

Validation of X-ray computed tomography for the quantification of the eye volume in cheese

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Introduction

X-ray computed tomography (CT) is widely used in human and animal medicine, in industrial applications and structural mechanics, failure analysis and in disciplines such as archaeology.

Eye formation is an important quality aspect of "Swiss-type" cheese and of many semi-hard cheeses. In this study, CT was applied to quantitatively determine the eye volume in cheese, to investigate differences in the activity of metabolic pathways of different microorganisms and for the development of eye forming cultures.

The objectives of the present study were to validate the image analysis methods which enable quantification of the total eye volume in cheese by means of CT technology and to analyse the influence of *Lactobacillus casei* supplements on eye formation.

Material and Methods

A Philips X-ray CT system was used in collaboration with the veterinary faculty at the University of Bern. To quantify the eye volume, a package of commercial image processing software (Disect Systems Ltd., UK) was applied to analyse the data received by the detected density differences between gas (eyes) and solids (cheese body). Pre-processing of the acquired data was followed by the calculation of the total cheese loaf volume and the total eye volume inside the cheese. Eyeless hard cheeses with the inclusion of hollow polypropylene balls of a diameter of 10 and 20 mm, were produced. Six cheeses per ball diameter with an increasing number of balls and hollow volumes from 0 to 33 mL and 0 to 309 mL, respectively, were ripened for 30 days within a hermetically sealed plastic film.

In the second part of the study, the CT system and the software were applied for the quantification of the eye volume increase in semi-hard cheeses (Tilsit) in a non-invasive manner to study the influence of *Lb. casei* as a adjunct culture.

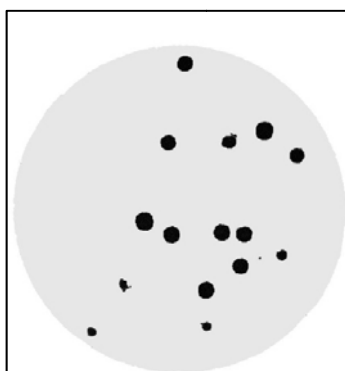


Figure 1: Pre-processed CT-Layer 94 of cheese no. 12 containing 100 balls with a diameter of 20 mm

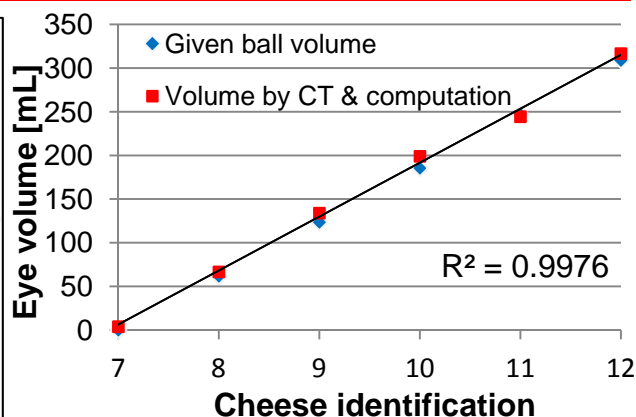


Figure 2: Comparison between the known volume of the embedded balls of 20 mm diameter in eyeless hard cheeses and the calculated volume by CT and image processing

Results and discussion

By utilising the 2D images of the pre-processed CT-data of the same cheese loaf, the exact area of the eyes in each layer was calculated (Fig. 1). The total eye volume was evaluated by integrating all the layers. The known and the computed eye volumes showed a very high correlation ($R^2 > 0.9912$; Fig. 2).

Fig. 3a and 3b show two horizontal cross-sections from the middle of experimental Tilsit cheeses produced with and without the addition of *Lb. casei*. The two Tilsit cheeses were analysed at the end of the ripening time of 4 months. In the variant with *Lb. casei* (Fig. 3a) citrate was completely metabolised. The additional production of CO_2 increased the relative eye volume from 0.27% to 0.67%, compared to the control without *Lb. casei* (Fig. 3b).

Conclusion

The study showed that X-ray computed tomography with the applied image processing was well suited to quantitatively measure the eye volume of semi-hard and hard cheeses in a non-invasive manner.

The results of the newly developed CT-methodology confirmed that the addition of *Lb. casei* increased the eye volume in semi-hard cheese.

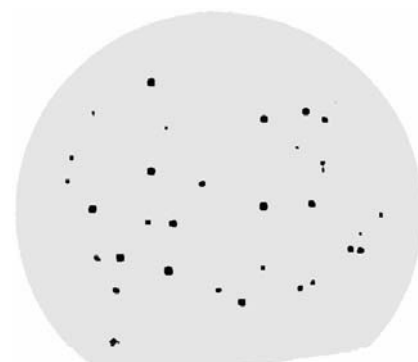


Figure 3a: Tilsit cheese with addition of *Lb. casei*. The complete metabolization of citrate increased CO_2 production and eye formation.

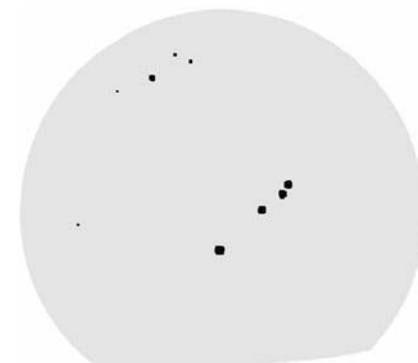


Figure 3b: Tilsit cheese without addition of *Lb. casei*.