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Investigation of pausing fermentation of salamis with multispectral imaging for optimal sensory evaluations

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ABSTRACT

The fermentation process of salamis involves several parameters influencing taste, texture, and color of the salami. One significant parameter is the fermentation time. It is difficult to conduct sensory evaluations to assess the effect of time without introducing variation between observation days. It may be possible to overcome this by stalling or pausing the fermentation by deep-chilling the salamis. This study investigates the difference of non- and deep-chilled salamis with the use of a multispectral imaging system. The statistical investigation, based on image features relating to size, visual texture, and color of the sausages over time, showed that it may be possible to stall the fermentation process. It was shown that a statistical difference in the two kinds of samples is present. For the size feature the difference could be quantified into a number of days. However, for the important color feature only a statistical difference was observed, whereas the visual difference expressed in terms of ΔE_{ab}^{*} was barely present.

1. Introduction

The visual changes during the fermentation process of salamis occur due to evaporation and acidification. The changes are expressed in terms of shrinkage of the salami diameter, a graduate color change and a texture change as visualized in Fig. 1.

A sensory panel is a strong method to precisely determine quality parameters of food (Van Kleef, van Trijp, & Luning, 2005), but variations in their assessment can occur, especially when the same product is assessed at different time points. This is of particular relevance for fermented products like salamis, where the sausage is developed over time. In order to avoid such variations it would be advantageous to present all fermentation stages of the salamis to the sensory panel at once. Having all fermentation stages could be achieved by starting the salami production at different time points, but this can cause variations between batches, which also should be avoided. Instead it would be beneficial to have a method for stopping or pausing the fermentation process, such that a sensory panel can be exposed to all fermentation stages at the same trial and perform an equal assessment of the salamis. This pausing of the fermentation process is possible by deep chilling the samples. It is however important that the deep-chilling does not influence the salami.

In this study we investigate how deep-chilling influence the appearance using multispectral images. To do this we provide a set of tools for processing and analyzing the multispectral images of salami. A vision system is an obvious choice for a comparison study like this, since the illumination is consistent across acquisition days, and therefore ensures equal and objective assessment properties across fermentation stages.

Image analysis is widely applied in assessment of food products. Several studies describe how computer vision systems and subsequent image analysis can be used in the process of describing various meat products (Chmiel, Slowinski, & Dasiewicz, 2011; Valous, Mendoza, Sun, & Allen, 2009). The studies relate to both color and visual texture of the products. Mendoza, Dejmek, and Aguilera (2006) reviewed how different vision systems were employed to assess color and other attributes of agricultural foods. Image analysis has also proven useful in the analysis of ripening stages for fruits and vegetables (Mendoza & Aguilera, 2004; Steinmetz, Roger, Moltó, & Blasco, 1999; Xing & De Baerdemaeker, 2005), identification of previously frozen products (Brosnan & Sun, 2004; Pu, Sun, Ma, & Cheng, 2015; Ropodi, Panagou, & Nychas, 2018; Sharifzadeh, Clemmensen, Løje, & Ersbøll, 2013), and spoilage detection in meat (Dissing et al., 2012; Tsakanikas, Pavlidis, Panagou, & Nychas, 2016). Feng and Sun (2013) investigated Pseudomonas loads in chicken fillets using near infrared hyperspectral imaging. Based on multispectral imaging in the visible and near infrared (NIR) regions, Ma et al. (2014) presented a rapid and non-destructive method for determining the aerobic plate count (APC) in cooked pork

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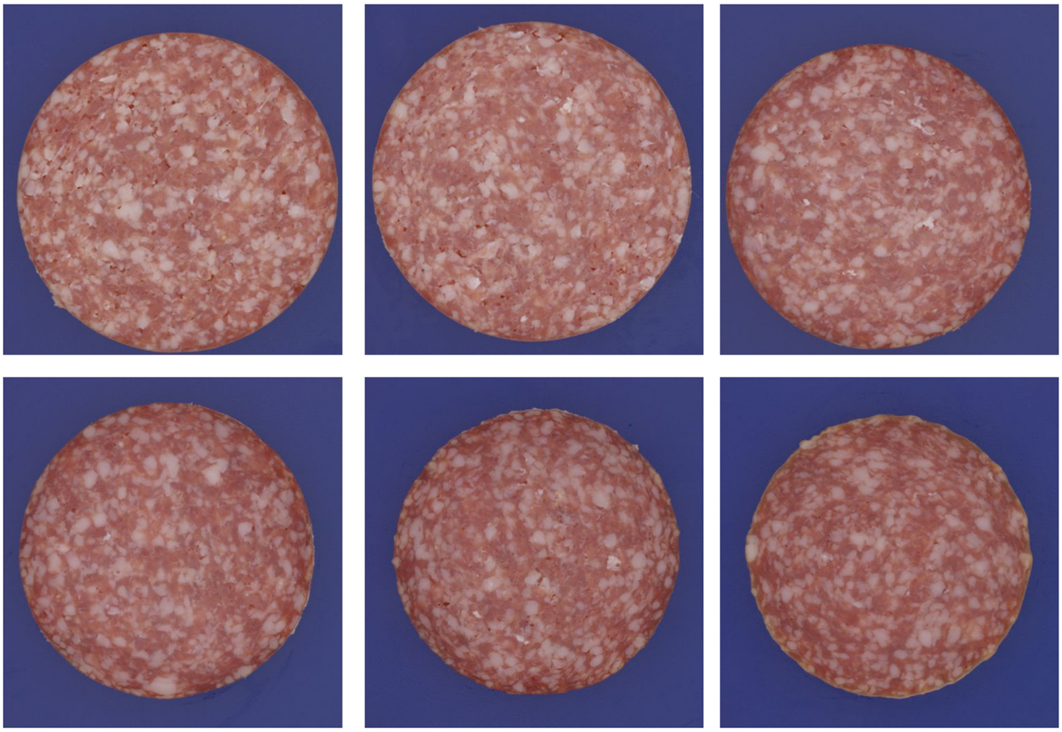

Fig. 1. Fermentation process for one recipe of salami at day 2, 3, 9, 14, 21, and 42 after production (ordered from upper left to lower right). These images are obtained from multispectral images as false color composite based on three spectral bands (660 nm, 470 nm, 435 nm).

sausages. Ropodi, Panagou, and Nychas (2017) used multispectral imaging in detection of minced beef adulteration with horse meat.

The feasibility of applying different data analytic methods in food science is addressed by several authors. Pu et al. (2015), were – among other things – investigating texture analysis, Ma et al. (2014) used partial least squares regression in calibrating relationships, Ropodi et al. (2018), and Tsakanikas et al. (2016) introduced methods related to machine learning. Work presented in this paper is inspired by the studies in Møller (2012).

We quantify appearance features related to size, color, and visual texture of fermented salami slices using image analysis. Our results showed subtle differences between deep-chilled and non-chilled samples. The differences were quantified by statistical models and principal component analysis (PCA). The analysis revealed a statistical difference, but this significance is not necessarily translatable to visual difference. Measured in the CIELAB color space this difference was below the human visible threshold.

2. Materials and methods

During the fermentation process of a salami its circumference decrease and the color changes. Moreover, the firmness or texture of the product also changes. This time dependent change was captured by extracting descriptive features from multispectral images. These features were compared for the deep-chilled and non-chilled samples to investigate whether a time dependent change was present.

2.1. Samples and instrument

The rate of the changes during the fermentation process is determined by factors like fermentation culture, smoke time, fat and meat content, pH drop, etc. In this study we considered four different recipes of starter cultures, and keept all other factors constant. This resulted in four different fermentation processes.

We studied samples from specific days (2, 3, 9, 14, 21 and 42) after fermentation start, as illustrated in Fig. 1. The observation frequency in the beginning of the fermentation process is higher than in the end since the meat cures faster in this period (Huefner & Hertel, 2008). On these days, two samples of each recipe were taken from the smoker. From one sausage three slices of ~ 2 cm were cut and imaged with the multispectral imaging system. The other sausage was placed in the cooler at $-2\,^{\circ}$C until day 42, deep-chilling. At day 42, these samples were taken out of the cooler and put in the refrigerator until they reached a temperature of $5\,^{\circ}$C. Similar to the non-chilled samples, the deep-chilled samples were now sliced and imaged with the multispectral imaging system. Consequently, the chilled samples were stored at $-2\,^{\circ}$C for a different number of days when imaged.

This study has a total of $n = 132$ observations. For the first five observation days, three replications of four recipes for both chilled and non-chilled samples were imaged. On the last observation day, only non-chilled samples were imaged, since the test series was finished and no more samples were deep-chilled.

In this study we employed the multispectral imaging system VideometerLab that depicts objects with a diameter of up to 10 cm using wavelength specific diffuse illumination, making it ideal for salami slices. The resulting images were 2056×2056 pixels with a pixel size of 45 µm. The instrument had 19 spectral bands – 12 visible and 7 near-infrared bands. More specific information on the vision system can be found in Ljungqvist et al. (2014).

2.2. Image analysis

Fig. 2 presents the steps in the analysis of the multispectral image – from segmentation to feature extraction and statistical analysis. All steps will be described in the rest of this section.

2.2.1. Segmentation

Canonical discriminant analysis (CDA) was applied to segment the images. This supervised classification procedure use training areas of k classes for defining a discriminator function, $\boldsymbol{Y} = \boldsymbol{d}^T\boldsymbol{X}$. $\boldsymbol{d}$ is found by maximizing the Rayleigh coefficient