Effect of chard powder on colour and aroma formation in cooked sausages

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Abstract. The use of nitrate-containing vegetable powders instead of sodium nitrite in meat products requires changes in technological production parameters in order to obtain traditional organoleptic characteristics in the finished products. The aim of this work was to study the effect of chard powder on colour and aroma formation in cooked sausages. Cooked sausage samples were: control with nitrite curing mixture; type 1 sausages with chard powder and ascorbic acid; type 2 sausages with chard powder and sodium ascorbate. To transform nitrate ions contained in the vegetable chard powder to nitrite ions using a denitrifying culture, preliminary thermal treatments were used: 30 and 60 min at 40±2°C, after which the sausages were cooked until a temperature of 72±2°C was achieved. The sausages were stored for 40 days at 0-6°C. When sausage meat was initially held at 40°C for 60 min, a homogenous pink colour formed in the sausages with the vegetable powder. The indicators of lightness, redness and yellowness in cooked sausages as well as the indicators of instrumental odour assessment did not differ significantly (p>0.05). The indicators of colour stability during storage were 1.1-3.0% higher in the sausages with the chard powder compared to the control. The mass fraction of sodium nitrite in the experimental sausages was 2.0-2.2 higher than in the control (p>0.05). As a result of cooked sausage storage, the differences in the sodium nitrite content in the control and types 1 and 2 sausages were similar. During storage, the mass fraction of sodium nitrite decreased in types 1 and 2 sausages by 55.6 and 54.8%, respectively (p<0.05). Cooked sausages with the chard powder contained 2.1-2.4 times more sodium nitrate than did control sausages (p<0.05). However, all tested sausage samples complied with legislative requirements in terms of their sodium nitrite and nitrate levels.

1. Introduction

The food additive sodium nitrite E250 is used in the meat industry as a colour fixing agent, and due to its multiple functions (colour formation, preservative and antioxidative abilities, participation in aroma formation), it is practically irreplaceable in meat product manufacture. Taking into consideration the negative effect of excessive amounts of sodium nitrite on human health, doses of this additive in meat product formulations are strictly limited by existing legislation. However, up to now, there are no scientific data on the negative effect on human health of meat products with sodium nitrite, even at increased (by 3-4 times) concentrations. In addition, methods for utilising sodium nitrite in health care to induce improvement in cardiovascular system function are known [1]. However, taking into consideration the negative consumer attitude to products with food additives, the use of alternative sodium nitrite sources is topical. These sources include vegetable powders that contain nitrate, which is transformed into nitrite by the effect of denitrifying bacteria, and nitrite then takes part in the
process of colour formation [2-5]. This technology exists in different countries and is interesting in terms of processing vegetables with excessive levels of nitrate and their further use.

For more complete expenditure of sodium nitrite on colour formation and, consequently, maximum effect of its use, on one hand, and the minimum residual content in a finished product, on the other hand, it is possible to use ascorbic acid (E300) and its salts (E301). Ascorbic acid occupies a special place among antioxidants. It is not only a means for retardation of the oxidative process in meat systems but also is an important auxiliary factor for colour formation with sodium nitrite participation. When using nitrate-containing components, it is necessary to use several technological steps, e.g., a preliminary stage of thermal treatment, denitrifying cultures that are necessary for full transformation of nitrate ions into nitrite ions, correct course of the colour formation process and assurance of the minimal residual sodium nitrite content. In this connection, the aim of this work was to study the effect of nitrate-containing chard powder on colour formation in cooked sausages made without the use of the colour fixing agent, sodium nitrite.

2. Materials and Methods
Cooked sausages contained the main raw materials, beef and pork, plus water, salt, spices, sugar and food-grade phosphates. The control sausages were made using traditional technology with a nitrite curing mixture (the mass fraction of sodium nitrite in the mixture was 0.6%) and sodium ascorbate. In type 1 sausages, sodium nitrite and sodium ascorbate were replaced with vegetable chard powder (0.26%) with a sodium nitrate level of 3.0%, ascorbic acid and a denitrifying culture containing Pediciococcus pentosaceus, Staphylococcus carnosus, Staphylococcus xylosus, Lactobacillus sake Deb. Hansen. Type 2 sausages differed from type 1 sausages by the use of sodium ascorbate instead of ascorbic acid. The vegetable chard powder was additionally dissolved in a small amount of water with constant mixing before adding into ground meat. The denitrifying culture with a small amount of water was added to meat raw materials with constant mixing. The temperature of prepared ground meat was not higher than 12°C.

To transform the nitrate ions occurring in the vegetable chard powder into nitrite ions with necessary participation of the denitrifying culture, preliminary thermal treatments at 40±2°C for 30 or 60 min was used. Then, sausages were cooked at 80±2°C until they achieved 72±2°C, and cooled to 4±2°C. After that, sausages were stored for 40 days at 0-6°C and relative humidity of 75-78%.

The odour visual fingerprints were determined using a VOCmeter device (electronic nose). Three specimens were taken from each test sausage sample for analysis on the VOCmeter device. To prepare a specimen, a test sausage sample (excluding the superficial layers) was minced and the necessary quantity was placed in a special glass container (vial). Each vial was tightly closed and incubated. After incubation, a needle was injected into each vial for automatic sampling of the analysed gas, which entered the VOC meter device. The readings of the MOS 1-4 sensors were used for visualisation of the experimental results.

Colour characteristics of the sausages were measured in the CIELab system using the spectrocolorimeter “Spectroton” with simultaneous determination of reflection coefficients at 24 fixed wavelengths located in 13 nm intervals in the visible spectral range from 380 to 720 nm with the measurement results mathematically processed using a microprocessor controller built into the measurement unit.

To detect colour stability during storage, a criterion for colour stability (U, %) was used. Colour stability was calculated according to the following equation:

$$U = \left(1 - \frac{|L_1 - L_2|}{3L_1} + \frac{|a_1 - a_2|}{3a_1} + \frac{|b_1 - b_2|}{3b_1}\right) \times 100$$

where: $L_1, L_2$ – values of lightness before and after storage;
$a_1, a_2$ – values of redness before and after storage;
$b_1, b_2$ – values of yellowness before and after storage.
The mass fraction of sodium nitrite was determined by the method based on the reaction of nitrite with n-(1-naphthyl) ethylenediamine dihydrochloride and sulphanilamide in a protein-free filtrate and photocolorimetric determination of colour intensity.

The mass fraction of sodium nitrate was determined by the method based on nitrate reduction to nitrite using a cadmium column, photometric measurement of the intensity of colour that was formed in the reaction of sulphanilamide and n-(1-naphthyl)ethylenediamine dihydrochloride with nitrite, determination of an amount of the latter and its conversion to nitrate minus nitrite in the sausage.

3. Results and Discussion
To transform nitrate ions to nitrite ions, the presence of the denitrifying culture for a specified temperature and duration is necessary. The reaction of colour formation is activated during product heating at a temperature higher than 30°C and proceeds up to the product achieving 50°C. With the further increase in temperature up to 60-70°C, nitrosomyoglobin and nitrosohaemoglobin lose their protein partly due to denaturation and change into nitrosomyochromogen and nitrosohaemochromogen that impart a red colour to meat. When nitrite ions are absent, the colour reaction proceeds to the development of metmyoglobin, and the finished product will have a grey colour after thermal treatment, which is unacceptable for the most types of traditional meat products and sausages.

These mechanisms for colour formation were taken into account upon optimisation of the conditions of vegetable powder transformation during holding in the thermal chamber.

Therefore, sausage meat was held at a temperature of 40°C for 30 min or 60 min in order to achieve the uniform colour of cooked sausages. Holding for 30 min was insufficient to achieve a uniform pink colour on the cross-section surfaces of type 2 sausages, which were characterised by the presence of grey spots. In contrast to the use of the vegetable chard powder with sodium ascorbate, its combination with ascorbic acid in type 1 sausages provided a uniform colour after just 30 min at 40°C. The control sausages were characterised by a uniform pink colour.

Holding sausages for 60 min at 40°C produced formation of a uniform colour in sausage of both types 1 and 2 (with the vegetable powder). Thus, an additional holding for 60 min at 40°C is necessary for nitrate transformation when manufacturing cooked sausages with chard powder.

After achieving a temperature of 72±2°C, all sausages attained the characteristic, traditional colour of cooked sausages. Based on the performed research, the additional preliminary stage of thermal treatment was established for cooked sausages to ensure transformation of nitrate ions to nitrite ions with participation of the denitrifying culture: not more than 60 min at 40°C.

As a result of the organoleptic assessment, it was established that during storage, all sausages had similar and acceptable consumer characteristics traditional for these types of meat products.

The instrumental assessment of colour characteristics suggested an absence of significant differences in lightness, redness and yellowness of the control cooked sausage samples and sausages of types 1 and 2 (table 1).

Colour stability in cooked sausages was 97.6-99.4% after 20 days of storage and 95.2-98.2% after 40 days of storage. With that, the experimental sausages were superior to the control in terms of colour stability (by 1.1 and 3.0% for types 1 and 2, respectively) after 40 days of storage.
**Table 1.** Colour characteristics of sausages.

| Sausage samples     | Colour characteristics, colour units | Colour stability during storage, % |
|---------------------|--------------------------------------|-----------------------------------|
|                     | L-lightness | a-redness | b-yellowness |                                      |
| 1 day               |             |           |              |                                      |
| Control             | 60.7±1.3    | 10.2±0.6  | 11.0±0.8     | -                                    |
| Sausage type 1      | 60.1±1.8    | 10.9±0.7  | 12.3±0.4     | -                                    |
| Sausage type 2      | 59.5±1.2    | 11.3±0.6  | 12.0±0.6     | -                                    |
| 10 days             |             |           |              |                                      |
| Control             | 60.8±0.8    | 10.0±0.2  | 11.2±0.4     | 98.8                                 |
| Sausage type 1      | 61.1±1.1    | 10.7±0.4  | 12.1±0.5     | 99.4                                 |
| Sausage type 2      | 60.8±1.3    | 11.0±0.4  | 12.4±0.6     | 98.7                                 |
| 20 days             |             |           |              |                                      |
| Control             | 60.6±1.3    | 10.2±0.5  | 11.8±0.6     | 97.6                                 |
| Sausage type 1      | 60.6±0.5    | 10.6±0.5  | 12.3±0.3     | 99.4                                 |
| Sausage type 2      | 59.7±1.7    | 11.2±0.7  | 12.4±0.5     | 98.7                                 |
| 40 days             |             |           |              |                                      |
| Control             | 60.9±1.5    | 9.0±0.5   | 11.3±0.4     | 95.2                                 |
| Sausage type 1      | 60.9±1.1    | 10.7±0.4  | 13.3±0.5     | 96.3                                 |
| Sausage type 2      | 60.5±1.1    | 10.8±0.3  | 11.7±0.5     | 98.2                                 |

During storage, all sausages had similar consumer characteristics, traditional for this type of meat product. For more reliable odour assessment, this was assessed instrumentally. The results of the multisensory investigations of cooked sausages are given in figure 1.

The readings of the sensors M1-M4 that characterise the content of aroma of volatile components in the gas phase of the sausage samples did not have significant differences.

Taking into consideration that the sodium nitrite content in meat products is strictly regulated, we determined the mass fraction of sodium nitrite in sausages during storage (table 2).
Table 2. Sodium nitrite content in cooked sausages

| Cooked sausages | Mass fraction of sodium nitrite, % |
|-----------------|-----------------------------------|
|                 | 1 day                              |
| Control         | 0.00164±0.00020                    |
| Sausage type 1  | 0.00360±0.00032                    |
| Sausage type 2  | 0.00336±0.00036                    |
|                 | 20 days                            |
| Control         | 0.00160±0.00015                    |
| Sausage type 1  | 0.00308±0.00024                    |
| Sausage type 2  | 0.00307±0.00026                    |
|                 | 40 days                            |
| Control         | 0.00152±0.00009                    |
| Sausage type 1  | 0.00160±0.00018                    |
| Sausage type 2  | 0.00152±0.00012                    |

During storage, all cooked sausage samples complied with Russian legislative requirements for sodium nitrite and nitrate content (not more than 0.005 and 0.025%, respectively).

The mass fraction of sodium nitrite in sausage types 1 and 2 in the process of storage decreased by 55.6 and 54.8% (p<0.05), respectively, after 40 days. The nitrite content in the control did not change during sausage storage (p>0.05).

After one day of cooked sausage storage, the mass fraction of sodium nitrite in the experimental sausages was 2.0-2.2 times higher than in the control (p<0.05). However, during storage, the mass fraction of sodium nitrite in all analysed sausages became similar, which, apparently, can be explained by transformation of formed nitrogen oxide to nitrate under the impact of oxygen (table 3). The sodium nitrate content in the experimental sausages was higher compared to in the control by 2.4 and 2.1 times for types 1 and 2 sausages, respectively (p<0.05).

Table 3. Sodium nitrate content in cooked sausages.

| Cooked sausage | Mass fraction of sodium nitrate, % |
|----------------|-----------------------------------|
| Control        | 0.00208±0.00021                   |
| Sausage type 1 | 0.00506±0.00042                   |
| Sausage type 2 | 0.00443±0.00032                   |

4. Conclusion

Based on the results of the performed investigations, we established a regime for the preliminary thermal treatment of cooked sausages to transform nitrate ions present in the vegetable chard powder to nitrite ions with participation of an added denitrifying culture: not less than 60 min at 40 °C. During storage, the control and experimental sausages had similar and acceptable consumer characteristics traditional for these types of meat products, which was confirmed by organoleptic assessment and instrumental analysis of colour and odour after production and during storage. The residual nitrite and nitrate content in the sausages with the natural, vegetable source of nitrate complied with legislative requirements.

References

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