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Influence of the low temperature drying process on optical alternations of organic apple slices

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Abstract
*Drying conditions for convective driers are often based on empirical approaches in which the final product quality is evaluated post processing. Modern sensor technology and data processing enable second-by-second quality analyses but conventional systems do not utilize this possibility. An industrial convective drying chamber was modified with a camera system to investigate the product during the drying process. The obtained data was analyzed on color alternation (CIE-L*a*b* color space and Browning Index), shrinkage and deformation. Both, shrinkage and deformation show minor dependence on drying conditons. The investigation shows the time depending optical parameter at different drying conditions. This might offer new "smart" drying programs with focus on improved product quality.*

Keywords: *color alternation; shrinkage; deformation; convective drying; smart drying*

1. Introduction

Organic products are a growing market for European producers and commonly associated with a sustainable food chain. The production of organic processed food is mostly carried out by small and medium sized enterprises which are facing a double challenge regarding the consumer awareness for high quality products and legal standards. In recent years the organic sector has put significant effort in the development of clear definitions of gentle and quality oriented processing. Drying was identified as a preservation technology which operate inefficient with respect to raw material utilization, resulting product quality as well as energy efficiency. Consumers mostly don't know about the used amount of energy behind a dried food product or its quality standards during the drying process. This is a problem especially for organic foods which are expected to be produced sustainable and with high quality regardless to its magnitude of processing. European Community legislation only has explicit rules for agricultural production and additives used in processed food. There is a clear correlation between product quality and drying conditions and low temperature drying is commonly used for products which require gentle processing.

There has been a vast development of sensor technology in the last decade and several mass-produced optical analyzing tools are available at the market. However, industrial drying systems mostly do not utilize the possibilities which e.g. camera sensors offer. Drying of organic apples is mostly performed as batch processes by SMEs and drying conditions (mainly temperature) are empirically determined. As a result, the product quality is not monitored or controlled during processing and final product quality is first determined at the end of drying.

For the present investigation the potential of low temperature drying of organic apples was evaluated at different relative humidity with respect to color changes and product deformation during processing. A camera sensor was installed in an industrial drier which enabled determination of optical alternations of the product like color alternation, shrinkage and deformation in a continuous way without any interruption of the drying process. The results are used to suggest an improved control strategy.

2. Materials and Methods

2.1 Product preparation

Organic apples of the sort "Red Delicious" with the origin Italia were used for the experiments. The apples were obtained from a local organic supplier in Trondheim, Norway and stored in a refrigerator at 8°C until further processing. The apples were cut in slices of 5 mm thickness by using a cutter machine. The core and the apple skin wasn't removed so that slicing the apples was the only processing. The time between getting the apples out of the fridge, cutting and starting the experiment was always within 5 min.

2.2 Experimental setup

The experiments were executed in a convective drying chamber with a dimension of ca. 3m * 1.5m * 1m with a tray area of 50 m^2. The drying chamber is equipped with an electric heater to set the drying temperature, a ventilator to set the air velocity and a heat pump to set the relative humidity. To avoid any interruptions or influences of the drying process due to measuring, a test rack was built and placed within the drying chamber at a representative point in the middle of the drier trays with all relevant measuring devices attached. The camera system (UI-5240CP-C-HQ Rev.2, company iDS Imaging Development Systems, Germany) contained a built-in heater to avoid influences of the image quality due to the surrounding temperatures in the drying chamber. The illumination was the LED-barlight (LHF300-M12-WHI, company Stemmer Imaging, Germany) with a color temperature of 6500K. The camera system was used to measure color alternations and deformations like shrinkage. To obtain also the sidelong deformation of the apple slices, a mirror was placed in a 45° angle next to the slices. In addition to the optical alternations there was also a pyrometer used for measuring the surface temperature of the apple slices and a scale (SB32000, company Mettler Toledo) to record the weight loss during the drying process. For each test series, four apple slices were analyzed by the camera system. The remaining space on the test rack was filled up with apple slices of the same thickness. The surface temperature of one representative apple slice was measured by the pyrometer. The process parameters of the test series are listed in Table 1 and are based on industrial low temperature drying conditions for organic apple producers. The drying temperature of 40 °C was used as reference case.

Table 1: Overview of the investigated drying conditions for organic apples.

Test series name	Humidity	Temperature	Air velocity
T20_RH25	25 %	20 °C	1,5 m/sec
T20_RH40	40 %	20 °C	1,5 m/sec
T20_RH60	60 %	20 °C	1,5 m/sec
T40_RH25	25 %	40 °C	1,5 m/sec

2.2 Optical analysis

For analyzing the optical alternations, an image was taken by the camera every 5 minutes and analyzed with a special application using the OpenCV libraries for image processing. An example is shown in Figure 1. The deformation of the apple slices was defined by the deviation of the actual slice area and the area of a corresponding circle whose diameter is the maximum width of the actual slice (yellow circle in Figure 1, left image). The ratio between these two areas gives a quantitative value about the deformation. A perfect round shaped apple slice e.g. would have the same area than its calculated minimum circle which results in a deformation of 1, proceeding deformation results in a value less than 1. The same principle was used to determine the deformation of the sidelong view but with using a minimum rectangle (yellow rectangle in Figure 1, middle image). The shrinkage was defined by the ratio of the area of the actual apple slice and the area of the apple slice at the beginning of the drying process. The color alternation was measured by reading the color information of each pixel within the apple slices and averaging it (Figure 1, right image). The so obtained RGB values were transformed into the CIE-XYZ color space according the ISO Standard 13655 which is the base of the CIE-L*a*b* color space and the Browning Index.

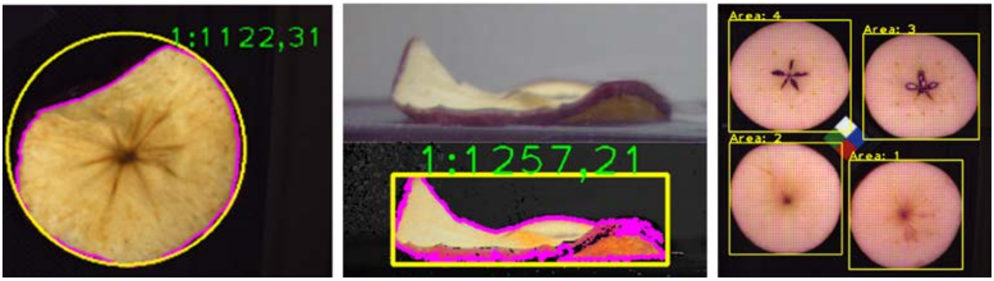

Figure 1:Measuring principle of the deformation top view (left), deformation sidelong (middle), color alternation (right)

The CIE-L*a*b* color model was developed with the aim of linearizing the representation of colors with respect to human color perception and at the same time creating a more intuitive color system [1]. The dimensions in this color space are the luminosity L* and the two-color components a*, b*, which specify the color hue and saturation along the green-red and blue-yellow axes, respectively. The CIE-L*a*b* color space is often used in literature to describe the color of food.

The Browning Index is an indicator of the color change due oxidation of a freshly cut fruit or vegetable surface during storage or drying. The best known and most often quoted Browning Index is a form of excitation purity that follows the suggestion of Buera et al. (1985) [2] and is expressed as follows [3]:

$$BI = \frac{(x_{D65} - 0{,}32)}{0{,}162} * 100 \qquad (1)$$

(for Illuminant: D65 and Standard Observer 10°)

where *x* is the CIE Chromaticity value and calculated by the CIE-XYZ values

$$x = \frac{X}{(X + Y + Z)} \qquad (2)$$

3. Results and discussion

Figure 2 shows the moisture ratio of the different test series over the drying time. The grey areas behind each test series shows the uncertainties of the data. The results shows that the differences between the T20_RH40 and T20_RH25 test series is much less than compared to the T20_RH60 test series. The same behavior was already measured in other publications for the drying of Temu Putih Herb, coriander leaves, okra and pistachio nuts [4]. The test series T40_RH25 however shows a much quicker drying than the other test series what indicates that the drying temperature has much more influence on the drying kinetics than the relative humidity.

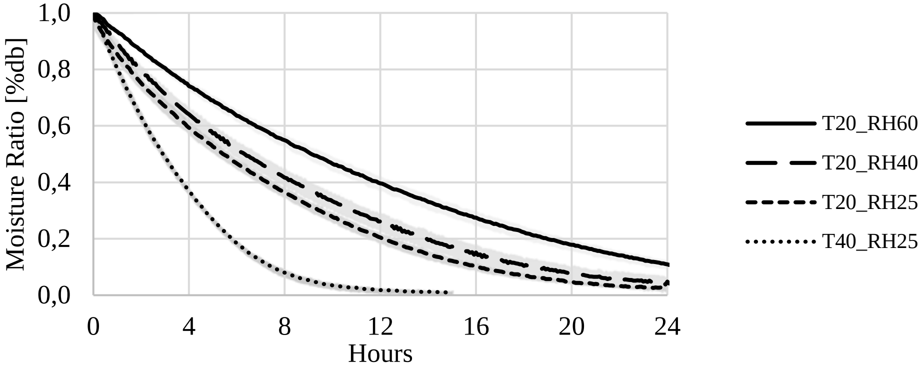

Figure 2: Moisture Ratio of organic apples at different drying conditions

The graph in Figure 3 shows that the CIE-L* value is basically decreasing for all experiments over the whole drying process, what means that the apple slices became darker. Hereby the biggest rate of change happens within the first 2-3 hours, afterwards the change rate becomes insignificant. The values of the T20_RH60 test series shows a continuous decrease of the CIE-L* value whereas the other test series have a minimum after about 2 hours with a followed increase of the CIE-L* value and a continuous decreasing afterwards.

Browning is one of the main quality parameters of dried apple slices and the consumer acceptance drops significant for products with increased brownish appearance. The browning Indices (BI) in Figure 4 shows, that the BI increases for all test series during the drying time. The biggest changing rate is taken place within the first 2-3 hours. All test series have a similar behavior where the browning index decreases after the first 2-3 hours and increases again afterwards. The T40_RH25 test series is much more distinct in its curve progression than the other test series and has a higher browning index than the T20_RH25 test series. This suggests, that a higher drying temperature and a higher relative temperature increases the browning index.

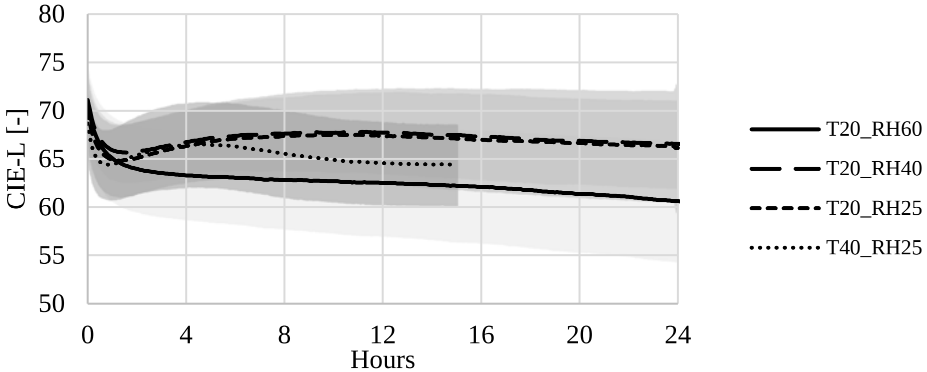

Figure 3: CIE-L* values of organic apples at different drying conditions

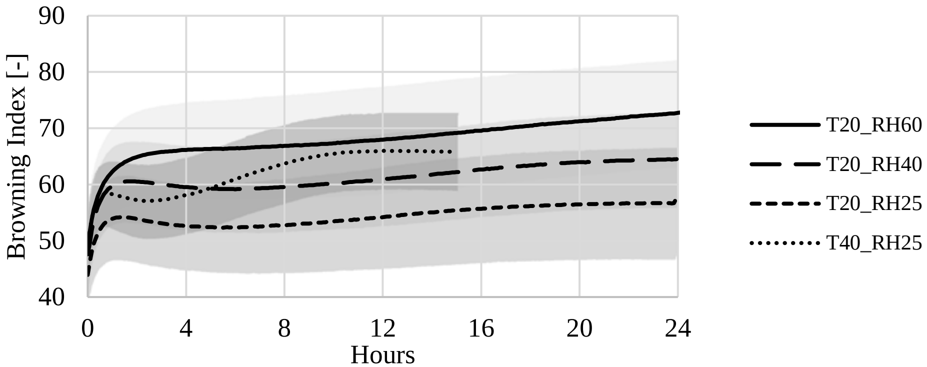

Figure 4: Browning index of organic apples at different drying conditions

Browning is mostly a surface effect and all tests showed clearly that this effect occurs in the beginning of drying when naturally the product surface is dried. This gives an indication that the product quality with respect to browning could be improved by a low temperature and low humidity drying period in the beginning. Once the surface is dried and stabilized the drying temperature could then be increased so that the drying time is reduced. With the current system it is possible to program such a control algorithm in a way that the drying conditions are continuously adapted to the color change and browning of the product.

Figure 5 shows the shrinkage of the apple slices related to the area of the top frontal view over the Moisture Ratio. All test series shows an area shrinkage at the end of the drying process between ca. 25% and 35%. Hereby the shrinkage seems to be nearly linear to the moisture ratio for a certain time and converges then to an end value. The curve progress of all test series is similar what indicates, that the relative humidity has only a minor influence on the area shrinkage process of the apple slices.

The sidelong deformation results in Figure 6 doesn't start at 100% since the apples slices in the beginning of drying are not a perfect rectangle. All test series shows an increasing deformation over the drying time. Thereby the test series with 20°C drying temperature shows a similar curve progression whereas the curve progression of the T40_RH25 test series is taken place much faster. The magnitude of the deformation at the end of each test series is like all test series about 30% but varied very strong from apple slice to apple slice.

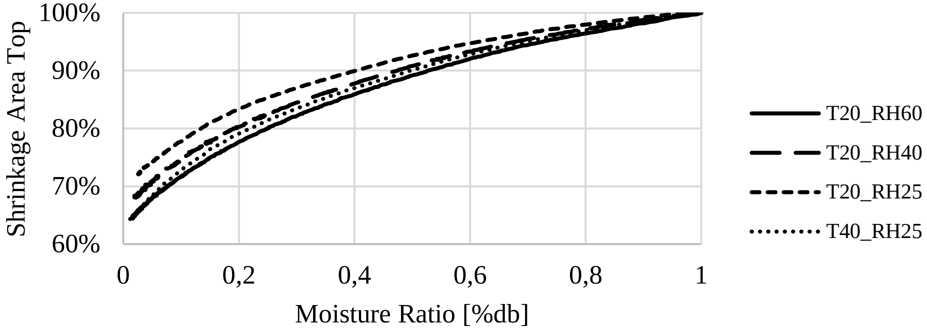

Figure 5: Top view shrinkage of organic apples at different drying conditions.

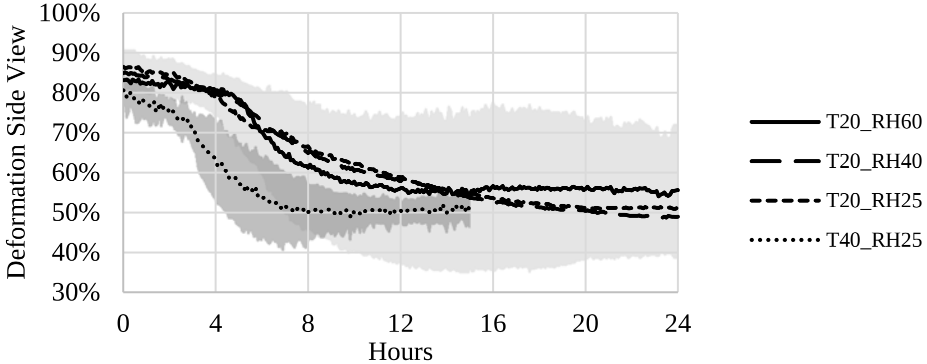

Figure 6: Side view deformation of organic apples at different drying conditions

The observations regarding deformation and shrinkage can be related to a certain mechanical stress in the product once the water is removed. Consequently, the deformation and shrinkage of the final product can most likely not be minimized by improved drying conditions. However, it can be considered to end the drying process with a higher final water content when the product is less shrunk or deformed. This would decrease the drying time and increase the amount market ready product.

4. Conclusion

The application of a sophisticated, robust camera system in combination with image processing algorithm can measure optical alternations of the drying product like shrinkage, deformation and color alternation in very precise and continuous way. The browning of organic apple slices showed a clear correlation to the humidity of the drying air, while the drying temperature only had secondary influence. The shrinkage and deformation of the product is mostly related to the moisture content of the product and the drying conditions seem not to influence the final shrinkage or deformation rate. Based on the achieved results an optimized control strategy for the industrial batch drier is suggested in which the product is first dried at low temperature and low humidity to reduce the browning effect, followed by short drying period at higher temperatures, which is finalized when the acceptable shrinkage and deformation is reached. This will result in a preservation process in which the drying conditions are continuously adjusted by the measured product changes. Such "Smart-Drying" systems require an advanced control system in which the process parameters like humidity and temperature are controlled by the actual optical conditions to improve the drying process with focus on product quality.

5. Nomenclature

BI	Browning Index	-
CIE-XYZ	color space according the ISO Standard 13655	-
x	Chromaticity value	-

6. Acknowledgement

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7. References

[1] Burger, W., Digital image processing : an algorithmic introduction using Java. 2016, New York, NY: Springer Berlin Heidelberg. pages cm.

[2] al., B.e., Definition of colour in the non enzymatic browning process. Die farbe, 1986. 32: p. 318-322.

[3] Hirschler, R., Whiteness, Yellowness and Browning in Food Colorimetry, in Color in Food: Technological and Psychophysical Aspects, M.d.P. Buera, Editor. 2016.

[4] Manalu, L., et al., The thin layer dring of temu Putih Herb, 2009