Influence of smoking intensity on the formation of white efflorescences on the surface of dry fermented sausages

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The formation of efflorescences on the surface of dry fermented sausages is a common quality problem. In this study, we investigated the influence of smoking intensity on the formation of efflorescences. Therefore, sausages were produced according to a standard recipe, applying 4 different smoking intensities (0, 30, 60 and 120 min). The amount of efflorescences was quantified using two visual methods, namely image analyses and sensory evaluation of the visual appearance, during 8 weeks of storage (0 / 2/ 4 / 6 and 8 weeks). The measurements revealed that the sausages that are not (0 min) or only little smoked (30 min) showed high amounts of efflorescences at the end of storage (31.6 %; 24.6 % respectively). In contrast, high smoking intensities lowered the formation of efflorescences (60 min: 7.5 %; 120 min: 3.4 %) during storage. This effect can be explained by minerals, phenolic compounds, and organic acids present in the smoke. They are deposited on the sausage surface and modify the physical and chemical behavior of efflorescence causing components such as salt complexes of the crystalline magnesium, lactate and creatine.

Key Words: white blooming; deposits; crystallization; smoking; fermented sausages; efflorescences

I. INTRODUCTION

Since modified atmosphere packaging is commonly used for the packaging of dry fermented sausages in the middle of the 80th efflorescence formation is one of the main quality problems [1, 2]. The efflorescence formation is a visual quality issue that is often wrongly associated with microbial spoilage by the consumers. Therefore such products are rejected and lead to high financial losses for the meat processing industry.

Regarding to the chemical composition and physical behavior the efflorescences can be divided into two groups. Type I efflorescences are reversible and disappear under specific conditions and type II efflorescences are irreversible and therefore imply a larger problem. Chemically the type I efflorescences consist of mainly disodium hydrogen phosphate heptahydrate [3, 4]. Chemical composition of type II efflorescences can be subdivided regarding to the ripening conditions. If the sausages are fatly ripened with a high pH drop efflorescences mainly consist of hardly soluble magnesium lactate. If a slow ripening is applied type II efflorescences consist of mainly creatine monohydrate [5, 6].

The temperature is one of the key factors for inducing the formation of reversible efflorescences. The reduction of temperature during storage lowers the solubility of disodium hydrogen phosphate heptahydrate and leads to the crystallization [7]. As well as the reducing temperature, the lowering of relative humidity is another influencing factor that causes the crystallization of type I efflorescences [8]. This takes place after opening of the packages which leads to changes of humidity. Both effects are reversible and therefore rising temperatures or humidities resolubilize the formed crystals and lead to disappearance of the efflorescences.

The factors that are inducing type II efflorescences as well as the mechanism are not yet known.

The aim of this study is the investigation of the influence of smoking intensity on the formation of efflorescences. It is assumed that different ingredients consisted in the smoke [9, 10] could modify the composition of the sausage surface. This could prevent the diffusion of components causing efflorescences to the sausage surface as well as the crystallization on the surface and therefore reduce the amount of efflorescences.

II. MATERIALS AND METHODS

II.1 Sausage production

The meat and fat that were used for sausage production were purchased from a local wholesale (MEGA, Stuttgart, Germany). The spices and starter cultures were gratefully provided by Gewürzmüller (Korntal-

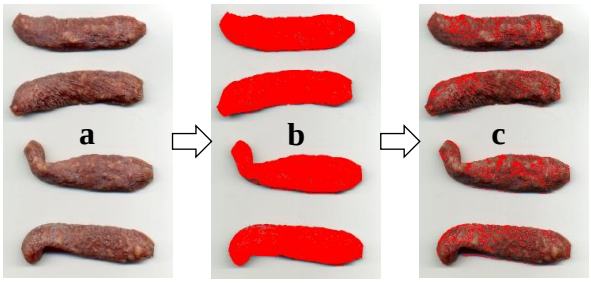
Münchingen, Germany). Fist-sized pork shoulder pieces (45 %) and pork back fat (20 %) were frozen and chopped in a vacuum bowl chopper Type K64 DC (Seydelmann, Aalen, Germany) until a particle size of around 3 mm was reached. Starter cultures (LS 25) (0.5 g/kg), ascorbic acid (0.5 g/kg), white pepper (3.0 g/kg) and dextrose (5 g/kg) were added to the chopped meat. Next, minced (3 mm) pork shoulder (35 %) was added to the mixture of meat and spices. Finally nitrite curing salt (28.0 g/kg) was added and the meat mass was mixed until a proper binding was reached. The sausage mass was filled into collagen casings NDC-D Cal. 21 mm (Naturin Viscofan GmbH, Weinheim, Germany) by using a vacuum filler VF 80/165-1 (Handtmann, Biberach, Germany). Within the first 24 h ripening took place at 95 % relative humidity in the Air-Master UK-1800 BE climatic chamber (Reich, Urbach, Germany). Afterwards, the sausages were randomly split into 4 groups. The groups were smoked in the digtronic 4 smoking chamber (NESS, Remshalden, Deutschland) by applying different smoking times (0, 30, 60 and 120 min). Afterwards, the sausages were dried until a weight loss of 42.5 % was reached in the climatic chamber. The sausages were packed under modified atmosphere (80 % CO_2 and 20 % N_2) Protadur C20 (Westfalen AG, Münster, Germany) into SL 170 × 220 PA/PE 90 MY vacuum bags (MEGA, Stuttgart, Germany) using C 400 packaging machine (Multivac, Wolfertschweden, Germany). Sausages were stored at 4 °C until the analyses took place after 0 / 2 / 4 / 6 and 8 weeks of storage.

II.2 Quantification of efflorescences

To quantify the amount of efflorescences 2 different optical methods were used after 0 / 2 / 4 / 6 and 8 weeks of storage. Visual sensory was performed by using 8 sausages of each smoking intensity performing a double determination. The sausages were hanged into corked up carafes (item number 902.797.19, IKEA, Sindelfingen, Germany) for 24 hours at 13 °C to induce efflorescence formation. The humidity was set to 68 % by adding 100 ml of 28.52 % calcium chloride solution at the bottom of the carafes. After efflorescence formation was induced 20 trained assessors rated the amount of efflorescences on a 10 point scale from 0 (no efflorescences) to 10 (many efflorescences) by visual examination.

The second optical method to quantify the amount of efflorescences was an image analyses. Therefore, the surface of the previously used sausages (visual sensory) were digitalized. This was done by split them into half and image them with the Perfection V100 Photo scanner (Epson, Suwa, Nagano, Japan). The software ImageJ (NIH, Methesda, Maryland, USA) was used to calculate the percentage content of efflorescences on the surface. Therefore first of all the total surface area was measured by adjusting the color threshold range (hue 0 – 255, saturation 61 – 255 and brightness 0 – 204). Next the area of efflorescences was determined by using a specific color threshold range (0 – 255, saturation 22 – 114 and brightness 61 – 181). The approach for determing these values is shown in **Figure 1**. These two values were then used to calculate the percentage content of efflorescences on the surface of the sausages.

Figure 1: Procedure of determining the percentage content of efflorescences on sausage surface. a: original image; b: total surface area; c: area of efflorescences



II.3 Statistical Analyses

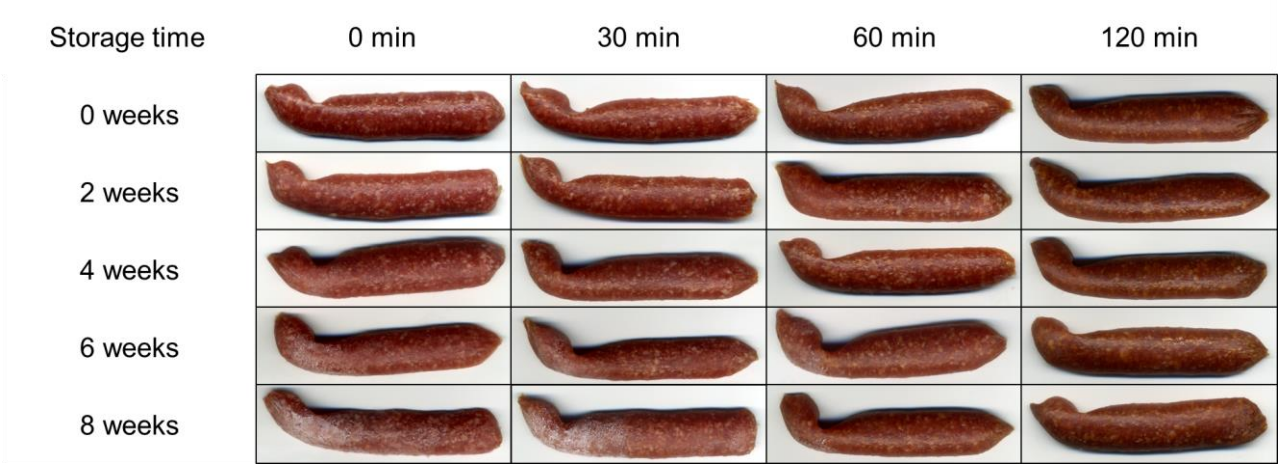
Statistical analyses were carried out with SAS (SAS Institute, Cary, North Carolina, USA). The analysis of variance was done by the Tukey test to indicate significant ($p < 0.05$) changes between the different smoking intensities. Furthermore the correlation coefficient between visual sensory and image analyses were determined by using the Pearson product-moment correlation of Sigmaplot 12.5 (Systat Software Inc., Erkrath, Germany).

III. RESULTS AND DISCUSSION

The images of the different smoking intensities are shown exemplarily in **Figure 2**. It can be seen that the color changes with increasing smoking intensity from mainly red (0 min) to a red brownish color (120 min). These images were used for the image analyses. The results of the image analyses can be found in **Figure 3**.

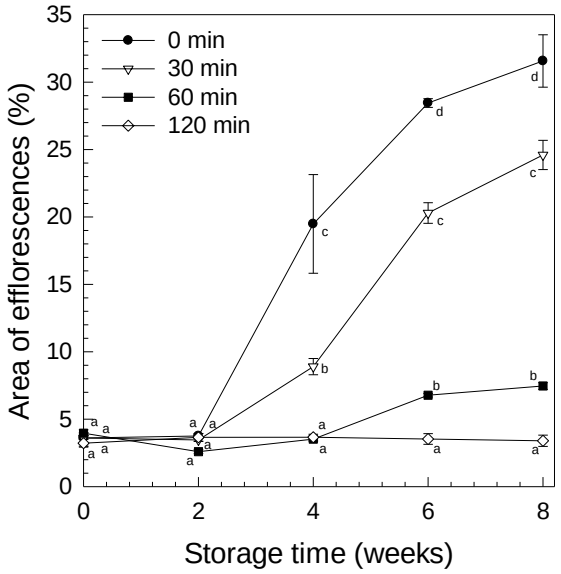
The image analyses revealed that without smoking (0 min) the area of efflorescences initially rises significantly after 2 weeks of storage up to 31.6 %

Figure 2: Images of the sausage surface during storage at different smoke intensities.



(8 weeks storage). The maximum area of efflorescences at the end of storage decreased with an increasing smoking intensity. When applying 30, 60 and 120 min of smoking the efflorescence area lowered to 24.6, 7.5, and 3.4 %, respectively. The area of efflorescences of 30 min smoking intensity began to rise at the same moment when efflorescences were formed on the unsmoked samples. The area of efflorescences for 60 min of smoking increased after 4 weeks of storage. The highest smoking intensity (120 min) did not show any significant formation of efflorescences during the investigated storage time of 8 weeks.

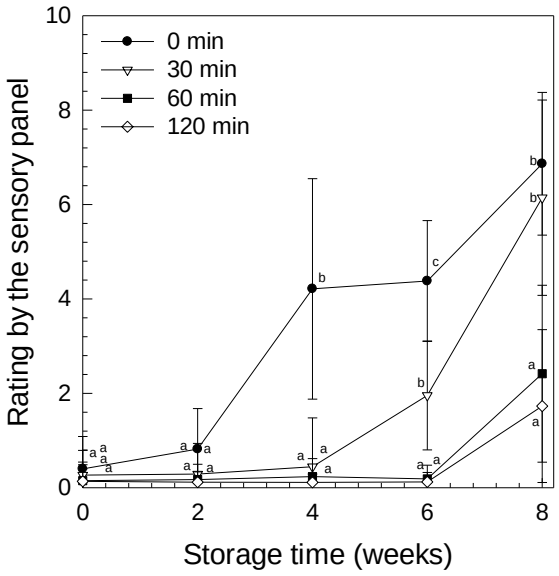
Figure 3: Percentage content of efflorescences on the surface calculated by image analyses. a - d: indicating significant ($p < 0.05$) differences between the different smoking intensities.



The results of the sensory analyses are shown in **Figure 4**. The results showed a similar behavior as already seen for the image analyses. High smoking intensities (60 and 120 min) prevented the formation of efflorescences during the investigated storage time. No smoking (0 min) and low smoking intensity (30 min) lead to high amounts of efflorescences on the sausage surface. When comparing the two different methods a high correlation was found between these. The high correlation coefficients of 0 min (0.963), 30 min (0.875), 60 min (0.681) and 120 min (0.633) smoking intensity showed that the different methods lead to similar results. In further studies

only one of both methods could therefore be used to generate significant results.

Figure 4: Results of the sensory analyses on a scale from 0 – 10 (0: no efflorescences; 10: many efflorescences) with a panel of 20 assessors. a - c: indicating significant ($p < 0.05$) differences between the different smoking intensities.



The results showed that the suggested hypotheses is confirmed, that high smoking intensities reduce the amount of efflorescences. This effect could be explained by modification of the sausage surface due to different physical and chemical properties of the applied smoke. Smoke contains a high amount of phenolic compounds, organic acids and minerals that are deposited on the surface [9]. The phenolic compounds could act as complexing agents [11] and therefore prevent the efflorescence causing components from crystallizing on the surface. The organic acids could modify the pH value of the sausage surface. As shown by Kühne et al. the formation of efflorescences is highly dependent of the pH [12]. Therefore the crystallization could be prevented due to a higher solubility of the components causing efflorescences. Furthermore, minerals that are deposited on the surface could act as an osmotic barrier that prevents the diffusion of the efflorescence causing components to the surface.

IV. CONCLUSION

The results have shown that the application of high smoking intensities prevents the formation of efflorescences. Due to the fact that there are also dry fermented sausages on the market that are produced without smoking further possibilities to inhibit efflorescence formation should be studied. The application of complexing agents could therefore be investigated. Furthermore the influence of the raw material and the sausage casing should be studied.

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