Agronomy Research **17**(S2), 1495–1500, 2019
https://doi.org/10.15159/AR.19.072

Utilization of image analysis for description of drying characteristics of selected tropical fruits

M. Wasserbauer[1], D. Herak[1,*], C. Mizera[1] and P. Hrabe[2]

[1]Czech University of Life Sciences Prague, Faculty of Engineering, Department of Mechanical Engineering, Kamycka 129, CZ16500 Prague, Czech Republic
[2]Czech University of Life Sciences Prague, Faculty of Engineering, Department of Material Science and Manufacturing Technology, Kamycka 129, CZ16500 Prague, Czech Republic
[*]Correspondence: herak@tf.czu.cz

Abstract. This study is focused on the utilization of image analysis for description of dimensions, and colours changes of fruits during drying process. Selected tropical fruits such are banana (*Musa acuminata*), mango (*Magnifera indica*) and pineapple (*Ananas comosus*) originally from North Sumatera in Indonesia were used in this experiment. Sliced pieces of the fruits were dried in experimental oven under temperature 90 °C for period of time 180 min and image of fruits samples were recorded by digital camera with HD resolution continuously throughout drying process. With aid of image analysis using Image J software and regarding to drying characteristics the colours and dimensions of the samples were analysed.

Key words: shape, dimensions, properties, mango, banana, pineapple.

INTRODUCTION

Understanding to the drying behaviour of tropical fruits is one of key factors which can strongly influence the quality and hence the sale price of final product (Mohsenin, 1970; Agrawal & Methekar, 2017). Tropical fruits such are banana (*Musa acuminata*), mango (*Magnifera indica*) and pineapple (*Ananas comosus*) are one of the main agricultural products of Southest Asia which are used in the production of drying commodities (Nakasone & Paull, 1998) and thus they are of great interest to food processors using ideas and theories of Industry 4.0 respectively Agriculture 4.0 with regard to high level quality of final products.

Nowadays in the era of Industry 4.0 it is necessary to use more accurate information as input data into virtual models or into artificial intelligence machines. Knowledge of the usual drying properties of agricultural products are not entirely sufficient and it is necessary to better understand to the changes of the shapes, dimensions, colours of dried fruits during whole drying process (Mongpraneet et al., 2002; Sharma et al., 2005; Adak et al., 2017). This precision information is also utilized in simulation models for the results` specification and verification (Petrů et al., 2012; Petrů et al., 2014; Mizera et al., 2017). In the current literature there are published studies focused on the drying characteristics (Karathanos & Belessiotis, 1997; Krokida et al., 2003; Soomro, 2014)

and several studies related to the dimensions' changes (Herák, 2016; Herák et al., 2018) however only few publications (Mizera et al., 2018; Salehi & Kashaninejad, 2018) are related to the description of the dimension, shape or colour changes in dependency on drying time.

Thus the aim of this article is to determine dependency between dimensions` changes, colour`s changes and drying time of banana (Musa acuminata), mango (Magnifera indica) and pineapple (Ananas comosus) with aid of image analysis.

MATERIALS AND METHODS

Sample

Banana (*Musa acuminata*), mango (*Magnifera indica*) and pineapple (*Ananas comosus*) obtained from Medan, Indonesia, were used for this experiment. Samples with diameter 20 mm and thickness 3 mm with following initial moisture content values, 77.7 ± 0.8% (w.b.) - banana, 87.5 ± 1.4% (w.b.) - pineapple, 86.6 ± 1.2% (w.b.) - mango, were prepared from peeled and sliced pieces of fruits (Fig. 1).

Drying experiments

Drying of samples were carried out in the experimental drying oven (CZU TF, Czech Republic) equipped with HD camera (EOS M10, Canon, Tokyo, Japan). Samples of all three fruits were placed on sieve in the oven (Fig. 1). To explore the effect of drying on the dimensions and colour of the samples the temperature of drying was set to 90 ± 1 °C. The process of drying was continuously recorded by HD camera with frame rates 25 fps for 180 min. Experiment was repeated three times.

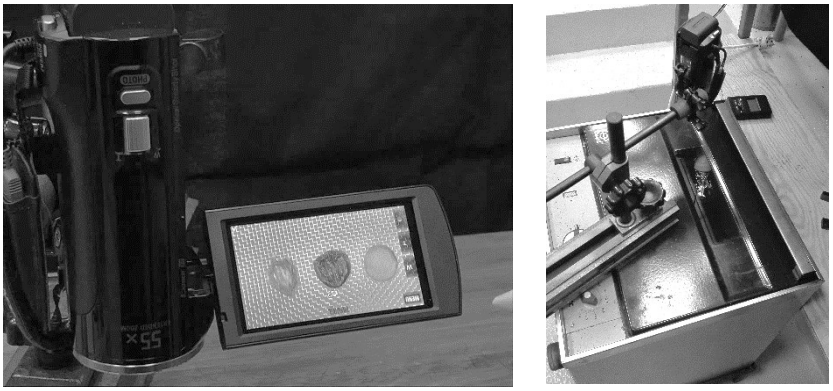

Figure 1. Experimental drying oven equipped wit HD camera.

Image analysis

Acquired pictures were analysed by the digital image analyses using Image J software, version 1.50b, that utilises java based image processing. The default threshold method based on IsoData algorithm was used in this experiment. Using Image J software dimensions of the samples, X (mm), Y (mm), and colour RGB histogram with mean of image intensity were determined for each picture (Fig. 2). Geometric mean diameter D_g (mm) was calculated using following equation (Eq. 1), (Mohsenin, 1970).

$$D_g = \sqrt{X \times Y} \quad (1)$$

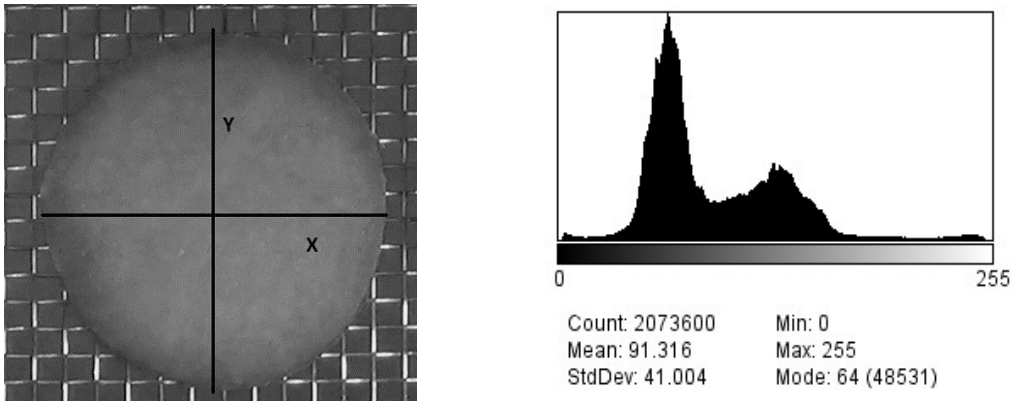

Figure 2. Determined dimensions of fruits` sample, image histogram.

RESULTS AND DISCUSSION

Selected images recorded at drying time of 0 min, 20 min, 40 min and 180 min are shown in Fig. 3. Individual samples are presented in the following order mango, banana, pineaple.

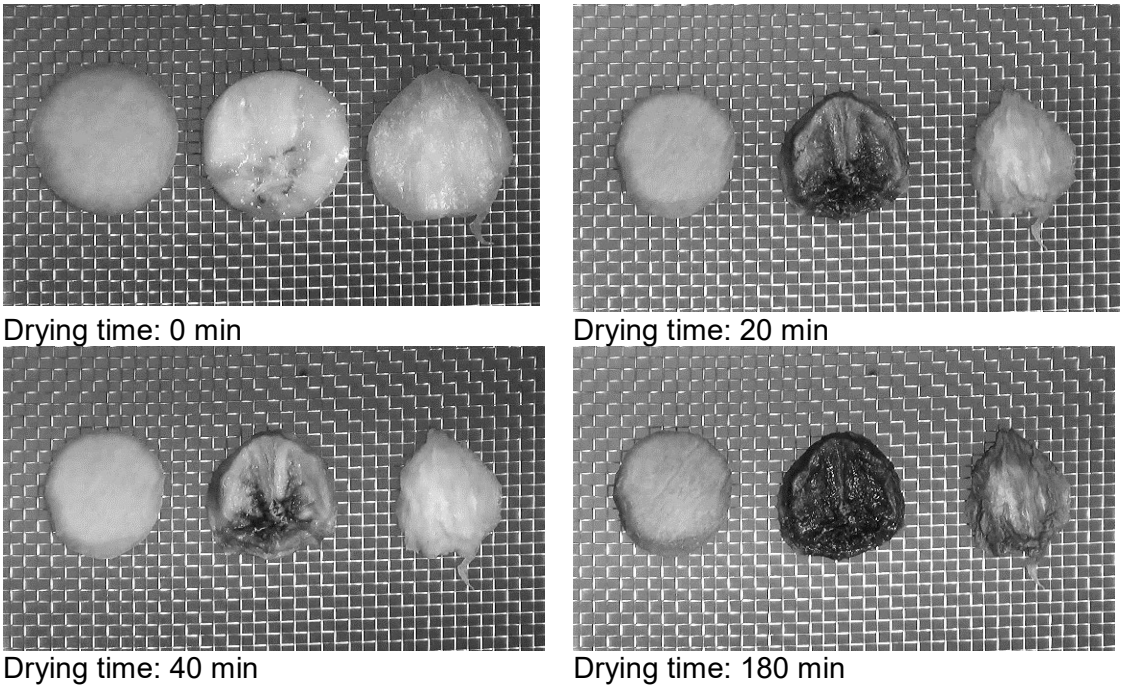

Figure 3. Selected images at given drying time. Order from left side: mango, banana, pineapple.

From determined dependencies between geometric diameter and drying time (Fig. 4) it follows that banana is more sensitive to dimension`s changes than pineapple or mango (Fig. 3). It is also evident that at drying time about 40 min the changes of dimensions were almost stopped and they can be considered as constant value. From the recorded images (Fig. 3) and dependency between image intensity and drying time

(Fig. 5) it follows that the colour`s changes were rapidly changed in interval from 0 to 40 min and after it the changes of colour became linear dependency.

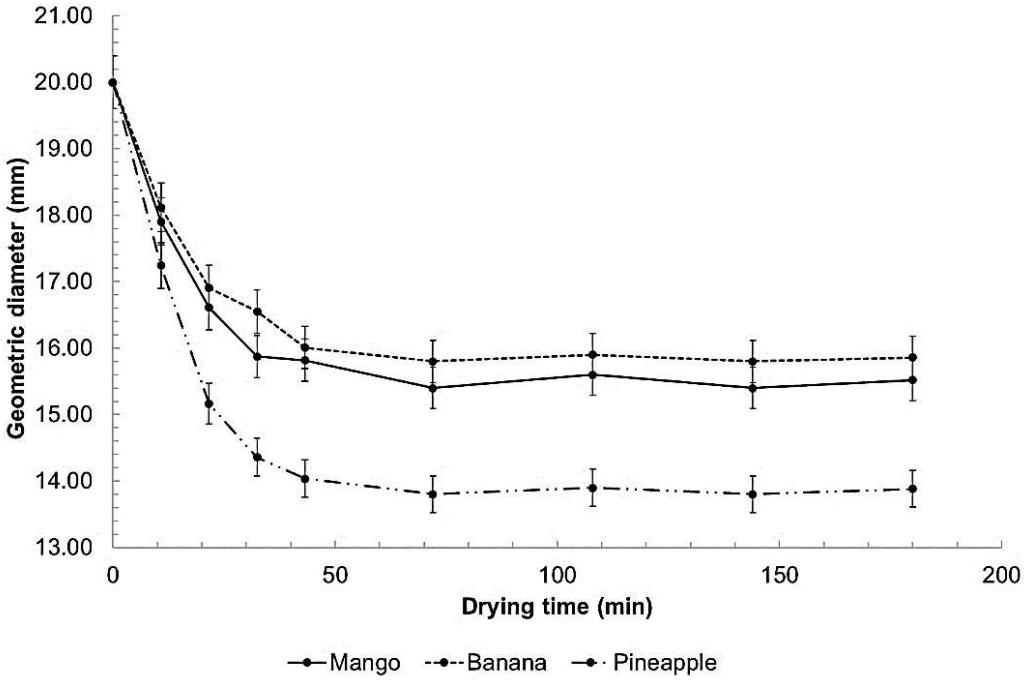

Figure 4. Dependency between geometric diameter and drying time.

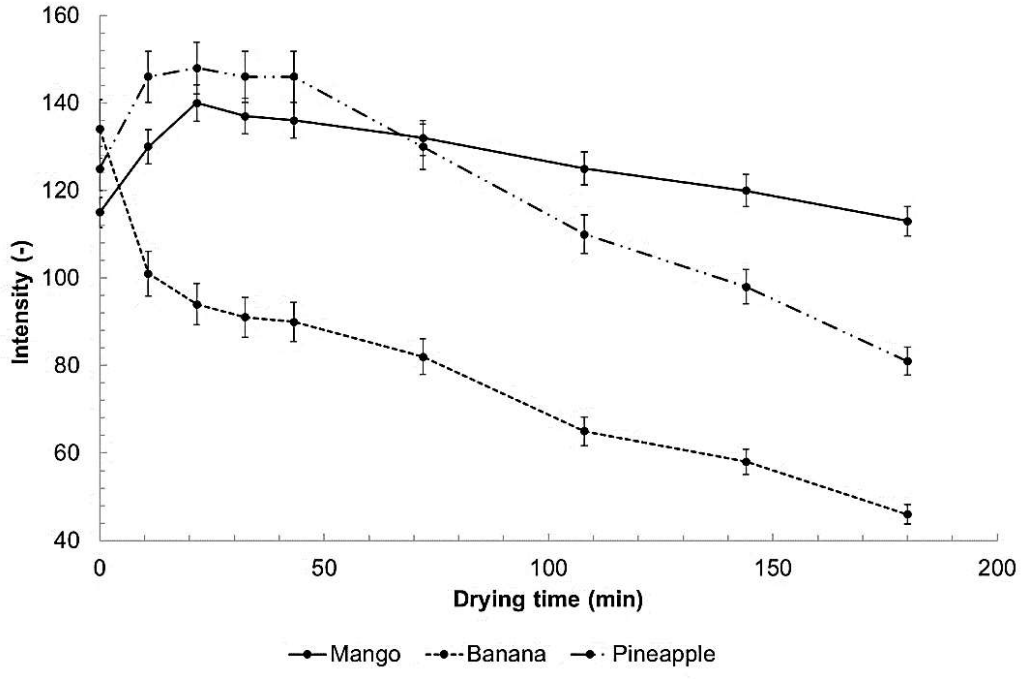

Figure 5. Dependency between image intensity and drying time.

From the beginning of the drying process the image intensity of mango and pineapple were increased and image intensity of banana was decreased (Fig. 3, Fig. 4). At drying time about 30 min the image intensity of mango and pineapple changed to linear declining trend and image intensity of banana continued at linear declining trend. Practically it means that during first 30 min of drying process the colour of mango and pineapple were very quickly brightened and the colour of banana was very quickly darkened. During last 150 min of drying process the colour of all fruits were slowly darkened. From determined results implies that conducted drying process can be divided into two intervals, first interval where the changes of dimensions and colours have nonlinear dependencies on the drying time and they occur very quickly, and second interval where the changes of dimensions are almost unobservable and changes of colour become linear dependency on drying time. This statement is in accordance with already published study related to the colour changes of lemon slice during the combined infrared-vacuum drying (Salehi & Kashaninejad, 2018).

According to the already published studies the differences in individual characteristic of colour and dimension changes are given by the structure of the sample being dried and the mechanism of internal liquid migration and it is strongly linked to the initial moisture content (Simović et al., 2016). Some previous authors determined, that moisture diffusion represents the dominant physical mechanism affecting drying characteristics (Singh & Gupta, 2007; Xiao et al., 2010). This effect can also be seen in the drying of different agricultural products indicating that the absence of constant water supply to the sample surface lowered the drying rate, which is expressed through the rapid decline of drying rate values (Stamboulis et al., 2001; Mizera et al., 2017). The gained results and knowledge in this study can be used as background for further research related to the modelling of drying behaviour under different drying temperatures, modelling of mass changes or modelling of heat transfers.

CONCLUSIONS

Dependencies between colour`s changes, dimension`s changes of mango, banana and pineapple and drying time were determined with aid of image analysis.

From determined results implies that conducted drying process can be divided into two intervals, which are given by drying time (0 to 40 min), (40 min to 180 min) for dimension`s changes and (0 to 30 min), (30 min to 180 min) for colour`s changes.

First interval where the changes of dimensions and colours have nonlinear dependencies on the drying time and they occur very quickly, and second interval where the changes of dimensions are almost unobservable and changes of colour become linear dependency on drying time.

Gained results in this study could be used for the development of further models of fruits` drying process and to design technology in the new era of Industry 4.0 respectively Agriculture 4.0.

ACKNOWLEDGEMENTS. This paper has been supported by Internal Grant Agency of Faculty of Engineering – Czech University of Life Sciences Prague – IGA 2018: 31130/1312/3110.

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