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Multispectral imaging of wok fried vegetables

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Abstract. This paper shows how multispectral images can be used to assess color change over time in wok fried vegetables. We present results where feature selection was performed with sparse methods from the multispectral images to detect the color changes of wok fried carrots and celeriac stored at +5°C over 14 days. A pairwise t-test was used to detect if the differences over days were significant. For both the original as well as a follow experiment significant differences were seen in particular for celeriac, but also to some extent for carrots.

Keywords: multispectral images, color change, celeriac, carrots, wok fried vegetables.

1. Introduction

Quality control in the food industry is an important issue and it is mainly conducted by measuring various chemical components in the food. In this study, we propose the use of multispectral imaging to evaluate colour changes of meal elements for professionally prepared meals with regards to change in surface colour after freeze-chilling and thawing at +5°C over a period of 14 days.

Meal elements are robust semi-prepared convenience components based typically on meat, fish or vegetables and meant for professional use. Earlier studies have shown that stir-fried vegetable meal elements have promising properties with respect to high culinary quality and robustness towards freezing and thawing, thereby potentially solving a major hindrance for the use of heat-treated vegetables as meal elements (Adler-Nissen, 2007). Freeze-chilling involves a complete freezing of the products followed by storage at freezing temperature after which the products will be thawed at refrigeration temperatures (O'Leary et al., 2000). Freeze-chiling allows the manufacturer flexibility in manufacturing and distribution. The pre-fried vegetables are produced by a new process for continuous stir-frying in industrial scale, which has been introduced for producing convenience high-quality vegetables (Adler-Nissen,

2002). The pre-fried vegetables produced according to the process are generally prepared from the raw. They have a low fat content (typically 1%–2% of the product weight), a texture and flavour similar to what can be achieved in the kitchen, and vitamins are preserved almost 100% (Burgaard et al., 2004).

Celeriac and carrots were the subjects of this study, and the colour changes were measured by a multispectral imaging device called VideometerLab (<http://www.videometer.com>). The VideometerLab acquires multi-spectral images of up to 20 different wavelengths ranging from 430 to 970 nm. The camera system uses a diffuse sphere to achieve a uniform and reproducible illumination, which enables the creation of detailed surface chemistry maps with a good combination of spectral and spatial resolutions plus reproducibility over time (Gomez et al., 2007).

2. Materials and methods

Celeriac and carrots (shaped as cubes of size approximately 0.5 cm³) were fried in a continuously wok (Adler-Nissen, 2002). Afterwards the products were packed in plastic bags and frozen at – 30°C. After 4 months of freezing (experiment 1) and 1½ months of freezing (experiment 2) the bags with the pre-fried vegetables were removed from the freezer and thawed up to 14 days at +5° in a refrigeration. One each day of analysis (day 2, 4, 8, 10, 12 and 14) one plastic bag was taken out from the refrigeration, the vegetables were placed in petri dishes, and the multispectral images were recorded by the VideometerLab.

Six images were recorded over 14 days for two different data set. Both experiments were conducted under the same circumstances and the data analysis were performed equally for the two sets.

During the 14 days of image recording, the surface changes and thereby reflectance properties were very subtle. Therefore advanced statistical techniques were applied to search a large featurespace of variables extracted from the chemistry maps. The features extracted were purely reflectance properties found by calculating pairwise interactions between bands within the region of interest. These interactions were then each converted to a set of percentiles which were used as features. With 20 spectral bands this amounts to a substantial amount of features. An elastic net regression was performed to extract the features of relevance and obtain good generalization (Zou & Hastie, 2005). The elastic net method uses an ordinary least squares regression with L_1 - and L_2 -norm penalization of the parameter estimates. The regularizations give sparsity and shrinkage to the parameters which preciously has proved to give good predictions in high-dimensional data with correlations amongst the covariates (Clemmensen et al., 2010). The number of days was used as response variable for the predictions.

3. Results

The results showed that the celeriac predictions were somewhat better than the carrots, although a trend was seen in both. The statistical tests for experiment 1 showed that for carrots a significant change in the mean from day 2 to day 4 was seen. After day 4, it was not possible to verify a significant change in mean for carrots anymore, which could indicate a steady state has been reached. For the celeriac the change in mean continued until day 12 with the exception of day 8 where some uncertainty appears (Dissing et al., 2009).

Pairwise two sided t-tests showed exactly that these changes were statistically significant at a 5% level of significance.

In the present study the wok fried vegetables were packed in plastic bags prior to freezing and storage. Plastic bags are not tight against oxygen molecules, thus we believe that the observed changes in the spectra is caused by oxidation of the plant pigments in the vegetables. An oxidation causes browning/graying of the celeriac and carrots to become more pale. An increasing brown/gray colour is changes in a wide range of the spectrum and thereby a change of brightness. For celeriac the most significant components consisted of wavelengths from the entire visible spectrum, which match a general shift in brightness. For carrots the components seem to have a tendency to lie in the red/NIR area, which also match with a general more pale appearance, or removal of redness/orangeness components due to oxidation of the beta-carotene.

A follow up experiment was performed to verify the robustness of the model. For comparison the model parameters estimated for the first experiment were used to predict the storage time for the second experiment. The output of the predictions shows very similar results to those from experiment 1, being significant changes for celeriac and less significant results for the carrots

For the first experiment, the corresponding sensory tests showed no difference over the 14 days, which makes it more important that we were able to detect minor changes under using multispectral imaging, while the detection limit for sensory changes (using a trained panel) was 14 days. These results show the strengths of multispectral imaging.

4. Conclusion

Multispectral image analysis was used as an objective measurement of surface changes in wok fried carrots and celeriac. During 14 days, images were recorded for wok fried carrot and celeriac. The results show a large change from day 2 to day 4 in the reflectance spectrum for both carrots and celeriac and this change continued until day 12 for celeriac samples. A follow up experiment show very similar results which verify the robustness of the model.

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