IMPACT OF PACKAGING AND ENVIRONMENTAL CONDITIONS ON FORMATION OF EFFLORESCENCES ON SURFACE OF DRY FERMENTED SAUSAGES

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Abstract ï The study showed the influence of packaging and environmental conditions on formation of white efflorescence on the surface of dry fermented sausages. The objective was to identify specific storage and packaging conditions that induces the formation of white efflorescences. Therefore, dry fermented sausages were produced, packed under modified atmosphere, and stored for 7 and 14 days such as varying of temperatures and relative humidities after opening the packaging. For assessment of most important factors impacting on efflorescence formation, a design of experiment (response surface design, Box-Behnken) was applied. Visual evaluation by a trained sensory panel and image analysis were performed to quantify the formed efflorescence. The results indicated that the relative humidity after opening of the bags has the greatest influence on the formation of crystalline deposits. The opening of the package implicates such changes in humidity. Furthermore, the storage time significantly increased the amount of deposits. Storage temperature and changes in the temperature when the package was opened also affected the formation of white efflorescences. In conclusion, the study demonstrated that the highest amount of deposits were caused by low relative humidity (68%) and low storage- (6°C) or medium high trigger temperatures (13°C).

Key Words ï Image analysis, sensory analysis, crystalline deposits

I. INTRODUCTION

The formation of efflorescence on the surface of dried meat products is a common defect that has been a persistent quality problem for manufacturers of dried fermented sausages (e.g. Salami) packed under controlled atmosphere. Generally, two different types of deposits may spontaneously appear on the surface of such products, e.g. a ñreversibleò and water soluble deposits with an appearance similar to that of a spotty mold growth (Type I). In addition, an ñirreversibleò and poorly water-soluble deposit that covers the entire product and gives the product a greyish appearance (type II). Both efflorescences ï type I and II - cause consumers to either discard the product since they assume that the products has been microbiologically contaminated and is spoiled. Chemical analyses of type I deposits depicted that they consist of mainly disodium hydrogen phosphate heptahydrate [1]. Literature studies have shown that two kinds of type II deposits may be formed, one which is based on creatine monohydrate and one on magnesium DL-lactate. When sausages are fast ripened the efflorescences consist mainly of poorly water-soluble magnesium lactate. In contrast, sausages that are slowly ripened contain mainly creatine monohydrate [2, 3]

The objective of this study was to understand in detail which specific environmental changes lead to the appearance of the efflorescences. For this purpose, we will investigate a specific product dried such as small caliber salami with a weight loss of 40%. To get information about the diffusion and crystallization process on the surface taking place during storage of sausages packed under controlled atmosphere, we hypothesized that we should get a maximal amount of deposits at specific conditions of temperature and relative humidity. Image and visual sensory analysis were conducted to quantify the amount of deposits.

II. MATERIALS AND METHODS

II.1 Sausage preparation

Meat and back fat were purchased from a local retailer (MEGA, Stuttgart, Germany). The spices, additives and starter cultures LS25 were obtained from 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. Then curing salt (28.0 g/kg) was added and the batter was filled into collagen casings (NDC-D Cal. 23 mm Naturin Viscofan GmbH, Weinheim, Germany) by using a vacuum filler VF 80/165-1 (Handtmann, Biberach, Germany). The ripening and drying took place in the climatic chamber Unigar 1800 BE (Ness & Co. GmbH, Remshalden, Germany). The setting of the ripening process is shown in Table 1 and a final weight loss of 40 % was achieved. 4 sausages were packed under modified atmosphere (80% CO_2 and 20% N_2) Protadur C20 (Westfalen AG, Münster, Germany) into plastic bags SL 200×279 PA/PE 90 MY (MEGA, Stuttgart, Germany) by using the vacuum station C 400 (Multivac, Wolfertschweden, Germany). Sausages were stored for 7 and 14 days according to the design of experiments (Table 2).

Table 1 Ripening process of dry fermented sausages

Process item	Temperature (°C)	Rel. Humidity (%)	Time (h)
Conditioning	25	94	18
Ripening-1	24	74	6
Ripening-2	24	70	1
Drying	22	50	0.1
Ripening-1	22	70	24
Ripening-2	22	68	24

II.2 Statistical Analyses

Design of experiments was carried out with SAS (SAS Institute, Cary, North Carolina, USA). The type of response surface (Box-Behnken, two-level fractional factorial design) containing 4 factors and 27 runs (low, center (3-times), and high levels) was applied for 7 and 14 days of storage, respectively. In Table 2 the design is shown. As dependent parameters the area of deposits per total area of sausages and mean of visual sensory value of all testers were used to quantify the effects. The factors for analyzing the impact on packaging and environmental conditions were the temperature during storage in the packaging, the conditioning temperature, the trigger temperature and the relative humidity after opening the packaging (conditions in the desiccator).

Table 2. Factors of Box Behnken design and residence time

Factor		Parameters			Time
Storage Temperature	X_1	6°C	13°C	20°C	7/14 d
Conditioning Temperature	X_2	6°C	13°C	20°C	1 h
Trigger Temperature	X_3	6°C	13°C	20°C	24 h
Relative Humidity	X_4	68%[1]	84%[2]	100%[3]	24 h

[1] 28.52 % calcium chloride solution
[2] Saturated potassium chloride solution
[3] distilled water

II.3 Sensory Analysis

Tests took place after 7 and 14 days of storage. Therefore, 4 sausages of each run of the design of experiment were taken out of the vacuum bags and hanged into desiccators (Weck Ruhrglas, Essen, Germany). The humidity of the dessicators 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 sensory panelists rated the amount of efflorescences on a scale from 0 (no efflorescence) to 10 (much efflorescences) by visual evaluation of the sausages in the desiccators.

II.4 Image Analysis

After the visual evaluation, images from the surface of each of the 8 sausages were taken. Therefore, the sausages were split into half and the surface was scanned (Perfection V100 photo, Epson, Suwa, NGN, Japan). The percentage content of deposits on the surface was calculated by using the software ImageJ (NIH, Methesda, MD, USA). First the total surface was analyzed by setting the color threshold to a range of hue 0 ï 255, saturation 61 ï 255 and brightness 0 ï 204. Deposit area was measured by setting the color threshold to hue 0 ï 255, saturation 20 ï 90 and brightness 120 ï 170. Out of these two values the percentaged content of deposits on the surface was calculated.

III. RESULTS AND DISCUSSION

The results of the design of experiments showed that the relative humidity, storage temperature, and trigger temperature are significant factors which influence the amount of deposits analyzed by

image analysis and sensory test. In Figure 1, the response surface of the calculated model of dependent sensory value consisting of high significantly factors of relative humidity and storage temperature is shown. Similar results were obtained by imaging of the dried fermented sausages (Figure 2). Most factors of influence are the relative humidity and less the storage (Fig. 2A) and trigger temperature (Fig. 2B). In comparison of the storage time of 7 and 14 days, demonstrated that the amount of efflorescence enlarged with elongated storage time (Figure 3). The relative humidity in the packaging was constant 84%. In particular, sausages (Figure 3 C) adjusted to 68% relative humidity showed a clear increase of the mean value of sensory evaluation of the sensory panelists. Samples which were put by adjusting the relative humidity of 100% in the desiccators result in no further increase. The samples stored by 84% and 68% relative humidity resulted in nearly double higher sensory values after 14 days than after 7 days (Figure 3).

A high significantly linear correlation was found between the methods of the sensory visually test and image analysis after storage time of 7 days ($r=0.67$ $p<0.001$) and 14 days ($r=0.76$ $p<0.001$).

When the relative humidity is low (68%) an increasing crystallization was induced by the available salt ions on the surface.

Figure 1. Influence of relative humidity X_4 and storage temperature X_1 on sensory evaluation after 14 days (trigger temperature X_3, conditioning temperature=13°C)

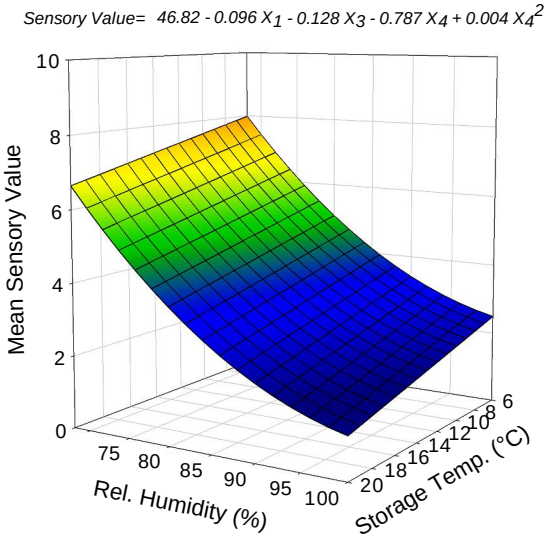
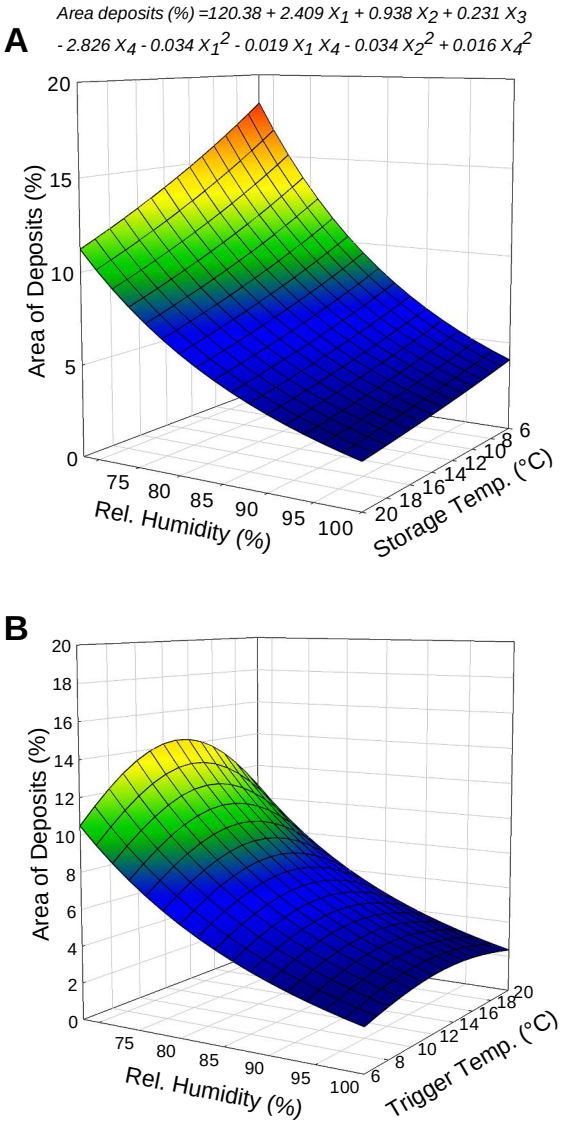


Figure 2. Impact of (A) relative humidity X_4 and storage temperature X_1 on image analysis (trigger and conditioning temperature 13°C) (B) relative humidity and trigger temperature X_3 (storage X_1 and conditioning temperature X_2 =13°C) after 14 days



Moreover, a low temperature (6°C) in the packaging during the storage and a medium high trigger temperature (13°C) in the desiccators simulating the opening of the packaging at specific environmental conditions increased the amounts of crystalline blooming. In Table 3, the fit statistics of the model is shown. The values of both visual and image analysis depicted that the statistic model is well described by the significant terms.

Figure 3. (A) Influence of storage time on the visual sensory evaluation. (B) Images of sausages before storage and packaging in modified atmosphere, (C) after a storage time of 14 days

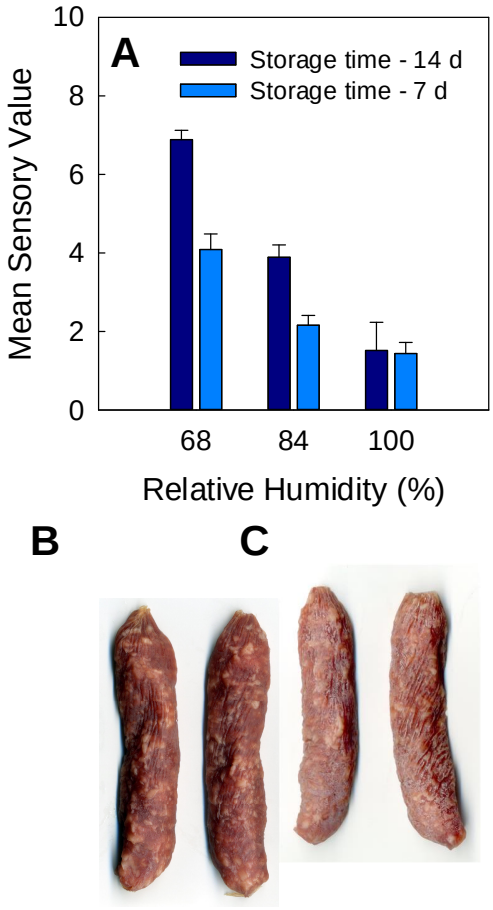


Table 2. Fit statistics of the model. Predictive model including only significant terms (p<0.05)

Analysis		Master model	Predictive model
Sensory value	RMSE[1]	0.807	0.0.743
	R-square	93.7%	90.2%
	Variation Coefficient	20.0%	18.4%
	p	<0.001	<0.001
Image analysis	RMSE[1]	1.19	1.22
	R-square	97.9%	96.4%
	Variation Coefficient	15.5%	15.7%
	p	<.0001	<0.001

[1]RMSE: Root mean squared error

The conditioning temperature (X_2) had only minimal effect (image analysis) on the quantity of white crystalline efflorescences.
Future studies should be conducted on the diffusion behavior of involved substances such as lactate, creatine and phosphate during drying process and storage. In addition, we will focus on the possibly involved cations such as magnesium, potassium, sodium and calcium. Also the possibility to reduce efflorescences should be investigated by alterations of the manufacture process or the formulation.

IV. CONCLUSION

The study showed that maximum amounts of efflorescences were obtained by adjusting the environmental conditions such as relative humidity and trigger temperature when the packaging is opened. However, the storage temperature during storage period in modified atmosphere packaging in plastic bags also showed a significant impact on the amount of deposits.

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