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Effect of red wine in dry fermented sausages produced with a starter culture for improving their quality and safety

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Abstract

The use of strategies aimed at the improvement of the quality and safety of dry fermented meat products through a scientific re-assessment of some original ingredients in their formulations, one of them being wine, is an approach strongly supported by consumers. The aim of the present study was to determine and evaluate the effect of red wine from the Cabernet Sauvignon variety in combination with a starter culture including *Pediococcus pentosaceus* and *Staphylococcus carnosus ssp*. on the quality characteristics of a dry sausage. The experiments were made using three groups of samples formulated with 25 mL and 50 mL of wine per kg of meat. The effect of the wine addition on the physicochemical and microbiological changes and the texture and sensory properties of the finished product was investigated. A trend to a faster decrease in the a_w and residual nitrite values was observed in the wine-containing samples. The highest hardness values were recorded through texture profile analysis in the wine-free samples, and the lowest values in samples with 50 ml of wine per kg of meat. The increase in the wine quantity from 25 to 50 mL led to lower sensory scores given to colour compared to the control sample.

Keywords: meat products; wine; sensory characteristics; nitrite; microflora; texture.

Practical Application: The obtained results reveal technological potential of red wine for the manufacture of dry sausages having improved sensory properties and safety characteristics.

1. Introduction

Dry meat products are the object of constant market demand maintained by their association with high-quality delicacies that integrate traditions, culture, sensory delight and, frequently, the feeling of luxury. Although numerous product varieties with strong social and geographical connotations have been created over the centuries (Leroy et al., 2013, 2015), dry meat products constantly attract the interest of manufacturers and researchers working in the area of meat science who direct their studies to the search for new strategies for the improvement of the quality and safety of these products.

The more important innovations in the technologies applied to the manufacture of dry meat products are related to the strategies aiming to achieve higher safety levels of the finished products, cost reduction and enhancement of their sensory quality by using starter cultures (Leroy et al., 2006; Wang et al., 2022) and chemical substances (Roncalés, 2007), as well as to improve their nutritional and health profile through the addition of probiotics and fibres (Bis-Souza et al., 2019), bioactive compounds (Borrajo et al., 2021), antioxidants (Lorenzo et al., 2013; Pateiro et al., 2015), or vegetable oils as fat substitutes (Pintado & Cofrades, 2020), or through sodium chloride reduction (Mugueza et al., 2004; Vidal et al., 2021), etc. Excessive interference in the traditional composition and technology of dry sausages may lead to products that are unacceptable to consumers from a sensory perspective. However, if consumers have access to information on the natural composition or origin of meat product, their reaction is often positive and they give higher scores on its sensory characteristics (Frank et al., 2017). There is evidence of valorization of the meat products with improved sensory characteristics and associated with the health concept (Vidal et al., 2020). One example is meat products made without the use of nitrates and/or nitrites. The latter are associated with a risk of exogenous exposition of the human body to nitrosamines and other N-nitroso compounds (Chan et al., 2011).

"Innovation through tradition", which makes it possible to preserve the traditional features of a product, is a powerful approach to the improvement of its quality and safety along with the preservation of its natural character and shelf life (Geyzen et al., 2012; Charmpi et al., 2021). The use of the modern scientific infrastructure presents possibilities for the scientific re-assessment of some "original formulation ingredients", such as wine. Being a beverage with a distinct taste, wine has always been connected with gastronomy. Its popularity is not limited to the pleasure its consumption causes; it also has numerous health benefits related to its polyphenol-rich composition and micro- and macroelement content (Wurz, 2019). The polyphenols in wine consist of two types of components, flavonoids and non-flavonoids, and depend on a number of factors, such as variety, field management or climatic conditions; on the specificity of the manufacturing technology applied, e.g., pre-fermentative maceration, thermovinification, the use of different yeasts and bacteria in fermentation, and post-fermentative processes such

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as maceration, fining agents and aging (Gutiérrez-Escobar et al., 2021).

Apart from the marination of raw meat intended for culinary treatment, in some regions that have traditions in wine-making, wine is used in the processing of dry sausages, where it undoubtedly contributes to the sensory properties of the finished products (Rason et al., 2007; Patarata et al., 2020). It has been reported that the use of white wine from the Cabernet Sauvignon variety in fermented sausages may enhance the safety of the sausages in terms of undesirable bacteria due to the reduced pH and the ethanol content (Coloretti et al., 2014). In addition to these microbiological advantages, the use of a combination of 10% wine (v/w) and garlic for replacement of the nitrates and nitrites added to chouriço sausages contributes to salmonella control during production (Patarata et al., 2020).

Nevertheless, the current scientific knowledge is limited with regard to the influence of red wine on the quality characteristics of dry meat products and its effect on the growth of the microbial populations in the sausage batter that participate in the formation of these characteristics. Therefore, the aim of the present study was to determine the technological influence of wine on microbiological changes and evaluate the effect of its combination with a starter culture on the physicochemical and oxidative transformations and the sensory properties of dry sausages.

2 Materials and methods

A dry fermented meat product was made for the purposes of the study from comminuted pork according to the following recipe: 4.8 kg of lean meat from a hind leg of pork, 1.8 kg of semi-fat pork belly, 120 g of sodium chloride, 15 g of nitrite salt (containing 4.95% of sodium nitrite), 6 g of fennel seeds, 18 g of black pepper, 4.8 g of garlic powder, a starter culture (BactoFlavor® BFL-T03, Chr. Hansen): 1.5 g, and a combination of sugars (glucose and fructose): 15 g. The red wine used was from the grape variety that is most common worldwide, i.e. Cabernet Sauvignon (vintage 2019, Mezzek brand, Mezzek winery, Bulgaria), with pH 3.42 and ethanol content 12.5 vol %. Three groups of samples were prepared: sample CSD, or the control sample without any red wine, sample SD25 formulated with the addition of 25 ml of wine per kg of meat raw materials, and sample SD50 formulated with the addition of 50 ml of wine per kg of meat raw materials.

The sausage batter was prepared on a cutter and then stuffed into natural casings 32 – 34 mm in diameter. The sausages were placed at a temperature of 20 – 22 °C and relative humidity of 92 – 95% for 24 h; after that, the relative humidity and the temperature were gradually reduced from 88 ÷ 85% and 18-16 °C to 75 ÷ 70% and 14 – 12 °C, respectively, and the drying and ripening continued until the moisture content in the product reached 40 ÷ 45% of the total mass. This happened on the 10th day of the manufacture; then, the products were vacuum-packed and stored at 2 – 4 °C. Samples were taken from the finished product for analysis of its colour, texture and sensory characteristics, and samples from the sausage batter were also taken for the microbiological analysis. Samples from the sausage batter, on the 5th day of manufacture, from the finished product and on the 21st day of the storage of the vacuum-packed sausages were analysed for a study of their physicochemical characteristics, pH and residual nitrites.

2.1 Physicochemical and colour analyses

An MS 2004 pH meter (Microsyst, Bulgaria), a LabSwift-a_w system (Novasina AG, Switzerland) and a KERN MLS-A moisture analyser (Kern & Sohn GmbH, Germany) were used for the determination of the pH, a_w and moisture content of the samples, respectively. The pH value of the samples was measured in an aqueous extract of the products (1:9 w/v). The residual nitrite and nitrate content was measured using the method described in EN 12014-3:2005 (European Committee for Standardisation, 2005).

The colour characteristics were measured using a Minolta Chroma meter, (model CR 410, Osaka, Japan) in the CIELab system. Illuminant C and a 2° standard viewing angle were used in the measurement, and all measurements were taken five times on non-overlapping zones of a pre-homogenised mean sample.

2.2 Lipid oxidation level

The peroxide value (POV), and thiobarbituric acid reactive substances (TBARS) were used in order to evaluate the lipid oxidation level in the samples. The peroxide value was determined spectrophotometrically on the basis of the Fe^{2+} oxidation to Fe^{3+} in the presence of hyperoxides and the formation of a colour complex between the resultant Fe^{3+} ions and SCN (thiocyanate) following the recommendations of Hornero-Méndez et al. (2001). The absorption was measured at 507 nm (UV-Vis Spectrophotometer, M550, CamSpec, UK). The secondary products of the oxidation reactions in the sausages were measured through TBARs according to the method described by Li et al. (2020).

2.3 Proteolytic level

The proteolysis index (PI) was determined according to the method described by Wang et al. (2021).

2.4 Texture analysis

The texture profile of the finished product was determined using a TA-XTPlus (Stable Micro Systems. Surrey, GB) texture analyser and pre-shaped test samples of the sausages 1.5 × 1.5 × 3 cm (height × width × length) in size. The samples were compressed twice until 50% of their height using a 50-mm diameter cylindrical aluminium probe attached to a 25 kg load cell. The rest time between two compressions was 3 s. The analysis was made with the following parameters: probe speed before reaching the sample: 3 mm.s^{-1}; probe speed during the test: 3 mm.s^{-1}; probe withdrawal speed: 3 mm.s^{-1}. Force-time curves were recorded (Barbut, 2009), and the following texture attributes were calculated in the TPA: hardness (N), springiness, cohesiveness and chewiness (N).

2.5 Microbiological analysis.

The samples were prepared for the microbiological analysis according to ISO 6887-1:2017 (International Organization for Standardization, 2017c). The following microbial populations were evaluated: total viable count (TVC) according to ISO 4833-1:2013 (International Organization for Standardization, 2013), LAB according to ISO 15214:1998 (International Organization for Standardization, 1998), coliforms through inoculation of 1 cm^3 of ten-fold dilutions on HiChrome Coliform Agar w/SLS (HiMedia), which were incubated at 37 and 44 °C for 48 hours; enterococci through inoculation of 1 cm^3 of pre-made ten-fold dilutions on bile esculin azide agar (HiMedia) and cultivation after 48 h at 30 °C; quantitative assessment of staphylococci (pathogenic and non-pathogenic) through inoculation of 1 cm^3 of pre-made ten-fold dilutions on Manitol salt agar (HiMedia) at 30 °C for 48 h; moulds and yeasts through surface inoculations on a selective medium for yeasts and moulds and cultivation at 20 °C for 7 days; *Salmonella spp* in 25 g according to ISO 6579-1:2017 (International Organization for Standardization, 2017b) and *Listeria monocytogenes* in 25 g according to ISO 11290-1:2017 (International Organization for Standardization, 2017a).

2.6 Sensory analysis

The sensory analysis was made when the dry fermented sausages were ready for consumption, on the 5^{th} day of their cold storage, after the samples had been taken out of the cold chamber and left at ambient temperature. The evaluation of the dry fermented meat products was made by a 28-member tasting panel including 14 men and 14 women. Before the analysis, a preliminary sensory session was held with a view to the clarification of the aims of the analysis and the sensory parameters to be evaluated. The main evaluation parameters were divided into 7 categories: 1) appearance; 2) colour; 3) consistency; 4) aroma; 5) taste; 6) aftertaste; 7) total score on the overall sensory perception. The product was awarded points from 1 to 9, the maximum score for each parameter being 9.

2.7 Statistical data processing

The statistical processing of the data obtained was performed using the STATGRAFICS XVI software product. Single-factor (colour, texture, microbiological and sensory evaluation) and two-factor (physicochemical results) dispersion analysis was used for the assessment of the effect of wine addition (factor I) and the manufacturing or storage stage (factor II) on the parameters studied. The calculations were made at confidence level $\alpha = 0.05$. The results presented are the arithmetic means of the data on two batches of dry fermented sausage, after three pieces of each type of sample had been analysed for each batch.

3 Results and discussion

3.1 Physicochemical analysis

The addition of red wine in 25 ml and 50 ml quantities per kg of meat raw materials did not cause any significant differences in the pH values of the sausage batter measured ($p > 0.05$), although dispersion in their mean values was recorded (Table 1). During the technological process, all samples demonstrated a trend to acidification of the batter as a result of the fermentation activity of the starter culture added, but it was only in the finished sausages that statistically significant lower pH values were measured in the sausages made with the addition of wine ($p < 0.05$) compared to those measured in the control sample. Later, on the 21^{st} day of the storage, there was a gradual increase in the pH mean values in these samples, whereas no such increase was recorded in the control sample. Furthermore, the pH increase was linearly dependent on the quantity of wine added and could be related to the higher activity of the endogenous and exogenous proteolytic enzyme systems in these samples, which led to the liberation

Table 1. Effect of Cabernet Sauvignon red wine on the changes in pH, moisture, a_w and the residual nitrite content of dry fermented sausages.

Sample	pH value	Moisture content, %	a_w value	NO_2. $mg.kg^{-1}$
Sausage batter				
CSD	$5.77 \pm 0.14^{x,b}$	64.56 ± 2.98^{x}	$0.952 \pm 0.002^{x,b}$	$78.03 \pm 2.28^{y,b}$
SD25	$5.74 \pm 0.04^{x,c}$	65.62 ± 3.67^{x}	$0.950 \pm 0.002^{x,d}$	$80.12 \pm 2.28^{y,c}$
SD50	$5.88 \pm 0.06^{x,d}$	62.99 ± 2.97^{x}	$0.952 \pm 0.001^{x,d}$	$66.20 \pm 2.28^{x,c}$
Dry fermented sausages on the 5^{th} day of manufacture				
CSD	$5.13 \pm 0.03^{x,a}$	*nm*	$0.942 \pm 0.001^{y,b}$	$20.05 \pm 0.76^{y,a}$
SD25	$5.17 \pm 0.03^{x,b}$	*nm*	$0.928 \pm 0.001^{x,c}$	$19.67 \pm 0.76^{y,b}$
SD50	$5.17 \pm 0.02^{x,b}$	*nm*	$0.918 \pm 0.003^{z,c}$	$17.00 \pm 0.76^{x,b}$
Finished product				
CSD	$5.06 \pm 0.01^{z,a}$	45.12 ± 2.00^{y}	$0.902 \pm 0.002^{y,a}$	$18.66 \pm 1.11^{z,a}$
SD25	$4.98 \pm 0.01^{x,a}$	$42.09 \pm 1.64^{x,y}$	$0.897 \pm 0.001^{xy,b}$	$14.75 \pm 1.11^{y,a}$
SD50	$5.03 \pm 0.01^{y,a}$	40.80 ± 2.16^{x}	$0.885 \pm 0.003^{x,b}$	$11.58 \pm 1.11^{x,a}$
Finished product on the 21^{st} day of storage				
CSD	$5.04 \pm 0.01^{x,a}$	*nm*	*nm*	$17.43 \pm 0.53^{z,a}$
SD25	$5.09 \pm 0.01^{y,b}$	*nm*	*nm*	$14.61 \pm 0.53^{y,a}$
SD50	$5.26 \pm 0.01^{z,c}$	*nm*	*nm*	$10.71 \pm 0.53^{x,a}$

Note: The results obtained have been presented as mean values ± standard deviation (n = 5); *nm*: the values were not measured at this stage. Values within the same column bearing different superscripts showed statistically significant differences (p > 0.05, Duncan's test). The following letter designations were used: ^{X,Y,Z} for the concentration of the wine added, and ^{A,B,C} and ^{D} for the manufacturing stage.

of peptides, amino acids and ammonia (Spaziani et al., 2009). These data on the red wine effect upon the pH evolution in dry fermented sausages were in conformity with those reported by Coloretti et al. (2014), who studied the effect of white wine (Cabernet Sauvignon) addition to dry fermented sausages in 7.5% and 15% (v/w) quantities. A reason for the different course of the changes in the pH of the test samples can be found in the selective role of the wine in the meat microbiota and its metabolic nature, as well as in the higher activity of endogenous proteolytic enzymes in the meat matrix to which wine had been added. This hypothesis can be supported by the results obtained in our study after the microbiological and texture analyses along with the calculated proteolytic index of the test samples.

In all samples of both experimental batches, the final dry fermented sausage reached moisture values of 40.82 – 45.12% on the 10th day of processing while the a_w ranged between 0.902 and 0.885. The water content decreased progressively during the investigated period of manufacture and storage (Table 1), with the most pronounced decrease recorded in the wine-containing samples.

In order to prevent the proliferation of bacterial pathogens, an ensemble of microbial hurdles has to be ensured in the dry fermented meat production. The achievement of an a_w value of 0.94 is of critical importance to the manufacture of dry fermented meat products (Leistner, 1991). In our experiment, the water activity values were reached as early as the 5th day in the samples made with wine, or 0.928 in SD25 and 0.918 in SD50, respectively.

The 0.92 – 0.80 a_w range, which guarantees the safety of the finished product in terms of microbiological hazards, was reached in all samples studied; however, statistically significant lower values were observed in the samples formulated with red wine compared to the control sample (CSD), ($p < 0.05$), (Table 1). These results are in conflict with the higher water activity values of sausages made with the addition of white wine reported by Coloretti et al. (2014), which could be attributed to the larger wine quantities added by these authors and to the different type and diameter of the sausage casings they used.

The technological possibility of controlling and reducing the residual nitrite quantity in meat products is of particular importance for the quality and safety of finished products. In this aspect, the effect of wine on their quantity in the sausages during manufacture and storage was investigated (Table 1). The residual nitrite quantities constantly decreased in the three samples throughout the period studied, the nature of the decrease being more pronounced in the wine samples. The trend to a faster reduction of the residual nitrites could be related to the antioxidant capacity of the phenolic compounds, anthocyanins and their hydrolysed products, and anthocyanidins contained in wine (Brewer, 2011; Kumar et al., 2015). Polyphenols can scavenge free radicals and contribute to the chelation of iron (Ferysiuk & Wójciak, 2020), which protects haem pigments (Riazi et al., 2016). At the same time, the lower pH values accelerate the processes of formation of nitric oxide derived from nitrite (Honikel, 2008), which is important for the formation of the colour of dry cured meat products and the anti-oxidant protection with regard to lipid and protein oxidation reactions (Skibsted, 2011). Furthermore, the lower residual nitrite quantities in the meat batter may also be related to the more intensive growth of gram-positive cocci in the wine-containing samples that contribute to the colour formation processes in fermented sausages (Ras et al., 2018).

3.2 Colour analysis

The colour characteristics of dry fermented sausages were affected ($p < 0.05$) by the addition of red wine (Table 2). In samples SD25 and SD50, statistically significant lower values were recorded for the colour lightness (L^*), ($p < 0.05$) according to control sample CSD. Similar results were reported by Sáyago-Ayerdi et al. (2009), who added freeze-dried powder of red grape pomace to poultry hamburgers as antioxidant. The oxidative browning of the red wine tannins was seen as a reason for the darker colour (Riazi et al., 2016). As regards the wine quantities added during the experiment, the concentrations used did not lead to any statistically discernible differences in the L^* values ($p > 0.05$) in samples SD25 and SD50 (Table 2). The measurement of the red colour component (a*), however, showed that not only the addition of wine but also the concentrations used led to statistically significant differences in the a* values in the following sequence: CSD>SD25>SD50. Lower a* and higher b^* values in chouriço colour after red wine addition were also reported by Patarata et al. (2020). They attributed these colour changes to the oxidation of the anthocyans in red wine.

Usually, the increase in b^* is related to undesirable oxidative changes in lipids and haem pigments that result in flaws in the colour of finished dry fermented sausages. In our study, however, the wine-containing samples (2.5% or 5% (v/w)) showed statistically significant lower b^* values compared to the b^* values measured in the sample formulated without the addition of wine (Table 2).

The highest colour hue values (*C (h)*) were obtained in the control sample, these values being statistically discernible from those obtained in the other two test samples (Table 2). Nevertheless, in the sensory evaluation, the control sample was perceived as paler compared to the wine-containing samples, perhaps due to

Table 2. Effect of Cabernet Sauvignon red wine on the colour characteristics of dry fermented sausages.

Sample	*L**	*a**	*b**	*C(h)*	*h*
Finished product					
CSD	43.76 ± 1.08 ^{y}	19.57 ± 0.29 ^{z}	9.88 ± 0.27 ^{y}	21.57 ± 0.63 ^{y}	26.77 ± 0.53 ^{y}
SD25	41.47 ± 1.08 ^{x}	16.65 ± 0.29 $^{y.}$	7.56 ± 0.27 $^{x.}$	18.69 ± 0.63 ^{x}	24.39 ± 0.53 ^{xy}
SD50	39.36 ± 1.08 ^{x}	14.97 ± 0.29 ^{x}	7.18 ± 0.27 ^{x}	19.13 ± 0.63 ^{x}	25.57 ± 0.63 ^{x}

Note: The results obtained have been presented as mean values ± standard deviation (n = 5); Values within the same column bearing different superscripts showed statistically significant differences ($p > 0.05$, Duncan's test). The following letter designations were used in relation to the wine added: $^{X,Y,Z.}$

its higher L^* values. Still, in spite of the higher a^* values, sample CSD showed a more significant shift from the desired red colour to a colour with more yellow tones, which was demonstrated by the higher *h* (hue) values (Table 2). Contrariwise, in the test samples formulated with wine, the colour was less saturated but there were fewer different colours. The comparison of the data obtained and the sensory evaluation of these samples drew the attention to the satisfactory sensory scores given to colour regardless of the lower a* and *C(h)* values.

3.3 Texture analysis

The TPA results on the effect of wine on the texture parameters and the proteolytic index of the dry fermented sausages have been presented in Table 3. The highest hardness values were measured in the wine-free sample, and the lowest in sample SD50 (Table 3). The degradation of the meat protein structure by proteolytic enzymes is a well-known process that contributes substantially to the improvement of the texture profile of dry fermented meat products (Toldra, 2002). The higher proteolytic index is related to more intense hydrolytic processes in meat proteins, the filament proteins that make up the myofibrils of the meat mass in particular (Ikonić et al., 2016). This structural degradation of the muscle proteins is connected with products of softer consistency, whereas less intense proteolysis results in products having a harder and rubbery consistency. The difference in the hardness values registered for samples SD25 and SD50 was not statistically discernible ($p > 0.05$) regardless of the higher degree of protein degradation in sample SD50, which can be seen in the proteolytic index results (Table 3). A probable reason for that was the lower moisture content measured in sample SD50 which was in a negative relationship with hardness (Spaziani et al., 2009).

In a sensory aspect, the TPA results indicated that the control samples would need a greater chewing force, which could be expected in view of the highest values measured for all three parameters (hardness, elasticity and cohesiveness) involved in the calculation of chewiness. The results of the TPA performed also corresponded to the sensory evaluation scores given to the consistency parameter of the dry fermented meat product made with or without the addition of wine.

3.4 Lipid oxidation analysis

The use of red wine contributed to a statistically significant lower content of hydroperoxides and malonaldehyde (MDA) in the finished sausages (samples SD25 and SD50), ($p < 0.05$), compared to the wine-free sample (Figure 1). These data correlate well with the antioxidant activity against free radicals reported for polyphenols (Nemzer et al., 2022). Slower lipid oxidation after addition of 5% red wine to the sausage batter was also observed by Feng et al. (2018), who, however, found accelerated lipid oxidation in the manufacture of a type of uncured frankfurter when the wine quantity was increased to 10% (v/w).

3.5 Microbial analysis

The addition of wine caused changes in the microbial population dynamics and contributed to the inhibition of the growth of hygiene indicator microorganisms. A proof of that was the statistically significant decrease in their number in the finished sausages in sample SD50 and, though to a lesser but still significant extent, in sample SD25 (Table 4). The highest microbial load was observed in the finished sample CSD products where fewer lactic acid bacteria and staphylococci and a larger number of enteropathogenic coliforms, enterococci, moulds and yeasts were enumerated compared to samples SD25 and SD50 ($p < 0.05$), (Table 4). It was interesting to observe the increase in the lactic acid population in samples SD25 and SD50, with the highest numbers registered in sample SD50, or 8.85 ± 0.03 log cfu/g, where the wine addition created a microecological niche for their greater proliferation.

3.6 Sensory characteristics

Gender differences in food preferences and consumption are well-known and probably most pronounced with regard to meat and meat products. Therefore, we performed the sensory tests with two different sensory panels composed on a gender basis. The analysis of the results obtained from both groups showed

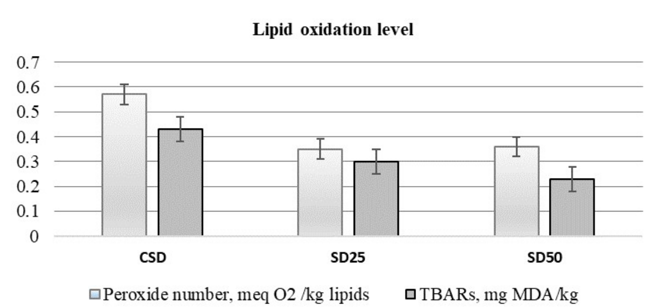

Figure 1. Effect of Cabernet Sauvignon red wine on the oxidative changes in the lipid fraction of dry fermented sausages.

Table 3. Effect of Cabernet Sauvignon red wine on the texture analysis (TPA) parameters of dry fermented sausages.

Parameter	Sample		
	CSD	SD25	SD50
Hardness, N	76.82 ± 1.17^{x}	68.65 ± 2.50^{y}	59.16 ± 1.53^{z}
Elasticity	0.62 ± 0.14 ^{x}	0.62 ± 0.02^{x}	0.61 ± 0.08 ^{x}
Cohesiveness	0.45 ± 0.03^{x}	0.45 ± 0.03^{x}	0.44 ± 0.07 ^{x}
Chewiness, N	20.13 ± 0.88 ^{y}	18.15 ± 0.71 ^{x,y}	16.09 ± 0.86 ^{x}
Degree of hydrolysis, %	12.55 ± 1.06 ^{x}	15.90 ± 1.18 ^{y}	18.32 ± 0.95 ^{z}

$^{x-z}$ – values within the same row bearing different superscripts showed statistically significant differences ($p > 0.05$).

fewer deviations in the sensory scores given by the women, along with some differences between them, compared to the scores given by the men's panel (Table 5). On the whole, the results from the sensory analysis made on the dry fermented sausage samples showed that the wine addition had a considerable effect on the development of the colour characteristics, aroma and taste properties and consistency of these products (Table 5). According to the men's sensory panel, the addition of 25 ml Cabernet Sauvignon led to higher and statistically discernible scores ($p < 0.05$) for appearance, colour and consistency compared to the control sample. However, the increase in the wine quantity from 25 to 50 ml per kg of meat raw materials did not result in any definite trend towards higher sensory scores except for the consistency parameter, which was awarded a statistically significant higher score for sample SD50 compared to samples CSD and SD25.

In the sensory evaluation performed by the women's group, sample SD25 also received higher scores both for the above sensory parameters and for the taste and aroma of the finished dry fermented sausage compared to the control sample. The increase in the wine quantity added from 25 to 50 ml per kg of meat raw materials did not cause any significant changes in the sensory

Table 4. Effect of Cabernet Sauvignon red wine on the different microbial groups in dry fermented sausages.

Parameter	Sample		
	CSD	SD25	SD50
Sausage batter			
TVC, *log cfu/g*	5.24 ± 0.50^{x}	6.89 ± 0.60^{x}	6.50 ± 0.59^{x}
LAB, *log cfu/g*	5.56 ± 0.31^{x}	5.92 ± 0.19^{x}	6.09 ± 0.15^{x}
Staphylococci and micrococci, *log cfu/g*	5.52 ± 0.27^{x}	5.74 ± 0.15^{x}	5.89 ± 0.17^{x}
Enterococci, *log cfu/g*	3.10 ± 0.87^{x}	3.23 ± 0.67^{x}	3.00 ± 0.85^{x}
Coliforms at 37 °C, *log cfu/g*	4.26 ± 0.65^{x}	4.49 ± 0.65^{x}	4.90 ± 0.80^{x}
Finished products			
TVC, *log cfu/g*	11.4 ± 0.19^{y}	8.79 ± 0.16^{x}	8.67 ± 0.19^{x}
LAB, *log cfu/g*	7.61 ± 0.04^{x}	8.2 ± 0.02^{y}	8.85 ± 0.03^{z}
Staphylococci and micrococci, *log cfu/g*	5.45 ± 0.07^{x}	5.52 ± 0.07^{xy}	5.75 ± 0.07^{y}
Enterococci, *log cfu/g*	8.37 ± 0.07^{x}	6.07 ± 0.03^{y}	6.09 ± 0.07^{z}
Coliforms at 37°, *log cfu/g*	3.57 ± 0.26^{x}	3.40 ± 0.30^{x}	3.44 ± 0.5^{x}
Coliforms at 44 °C, *log cfu/g*	2.21 ± 0.08^{y}	2.05 ± 0.08^{xy}	1.85 ± 0.08^{x}
Moulds and yeasts, *log cfu/g*	2.98 ± 0.25^{z}	2.27 ± 0.12^{y}	1.48 ± 0.05^{x}
Salmonella sp.		*not found in 25 g of the product*	
Listeria monocytogenes		*not found in 25 g of the product*	

Note: The results obtained have been presented as mean values ± standard deviation (n = 5); Values within the same row bearing different superscripts showed statistically significant differences ($p > 0.05$, Duncan's test). The following letter designations were used in relation to the wine added: ^{X,Y,Z}.

Table 5. Effect of Cabernet Sauvignon red wine on the sensory characteristics of dry fermented sausages.

Parameter	Sample		
	CSD	SD25	SD50
MEN			
Appearance	$7.42 \pm 0.50^{x,y}$	8.00 ± 0.24^{y}	6.55 ± 0.49^{x}
Colour	7.95 ± 0.36^{x}	8.87 ± 0.29^{y}	7.34 ± 0.28^{x}
Consistency	6.60 ± 0.43^{x}	7.60 ± 0.15^{y}	8.55 ± 0.30^{z}
Taste	6.87 ± 0.27^{x}	6.94 ± 0.25^{x}	6.36 ± 0.35^{x}
Aroma	7.00 ± 0.87^{x}	7.30 ± 0.67^{x}	7.13 ± 0.85^{x}
Aftertaste	8.26 ± 0.35^{x}	8.49 ± 0.35^{x}	7.90 ± 0.55^{x}
Total score	7.47 ± 0.26^{x}	8.04 ± 0.23^{y}	$7.70 \pm 0.21^{x,y}$
WOMEN			
Appearance	7.55 ± 0.25^{y}	8.57 ± 0.17^{x}	8.45 ± 0.10^{x}
Colour	8.33 ± 0.07^{x}	8.72 ± 0.10^{y}	8.20 ± 0.28^{x}
Consistency	8.05 ± 0.22^{x}	8.45 ± 0.15^{y}	8.90 ± 0.30^{y}
Taste	7.60 ± 0.16^{x}	8.09 ± 0.26^{y}	$7.94 \pm 0.15^{x,y}$
Aroma	7.04 ± 0.56^{x}	8.32 ± 0.33^{y}	8.84 ± 0.40^{y}
Aftertaste	8.36 ± 0.27^{x}	8.38 ± 0.22^{x}	8.76 ± 0.60^{x}
Total score	7.73 ± 0.21^{x}	8.37 ± 0.23^{y}	$7.92 \pm 0.23^{x,y}$

Note: The results obtained have been presented as mean values ± standard deviation (n = 5); Values within the same row bearing different superscripts showed statistically significant differences ($p > 0.05$, Duncan's test). The following letter designations were used in relation to the wine added: ^{X,Y,Z} .

scores given; even, a significant decrease in the colour perception was recorded compared to the control sample (Table 5).

Regarding the total sensory score of the samples studied, the sample that was most preferred by both panels was the 25 ml wine sample (SD25). The explanation of the reasons for the lower scores given to sample SD50 compared to sample SD25 elicited the following flaws that had led to the reduced sensory scores for this sample: darker colour with occurrence of iridescence together with a more pronounced spicy taste. Future studies considering temporal sensory methods as TDS and TCATA (Paglarini et al., 2020) to assess the main drivers of liking and disliking of dry sausages would be an interesting strategy to describe the perception involved during their consumption.

4 Conclusion

The addition of 25 ml and 50 mL *Cabernet Sauvignon* red wine along with the starter culture strains used contributed to an enhanced texture profile of the dry fermented sausages as a result of the accelerated rate of proteolytic degradation of meat proteins. Furthermore, red wine contributed to the management of the selection and growth dynamics of the desired microbial populations during the fermentation and ripening of the meat batter, simultaneously creating a technological possibility of reducing the residual nitrite quantity in the finished product. The present study demonstrated the considerable technical and functional potential of red wine for the manufacture of dry fermented sausages innovated by use of traditional ingredients and having improved sensory properties, microbiological characteristics and chemical safety with regard to residual nitrites and the risk of nitrosamine formation associated with them.

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