

The dry cooked product salami samples were tested for NO_2^- time depletion, NO_2^- to NO_3^- oxidation with no addition of NO_3^-. The samples tested were packaged in two different forms except for the unpackaged products. These products have been analyzed to study the time depletion of nitrite ion and the dependence of storage condition in different packaging modes compared to the unpackaged product. The results showed NO_2^- to NO_3^- conversion is more apparent for unpackaged product (TO) which is expected by its direct contact with air. Unfavorable condition for NO_2^- conversion to NO_3^-showed the modified atmosphere packaged product (TAAM), which may be explained of its lower pH value compared to two other products. While nitrite depletion showed similar trends for all the three product types, nitrate showed quite a remarkable different pattern compared to nitrite degradation. Its formation follows a gradual increase arriving at a maximum dependent of the recommended use–by date of the product. Longer the product shelf life, lower the sum of both nitrite and nitrate residual content, but highest the possibility to form any other degradation N-compounds. In any case it is advisable to consume products as near as their production date.

Relating to effect of cooking mode, it may be noticed that the three-cooking mode i.e. boiling, frying and grilling on hot plate showed a nitrite decrease which resulted higher in boiling compared to frying and grilling, whereas nitrate showed a different situation, a higher nitrate content for boiling than for two other cooking modes leading to the fact that the nitrite to nitrate is highly favored during boiling. Though the total sum nitrite plus nitrate (expressed as sodium nitrite and sodium nitrate) resulted almost the same between boiling and grilling on hot plate at about 95% and 91.6% respectively compared to the initial contents. Frying showed a considerable reduction in the sum of nitrite and nitrate, compared to the initial content at about 71% leading to a possible conclusion that other nitrite degradation compounds may have been formed. Further study is required to identify the potential derivatives compounds.

References

Akcan, T., Özünlü, O., Ergezer, H. and Gökçe, R. (2023). Exploring the impact of acorn extract on the quality and taste of beef meat burgers. *Revista Mexicana de Ingenieria Química, Vol. 22, No. 2 Alim2311*, 1-10. http://rmiq.org/iqfvp/Numbers/V22/No2/Alim2311.pdf

Boci, I. and Hamiti, Xh. (2014). Niveli i përmbajtjes së nitriteve në produktet e përpunuara të mishit të prodhuar në vend. *Buletini i Shkencave te Natyres* 18, 191-198, ISSN 2305-882 X. https://www.researchgate.net/publication/301339188

European Commission Scientific Committee for Food. (1997). Opinions of the scientific committee for food on: Nitrates and Nitrite. *Reports of the Scientific Committee for Food (thirty eighth series).* https://food.ec.europa.eu/document/download/5a499138-72ea-47c3-b1a5-dd8544689446_en?filename=sci-com_scf_reports_38.pdf

European Environmental Agency. (2023.) Nitrates in groundwater. Available at: https://www.eea.europa.eu/en/analysis/indicators/nitrate-in-groundwater-8th-eap

Feiner, G. (2006). *Nitrite and nitrate: Meat Products Handbook.* Woodhead Publishing Limited, Cambridge, England.

Flores-Silva, P., Martínez-Yañez, R.C., Rodríguez-Huezo, M. E. and Alvarez-Ramirez, J. (2022). Nutritional protein quality and digestibility changes during food processing. *Revista Mexicana de Ingenieria Química, Vol. 21, No. 1(2022) Alim2748.* 1-10. http://rmiq.org/iqfvp/Numbers/V22/No2/Alim2311.pdf

Food Albania. (2023). Statista. Available at: https://www.statista.com/outlook/cmo/food/albania#analyst-opinionFood - Albania | Statista Market Forecast,

Honikel, K.O. (2007). The use and control of nitrate and nitrite for the processing of meat products. *Meat Sciences, Jan 78 (1-2),* 68-76. https://doi.org/10.1016/j.meatsci.2007.05.030

Iammarino, M., Berardi, G., and Tomasevic, I. (2023). Effect of Different Cooking Treatments on the Residual Level of Nitrite and Nitrate in Processed Meat Products and Margin of Safety Assessment, *Foods 12(4)*: *869,* 1-12. https://doi.org/10.3390/foods12040869

ISO 3091:1975 (revised 2023). Meat and meat products. Determination of nitrate content. (Reference method) https://www.iso.org/standard/8231.html

Meat Albania, Statista (2023). Available at: https://www.statista.com/outlook/cmo/food/meat/albania#revenue.

Merino, L. (2009). Nitrate in Foodstuffs: Analytical Standardization and Monitoring and Control in Leafy Vegetables, *Thesis in Food Sciences*, Swedish University of Agriculture Sciences Upsala. ISBN: 978-91-86197-34-6

Merino, L. (2009). Development and Validation of a Method for Determination of Residual Nitrite/Nitrate in Foodstuffs and Water After Zinc Reduction. *Food Analytical Methods 2*, 212–220. https://doi.org/10.1007/s12161-008-9052-1

Merino, L., Darnerud, P.O., Toldrá, F., and Ilbäck, N.G. (2016). Time-dependent depletion of nitrite in pork/beef and chicken meat products and its effect on nitrite intake estimation. *Food Additives and Contaminants: Part A, 33(2)*, 186-192. https://doi.org/10.1080/19440049.2015.1125530

Mortensen, A., Aguilar, F., Crebelli, R., Di Domenico, A., Dusemund, B., Frutos, M. J., Galtier, P., Gott, D., Gundert-Remy, U., Lambré, C., Leblanc, J., Lindtner, O., Moldeus, P., Mosesso, P., Oskarsson, A., Parent-Massin, D., Stankovic, I., Waalkens-Berendsen, I., Woutersen, R. A., Wright, M., van den Brandt, P., Fortes, C., Merino, L., Toldra, F., Arcella, D., Christodoulidou, A., Abrahantes, A. C., Barrucci, F., Garcia, A., Pizzo, F., Battacchi, D. and Younes, M. (2017). Re-evaluation of potassium nitrite (E 249) and sodium nitrite (E 250) as food additives. *European Food Safety Authority Journal*, *15(6),* 1-157. https://efsa.onlinelibrary.wiley.com/doi/full/10.2903/j.efsa.2017.4786

OJ L 354, (2008), Regulation (ec) no 1333/2008 of the European Parliament and of the Council of 16 December 2008 on Food Additives. *Official Journal of the European Union,* Pp. 16–33. Available at: https://eur-lex.europa.eu/eli/reg/2008/1333/oj

Pegg, R.B. and Honikel, K.O. (2015). Principles of Curing. In: *Handbook of Fermented Meat and Poultry: 2nd Edition*, (Toldrá F. ed.), Pg. 19–30. John Wiley & Sons, Ltd.

Salehzadeh, H., Maleki, A., Rezaee, R., Shahmoradi, B. and Ponnet, K. (2020). The nitrate content of fresh and cooked vegetables and their health-related risks. *PLoS One* January 9, *15(1),* e0227551 1–14. https://doi.org/10.1371/journal.pone.0227551

Shen, Q., Zeng, X., Kong, L., Sun, X., Shi, J., Wu, Z., Guo, Y., and Pan, D. (2023). Research Progress of Nitrite Metabolism in Fermented

Meat Products. *Foods 12: 1485*, 1-17. https://doi.org/10.3390/foods12071485

Verçuni, A., Zhllima, E., Imami, D., Bijo, B., Hamiti, Xh. and Bicoku Y. (2016). Analysis of Consumer Awareness and Perceptions about Food Safety in Tirana, Albania. *Albanian Journal of Agricultural Sciences 15(1)*, 19–26. https://www.researchgate.net/publication/336639822_Analysis_of_Consumer_Awareness_and_Perceptions_about_Food_Safety_in_Tirana_Albania