



## INFLUENCE OF FERMENTATION ON CREATINE AND LACTATE CONCENTRATIONS IN WHITE EFFLORESCENCES ON DRY FERMENTED SAUSAGE

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### Background

Undesired white efflorescences or surface blooms on packaged dry fermented sausages have been repeatedly observed in recent years. Since around the mid-1980ies this phenomenon was noticed with products packed in polyethylene (PE) bags under protective atmospheres such as nitrogen. The problem is observed worldwide wherever dry fermented sausages are produced (Kroeckel, unpublished). The efflorescences are known to be due to racemic magnesium-di-lactate derived from microbially produced D,L-lactate and meat-borne L-lactate (Kuehne *et al.*, 1986) and/or meat-borne creatine (Kroeckel *et al.*, 2003). Dew point changes during storage of the packaged sausages apparently favour the formation of these blooms.

### Objectives

There is no published work so far on the nature of efflorescences on different types of dry fermented sausages. Also, it is not clear how the formation of the coatings can be prevented. To get more insight into the conditions necessary for the generation of the efflorescences their appearance and composition have to be related to sausage parameters such as type of sausage, physical characteristics as well as chemical and microbiological composition. The present study aimed at collecting this kind of informations and detecting links between these parameters and bloom formation.

### Materials and methods

Different types of sausages with characteristic efflorescences were obtained from various national and international manufacturers. From all sausages the composition of the blooms were analysed. On a limited number of samples further analyses were performed to varying extent. Creatine and lactate were determined as described earlier (Kroeckel *et al.*, 2003). Physical (pH,  $a_w$ , water content) and microbiological parameters were determined using standard methods.  $Mg^{++}$  in the efflorescences was determined complexometrically.

### Results and discussion

#### Rapidly fermented smoked salamis produced in Germany

*Paprika salamis of manufacturer H.* All salamis (samples no. 1 – 6 in Tab. 1) were vacuum packed upon arrival. The white efflorescences became visible within minutes after removal of the packaging foil and reached maximum intensity within 3 – 4 hours. According to the manufacturer, the sausage recipe contained pork, nitrite curing salt, spices (including paprika extract), sugars (lactose, maltodextrine, dextrose). The white blooms were found to contain 60 – 64 % of D,L-lactate and only 0.3 % of creatine (Tab. 1). The magnesium content in the blooms of sausage no. 2 was 8.7 %. The sausage with the strongest efflorescence (80-90 % of the casing surface affected) had the lowest water activity (sample no. 2 in Tab. 1). The sausage with the highest water activity and the highest water content (sample no. 1 in Tab. 1) showed almost no efflorescence, although the lactate content inside the sausage was even higher than in sample no. 2. Bloom formation was stronger in older sausages, i.e. those with lower residual shelf life (RSL). Therefore, bloom formation does not only depend on water activity but also on storage time after packaging. The extent of blooming was higher in sausages without dry fringe which indicates that the formation of a dry fringe possibly reduces blooming. Microbiological analysis showed remainder of starter culture lactic acid bacteria (*Pediococcus pentosaceus* and *Lactobacillus plantarum*) and other LAB. D(-) and L(+) lactate were found in similar ratios in the blooms and inside the sausages. However, the concentrations outside were 13 – 20 times higher than inside. D(-) lactate is derived exclusively from microbial activities, in contrast to L(+) lactate which is present already to some extent in *post rigor* muscles, usually at concentrations below 1%. Taking into account the participation of magnesium and considering the hydrated form of Mg-D,L-lactate, the tri-



hydrate, the value of 63.9 % of lactic acid for sample no. 6 would correspond to about 91 % of [Mg-D,L-lactate] x 3 H<sub>2</sub>O in the white blooms.

Sample no.	1	2	3	4	5	6
Type	spicy	spicy	spicy	sweet	sweet	sweet
Lot no.	62	54	54	72	72	72
RSL <sup>a</sup> , days	50 <sup>b</sup>	41	41	62	62	62
Dry fringe <sup>c</sup>	+	-	-	++	+	+
Surface blooms % <sup>c</sup>	5 - 10	80 - 90	60 - 70	40 - 50	40 - 50	40 - 50
Water content %	36.9	28.7	nd	nd	nd	35.1
Water activity	0.8824	0.8572	0.8634	0.8730	0.8662	0.8636
pH	4.32	4.52	4.62	4.47	4.55	4.55
Creatine %						
in sausage	0.64	0.32	nd	nd	nd	0.45
in surface bloom	nd	0.30	nd	nd	nd	0.30
Lactic acid %						
in sausage						
L(+)	2.27	1.48	nd	nd	nd	2.71
D(-)	2.45	1.49	nd	nd	nd	2.36
L(+) + D(-)	4.72	2.97	nd	nd	nd	5.07
in surface bloom						
L(+)	nd	30.1	nd	nd	nd	31.8
D(-)	nd	29.4	nd	nd	nd	32.1
L(+) + D(-)	nd	59.5	nd	nd	nd	63.9
Bacterial counts <sup>d</sup>						
<i>Pc. pentosaceus</i>	5.00	7.54	7.67	7.7	7.60	8.00
<i>Lb. plantarum</i>	6.53	6.00	6.48	6.70	5.70	6.95
other LAB	5.70	7.65	7.68	7.90	8.04	7.85

<sup>a</sup> residual shelf life; <sup>b</sup> estimated from Lot no.; <sup>c</sup> estimated by eye; <sup>d</sup> log<sub>10</sub> CFU/g sausage;

Tab. 1: Chemical and microbiological characteristics of paprika salamis from manufacturer H showing white surface blooms after removal from the vacuum packs.

*Paprika salami of manufacturer R.* One sample (calibre: 45 mm, pH 5.0) was obtained in modified atmosphere package. In the bloom a lactic acid concentration of 57.9 % (D : L = 1.0) was found. Magnesium amounted to 7.0 % and creatine was below the detection limit (< 30 µg/g). Inside the sausage D,L-lactic acid amounted to 2.0 % (D : L = 0.95). Thus, the scraped off crystals corresponded to 58 - 69 % Mg-D,L-lactate or 74 - 87 % of its tri-hydrate. Microbial analysis revealed 2 x 10<sup>7</sup> CFU/g LAB and 10<sup>4</sup> CFU/g *Micrococcaceae*. *Smoked salami of manufacturer GH.* Blooms from three sausages (calibre: 50 mm) were found to contain 50.5 % D,L-lactic acid (D : L = 1.0), 7.8 % magnesium and 23.4 % creatine. Assuming that racemic Mg-di-lactate is present as its tri-hydrate, the analytical results explain 100 % of the composition of the efflorescences.

#### Slowly fermented salamis and thin calibre dry fermented sausages

*French saucisse of manufacturer B.* All salamis arrived packed in PE foils under modified atmosphere. Recommended storage was below 18 °C. White efflorescences were visible already before removal of the sausages from the packages. According to the manufacturer, the sausage recipe contained pork, common salt plus nitrate, spices, sugars (lactose, dextrose, sucrose), lactic acid bacteria (LAB) and ascorbate. Microbiological analysis showed reminder of starter culture bacteria (*Lactobacillus plantarum*, *Micrococcaceae*) and other LAB (Tab. 2). Both, D(-) and L(+) lactic acid were present in the sausages in similar ratios but in comparatively small concentrations indicating that only a mild fermentation had taken place before further ripening (drying). The relatively high pH of 5.7 is a typical result of this kind of salami



technology. The residual shelf life was comparable to the paprika salami sample no. 2 in Tab. 1 while the water activity was even lower.

Sample no.	1	2	3
Type	collagen casing	natural casing	natural casing
RSL <sup>a</sup> , days	52	52	52
Surface blooms % <sup>b</sup>	50	50	50
Water content %	32.4	nd	nd
Water activity	0.8425	nd	nd
pH	5.68	nd	nd
Creatine % in sausage in surface bloom	0.67 - 1.15 95	nd 90	nd 93
Lactic acid % in sausage L(+) D(-) in bloom	0.79 0.88 nd	nd nd nd	nd nd nd
Bacterial counts <sup>c</sup> <i>Lb. plantarum</i> <i>Lb. sakei</i> other LAB <i>Micrococcaceae</i> Yeasts	6.83 4.84 5.14 5.67 4.74	nd nd nd nd nd	nd nd nd nd nd

<sup>a</sup> residual shelf life; <sup>b</sup> estimated by eye; <sup>c</sup> log<sub>10</sub> CFU/g sausage;

Tab. 2: Slow fermented salamis (saucisses) in modified atmosphere packages showing white surface blooms already before removal from the packages.

The creatine concentration inside the sausage was at the upper limit of what should be expected and, the efflorescence was composed of creatine only. Magnesium was not detected in the blooms. These results suggest that at pH values around 5.7 only minor amounts of Mg-D,L-lactate is formed. Also, creatine is more stable at pH 5.7 than at pH 4.5 (see paprika salamis in Tab. 1).

*German thin calibre dry fermented sausages.* Salami-style sausages in sheep gut casings (10 mm calibre) were obtained in a PE package under protective atmosphere with a residual shelf life of 24 days. According to the product label the sausages were smoked and were composed of pork, nitrite curing salt, spices, glucose, taste enhancer and wort. The surface blooms were not visible upon arrival but were inducible by subjecting the packages to repeated temperature changes (8 °C / 20 °C). The efflorescences formed consisted almost entirely of creatine (83 %) and did not contain any lactate. The pH value of the sausages was around 5.8 – 5.9, i.e. even higher than the pH of the French saucisse in Tab. 2. The concentration of D,L-lactate in the sausage was 10.9 mg/g (D : L = 0.36). The D:L ratio indicated that hardly any microbial lactic acid formation had taken place, i.e. the sausages were more dried than fermented. The LAB count was less than 10<sup>4</sup> CFU/g, probably because of the low water activity of 0.812. The creatine and creatinine contents of the sausage were 2.4 mg/g and 0.4 mg/g, respectively.

*Other thin calibre sausages.* Creatine was present in the surface crusts of vacuum packaged 'beersticks' from New Zealand and, in the efflorescences of four loose sausages that apparently had been subjected to storage conditions favouring bloom formation. The pH values of the sausages ranged from 5.4 to 6.1. The white coating obtained from sample no. 1 in Tab. 3 also contained some D,L-lactate which, however, was about 10 times lower in concentration than creatine. Interestingly, there was hardly any D(-) lactate inside this sausage. This finding is in agreement with the low LAB count which suggests a drying-type process rather than a fermentation-type process. However, the LAB count also may have been reduced by the low water activity in this sample. In contrast, samples no. 3 – 5 showed a typical bacterial count of a fermentation microflora.



Sample	Hungarian 'Kolbasz'-style sausage	'Beersticks' from New Zealand	Thin calibre dry fermented sausage from organic production (Germany)		
Sample no.	1	2	3	4	5
Calibre, mm	20	10	10	10	10
Smoked	+	+	+	+	+
Packaged	-	vacuum	-	-	-
Meat	porc, beef	porc, beef	porc, beef	lamb, porc	porc, beef
Surface blooms % <sup>c</sup>	50	10-20	50	50	50
Water content %	29.9	nd	nd	nd	nd
Water activity	0,8386	nd	nd	nd	nd
pH	6.15	nd	6.01	5.71	5.37
Creatine % in surface bloom	13	8.5	2.9	2.6	2.1
Lactic acid % in sausage					
L(+)	0.9	nd	nd	nd	nd
D(-)	0.04	nd	nd	nd	nd
L(+) + D(-)	0.94	nd	nd	nd	nd
in surface bloom					
L(+)	0.7	< 1.6	< 1.6	< 1.6	< 1.6
D(-)	0.8	< 1.6	< 1.6	< 1.6	< 1.6
L(+) + D(-)	1.5	< 1.6	< 1.6	< 1.6	< 1.6
Bacterial counts					
Lactic acid bacteria	< 4	nd	8.2 <sup>c</sup>	7.9 <sup>c</sup>	8.5 <sup>c</sup>
<i>Micrococcaceae</i>	< 2	nd	6.0	5.2	6.0

<sup>a</sup> estimated by eye; <sup>b</sup> log<sub>10</sub> CFU/g sausage; <sup>c</sup> *Lactobacillus sakei*;

Tab. 3: Characteristics of some thin calibre dry fermented sausages from different origin.

## Conclusions

The fermentation process determines the nature of the surface blooms on dry fermented sausages while bloom formation itself is determined by physical factors such as water activity of the sausages and storage conditions. Racemic lactic acid is the major component of efflorescences on dry sausages which were subjected to a rapid fermentation in the presence of added starter cultures and fermentable carbohydrates. In contrast, slowly fermented dry sausages and thin calibre dry sausages which are more dried than fermented may contain creatine as the sole component. High pH values in the sausage favour creatine blooms while low pH values favour Mg-di-lactate blooms. Appearance of the efflorescences is correlated with water activities of the sausages in the range of 0.81 – 0.88. Some efflorescences may contain both, creatine and Mg-D,L-lactate. The results of this study may help to develop strategies for preventing undesired efflorescences on dry fermented sausages.

## References

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