OPTICAL ANALYSES OF EFFLORESCENCE FORMATION ON DRY FERMENTED SAUSAGE SURFACE – COMPARISON OF SENSORY AND IMAGE ANALYSES

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The influence of fast ripening and drying of sausages was investigated and compared to a normal ripening and drying. Furthermore optical and image analyses were carried out to quantify the content of efflorescences. Normal ripening and drying lead to initial efflorescence formation after 2 weeks of storage. Fast ripened and dried sausages however formed first time efflorescences after 4 weeks. Differences were explained by the physical changings of the outermost layer during fast drying. Image and visual analyses were established as comparable methods to quantify the amount of efflorescences. Both methods are highly correlating (0.99) and therefore lead to equivalent results.

Key Words: white blooming, deposits, crystallization

I.   INTRODUCTION

Since the middle of the 80th modified atmosphere packaging is applied to ensure shelf life of meat products such as dry fermented sausages [1, 2]. Since the packaging under modified atmosphere white efflorescences were found during storage as covering on the surface of dry fermented sausages. Efflorescences are wrongly associated with microbial spoilage and therefore rejected by the consumer. This leads to high financial declines for the meat processing industry.

Efflorescences can be divided into reversible (type I) and irreversible (type II) coverings. Chemical analyses of type I efflorescences revealed that they consist of mainly disodium hydrogen phosphate heptahydrate [3, 4]. Composition of irreversible efflorescences depends on the ripening speed. When sausages are fast ripened the efflorescences consist mainly of hardly soluble magnesium lactate and when sausages are slowly ripened the main component of the efflorescences is creatine monohydrate [5, 6].

Temperature is one of the key factor for inducing the formation of type I efflorescences. When the temperature reduces during storage the solubility of disodium hydrogen phosphate heptahydrate salt deteriorates and the crystallization starts [7]. Reduction of humidity is another influencing factor that causes the crystallization of type I efflorescences [8]. This takes place when packed sausages are opened and therefore humidity reduces.

The mechanism of formation of type II efflorescences is not known.

The aim of this study is the investigation of the influence of a fast drying compared to normal drying on the formation of efflorescences. Furthermore sensory and image analyses are compared regarding to the quantification of efflorescences.

II.   MATERIALS AND METHODS

II.1 Sausage production
Meat and fat that were used for sausage production were purchased from a local wholesale (MEGA, Stuttgart, Germany). The spices and starter cultures were acquired from a spice trader (Gewürzmüller, Korntal-Münchingen, Germany). Frozen pork meat (45 %) and pork back fat (20 %) were chopped in a vacuum bowl chopper Type K64 DC (Seydelmann, Aalen, Germany). Starter cultures (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. Pork shoulder (35 %) was minced to 3 mm with a meat grinder Type WD 114 (Seydelmann, Aalen, Germany) and added to the mixture of meat and spices. Last nitrite curing salt (28.0 g/kg) was added and the sausage batter 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). Normal sausage ripening and drying took place in the climatic chamber Air Master UK-1800 BE (Reich, Urbach, Germany) within 102 hours. The fast ripening and drying took place in the climatic chamber Unigar 1800 BE (Ness & Co. GmbH, Remshalden, Germany) within 91 hours. For both ripening and drying conditions, a final weight loss of 42.5 % was achieved. Two pair of sausages were packed under controlled atmosphere (80 % CO_2 and 20 % N_2) Protadur C20 (Westfalen AG, Münster, Germany) into vacuum bags SL 170 × 220 PA/PE 90 MY (MEGA, Stuttgart, Germany) by using the vacuum station C 400 (Multivac, Wolfertschweden, Germany). Sausages were stored at 4 °C until the optical analyses took place.

II.2 Optical analyses
Optical analyses were divided into a visual sensory and image analyses. Analyses took place after 0 / 1 / 2 / 4 / 6 and 8 weeks of storage. Therefore 4 sausages of each drying condition were taken out of the vacuum bags and hanged into desiccator glasses (Ruhrglas, Essen, Germany) for 24 hours at 13 °C. The humidity of the glasses was set to 68 % by adding 100 ml of 28.52 % calcium chloride solution at the bottom of the desiccator. A panel of 20 trained assessors rated the content of efflorescences on a scale from 0 (no efflorescences) to 10 (many efflorescences) by optical examination of the sausages in the glasses. The sensory analyses took place in double.

Afterwards images from the surface of each of the 8 sausages were taken. Therefore the sausages were split into half and the surface was imaged with the scanner Perfection V100 Photo (Epson, Suwa, Nagano, Japan). The percentage content of efflorescences on the surface was calculated by using the software ImageJ (NIH, Methesda, Maryland, USA). The area of total surface was determined by setting the color threshold to a range of hue 0 – 255, saturation 61 – 255 and brightness 0 – 204. Efflorescence area was measured by setting the color threshold range to hue 0 – 255, saturation 22 – 114 and brightness 61 – 181. In Figure 1 the approach of determining the total area and the area of efflorescences is shown. Out of this two values the percentage content of efflorescences on the surface was calculated.

Figure 1: Approach for calculating the percentage content of efflorescences on sausage surface. a: original image; b: determination of total sausage area; c: determination of efflorescence area
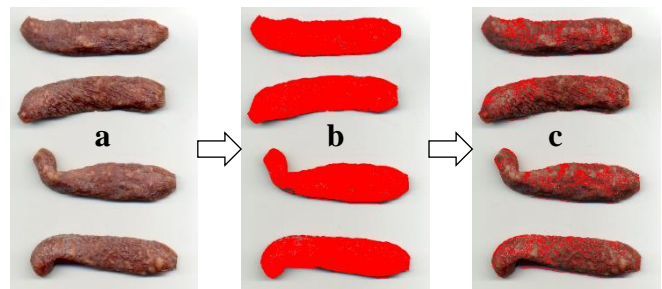
II.3 Statistical Analyses
Statistical analyses were carried out with SAS (SAS Institute, Cary, North Carolina, USA). The analysis of variance was done by the Tukey test to indicate significant ($p < 0.05$) changes between normal and fast ripening and drying and within one group during storage. Furthermore the correlation coefficient between optical and image analyses was determined for normal and fast ripening.

III. RESULTS AND DISCUSSION

The results of the visual sensory analyses are shown in Table 1. In the first week of storage, there are neither significant changes within one group (fast or normal ripening and drying) nor significant differences between fast and normal ripening and drying. After two weeks of storage the content of efflorescences raises significantly for normal ripening and drying until 28 days of storage. During the further storage time the values are not changing significantly. The results of fast ripening and drying exhibited an initial increase of efflorescences after 4 weeks. Until the end of the investigation the efflorescence content rises significantly above the level of normal ripened and dried sausages.

Table 1: Results of the sensory analyses on a scale from 0 – 10 (0: no efflorescences; 10: many efflorescences) with a panel of 20 assessors. ***: indicating significant (p < 0.05) differences between fast and normal ripening and drying; a – d: significant changes (p < 0.05) within the ripening and drying conditions.

Storage time (weeks)	Fast ripening and drying	Normal ripening and drying	Difference between fast and normal
0	0.04 ± 0.05 [a]	0.04 ± 0.05 [a]	
1	0.04 ± 0.07 [a]	0.04 ± 0.07 [a]	
2	0.82 ± 0.95 [a]	1.58 ± 1.36 [b]	***
4	2.55 ± 1.14 [b]	5.64 ± 1.14 [c]	***
6	7.46 ± 1.30 [c]	5.29 ± 1.02 [c]	***
8	8.52 ± 1.10 [d]	5.11 ± 0.91 [c]	***

The percentage content of efflorescences on the surface of the sausages is shown in Table 2. In Figure 2 and 3 images of the sausages are shown exemplarily during storage. The results are showing the same behavior as described for the results of sensory analyses. Therefore, the correlation coefficient of the two methods was calculated. For both normal and fast ripening and drying the correlation coefficient was 0.99 between sensory and image analyses.

Table 2: Percentage content of efflorescences on the surface calculated by image analyses. ***: indicating significant (p < 0.05) differences between fast and normal ripening and drying; a – d: significant changes (p < 0.05) within the ripening and drying conditions.

Storage time (weeks)	Fast ripening and drying	Normal ripening and drying	Difference between fast and normal
0	1.50 ± 0.18 [a]	1.58 ± 0.32 [a]	
1	1.76 ± 0.49 [a]	1.53 ± 0.38 [a]	
2	1.73 ± 0.14 [a]	7.81 ± 3.18 [b]	***
4	8.99 ± 2.93 [b]	23.38 ± 4.21 [c]	***
6	32.10 ± 1.88 [c]	23.05 ± 1.75 [c]	***
8	42.20 ± 2.94 [d]	25.38 ± 1.47 [c]	***

The enlargement of storage time without efflorescence formation of the fast ripened and dried sausages can be explained by physically changings of the surface. Fast drying causes high water loss in the outermost layer. This can cause glass transition of the contained proteins. Therefore the diffusion coefficient is reduced by the glassy state [9]. This behaves like a barrier layer for the efflorescence causing components.

The higher content of efflorescences at the fast ripening and drying can also be explained by the barrier layer. Underneath this layer the efflorescence causing components are concentrating. When enough water of the core is diffused to the outermost layer the glassy state is reversed. Therefore the diffusion coefficient raises and the efflorescence causing components are able to diffuse to the surface. This takes place between week 4 and 6 of storage.

The high correlation coefficient of sensory and image analyses has shown that both methods can be used to quantify the efflorescence content. This agrees with other studies where image analyses are used to predict sensory properties [10].

Figure 2: Images of the fast ripened and dried sausages used for image analyses at different storage times.
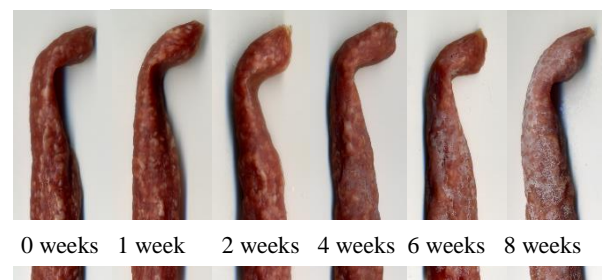

0 weeks   1 week   2 weeks   4 weeks   6 weeks   8 weeks

Figure 3: Images of the normal ripened and dried sausages used for image analyses at different storage times.

0 weeks   1 week   2 weeks   4 weeks   6 weeks   8 weeks

IV.   CONCLUSION

The results have shown that both optical methods lead to comparable results. In further studies only one of both methods could therefore be used to generate significant results. Additionally more

studies on the mechanism of efflorescence formation should be carried out.

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