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Micro structural approach of potato and pumpkin drying and rehydration

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ABSTRACT

The food structure is subjected to a change of the integrity during dehydration which will affect rehydration. Changes in the underlying microstructure of this deformation and rehydration generally fails in restoring the integrity and quality of the food material to the original status. In this context, there are not many studies performed which correlate cellular structural changes to the desorption-sorption behaviour of food materials after dehydration. This study was undertaken to understand desorption-sorption behaviour of food considering potato (cv *Sebago*) and pumpkin (cv ecotype) as the model materials during drying and further explanations on rehydration. Pumpkin was used to construct only for dehydration and rehydration graphs. For potato SEM images were taken for dehydration and rehydration. Corresponding behaviours show the irreversible trend of dehydration-rehydration exists and changes to the scenario of relationship of the cellular structure.

Keywords: Hot air drying, Potato, pumpkin, shrinkage, rehydration, cell damage.

1. INTRODUCTION

Microstructure studies are important in studying the dehydration and rehydration characteristics in food materials. Generally, the food microstructure can be identified as a large network comprising small subunits called cells. A cell normally contains about 90%-95% of water of its volume (Taiz L. and Zeiger E., 2002) in natural form. Hence, water removal from the cells during dehydration results the structural changes of the food material which can be commonly observed. Rehydration is a process to hydrate the dried material. Although this is not exactly the reverse of dehydration, certain amount of water is absorbed by the cellular structure and there are effects from case hardening of the material (Karunasena et al., 2015). However, depending on the parameters such as food material, dehydrated temperature (Senadeera, 2008) the desorption-sorption characteristics behaviour of the material may vary. The food industry develops many products worldwide and there is a demand for improving technologies within this field. By examining the microstructure of food materials throughout the drying and rehydration process, trends in energy consumption and transfer may be found.

Rehydration is an important quality indicator as it is a measure of the injury to the product caused by drying. The hysteresis that exists in the product after rehydration is attributed to the product changes that occur during drying (Krokida and Philippopoulos, 2005, Krokida and Marinos-Kuoris, 2003). The rehydration rate and extent largely depend on the porosity, structural disruption and surface and capillary structure (Ngamwonglumlert, and Devahastin, 2017). In plant matrices, the capacity of cell walls to bind and hold water determines the rehydration and textural characteristic (Prothon et al., 2003).

Also, rehydration is a complex phenomenon affected by various factors such as drying method, physical structure, chemical composition, and drying and rehydration medium characteristics. It is therefore expected that the porous microstructure and porosity will play important roles in the rehydration mechanism (Marabi and Saguy, 2004).

This study aims to study the desorption-sorption characteristics of food material quantitatively and to qualitatively explain the non-reversibility of drying by rehydration using Scanning Electron Microscopy (SEM) images. Accordingly, potato and pumpkin are subjected to rehydration followed by dehydration to observe the corresponding behaviours. Potato was used for SEM image analysis under fresh, dried, and rehydrated conditions.

2. MATERIALS PREPARATION

The pumpkin used in this study is a C. *maxima* ecotype as "di Teggiano" which is cultivated in Campania region, Italy. Fresh whole pumpkin was washed, peeled, sliced. Cylindrical slices with a diameter of 30 mm and thickness of 6 mm were prepared using a suitable steel mould. The zone near the peel (< 10 mm) was removed because of its different texture. The average initial moisture content was 0.93 of g/g (wb) of sample (or on dry basis (db) 15.23$\pm$0.05 g/g db) (AOAC, 1990). But prior to experimentation they were kept in the laboratory and resulted in different moisture contents at the beginning. The potato used in these experiments is *Sebago* commonly cultivated in Australia. For the experiments, fresh potato was washed, peeled, and cut into cubes of 1 cm x 1cm x 6 mm dimensions from the interior part of it. The zone near the peel (<10 mm) was removed because of its different texture.

Drying and rehydration kinetics: Experimentation

The pumpkin and potato (initial sample weight 0.5 kg) drying experiments were conducted at constant temperatures at 55, 60, 65 and 70°C using a convective dryer (Zanussi FCV/E6L3) with a constant air flow rate of 2.3 m/s, until they reached safe moisture content under 5% (wet basis). During drying, potato samples were withdrawn from the dryer at fixed times and their weight was measured by a digital balance (model Gibertini E42, Italia). The results were reported in terms of moisture content as the amount of moisture removal with time. Drying tests were replicated three times at each inlet air temperature and averages were taken to represent final values. Potato was dried at 70^0C using the convective dryer. Potato and Pumpkin samples were kept in a desiccator at room temperature before subject to rehydration experiments. During rehydration experimentation, potato and pumpkin samples were rehydrated in distilled water at 25°C until constant water content was reached. Approximately 1g of dried samples was added to 100mL distilled water. The samples were removed, dried off with tissue paper and weighed at regular intervals until constant water content was reached. Time of saturation was varying and more than 30 min. Weights of dried and rehydrated samples were measured using an electronic digital balance (mod. Gibertini E42, Italia). The measurements were repeated three times. Rehydration graphs were constructed only for Pumpkin. The amount of water added used in the Y-axis and times are in min in the X-axis. Potato SEM images were taken at the beginning of drying, end of drying and after rehydration.

SEM images for potato samples

SEM images were obtained from fresh, dehydrated, and rehydrated potato samples. Samples were prior coated with a thin layer of gold in a sputter coater for 150 s. SEM images were obtained for the potato samples under resolutions of 100x, 300x and 600x.

3. RESULTS AND DISCUSSION

At the end of drying at 55°C, 60°C, 65°C and 70°C temperatures moisture content was measured, and drying curves were constructed. After keeping the samples to cool down to the room temperature in a desiccator. At the beginning of rehydration, moisture showed a lesser value shown in the graphs (Fig 1-4) of rehydration may be due to further moisture reduction due to absorption of moisture by desiccant during cooling process and facilitate it by the opening of the structure of the food material at the end of drying to the environment.

Rehydration tests were performed, and respective moisture contents were measured until the sample was saturated. Resulting drying and rehydration curves are shown in Fig 01, Fig 02, Fig 03, and Fig 04 below. When constructing the graphs two horizontal time axes were constructed for rehydration (top) and dehydration (bottom) to follow the moisture reduction and absorption in the same graph axes.

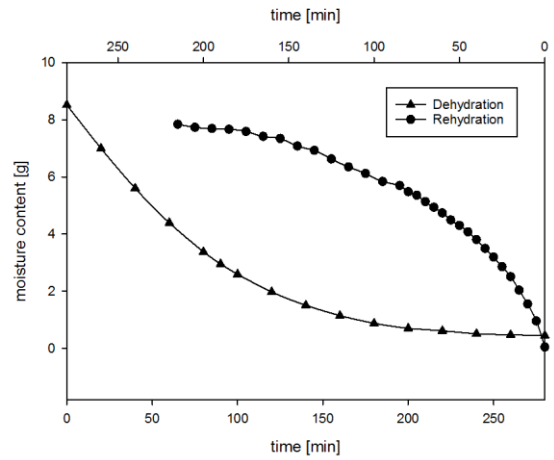

Fig 01: Dehydration-Rehydration curve for 55°C

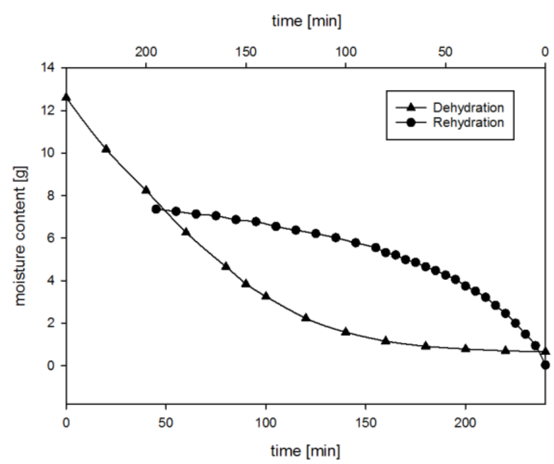

Fig 02: Dehydration-Rehydration curve for 60°C

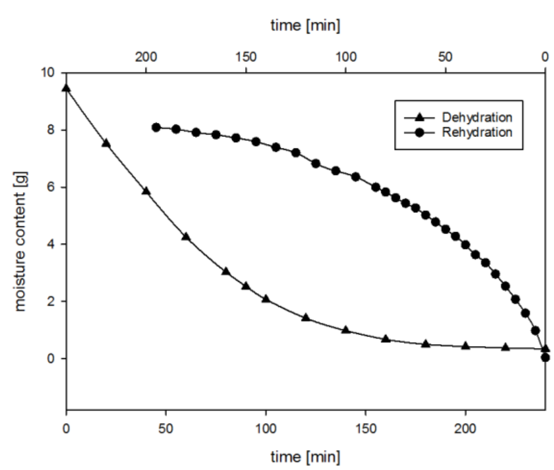

Fig 03: Dehydration-Rehydration curve for 65°C

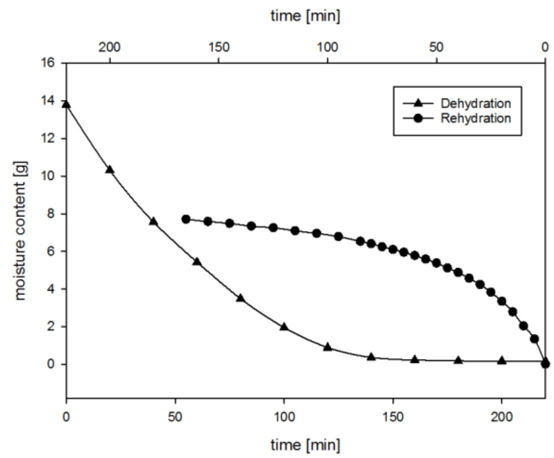

Fig 04: Dehydration-Rehydration curve for 70°C

According to the figures (1 to 4), it is obvious that no sample could recover up to its initial moisture content by the time of saturating the structure. Also, it is obvious that, for most cases, moisture recover ability of the food samples decreases as the drying temperature increases. This fact strongly indicates that the structural collapse is proportional to the drying temperature for pumpkin as a food material.

Potato drying SEM images shown at different magnification from Fig 05 to Fig 08. Following the SEM images, referring to Fig 07 and Fig 08, the dehydrated structure shows an open cellular structure and cell geometry shows a deformation compared to fresh condition depicted in Fig 05 and Fig 06. It was obvious that there was a change in the micro-structure.

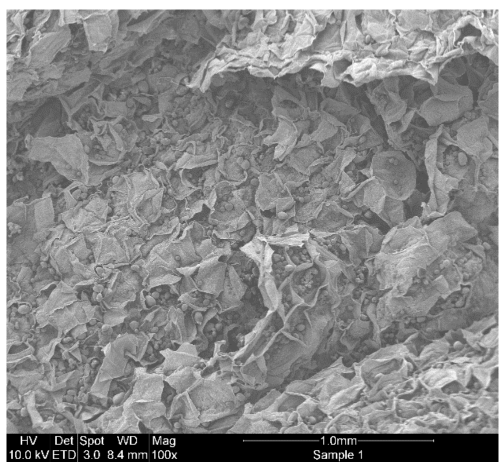

Fig 05: SEM image before drying (100x)

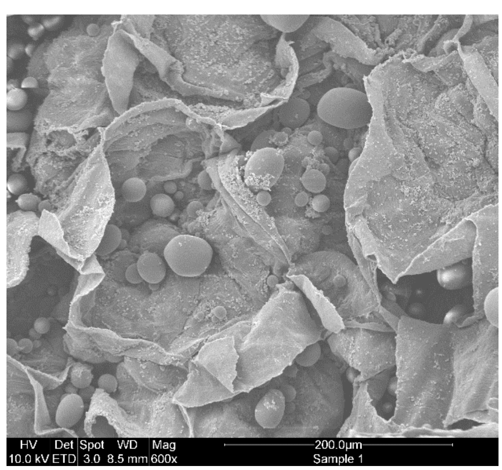

Fig 06: SEM image before drying (600 x)

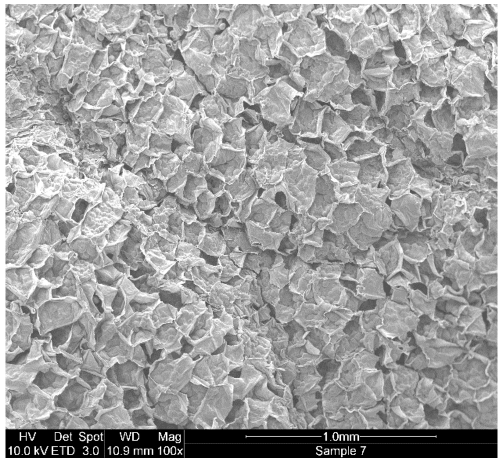

Fig 07: SEM image after drying at 70°C (100 x)

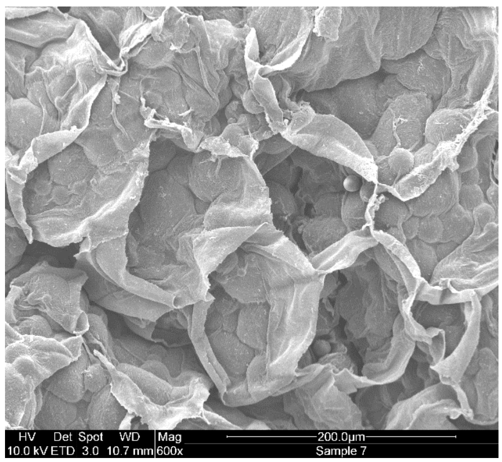

Fig 08: SEM image after drying at 70°C (600 x)

However, after rehydration this microstructure changes to a closed type of cellular structure as shown in Fig 09 and Fig 10.

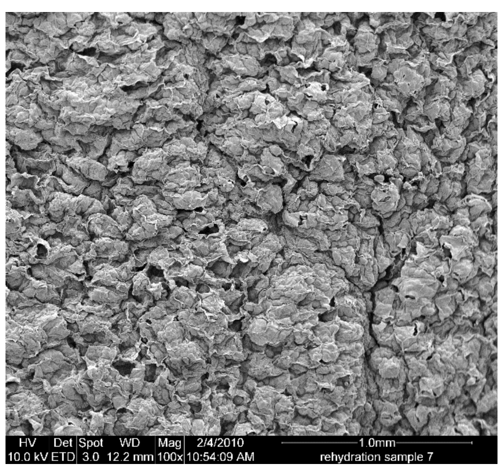

Fig 09: SEM image after rehydration (100 x)

Fig 10: SEM image after rehydration (600 x)

In this state water holding capacity by the cells is restricted. This causes the bursting of structure upon further water insertion. Also, compared with Fig 05 and Fig 06, it can be observed that original microstructure cannot be recovered at the end of rehydration. As explained earlier, structural collapse of the microstructure causes this. According to these curves and SEM images, it can be deduced that, as the internal moisture is evaporated, the cell is shrunken and hence the cell volume decreases. Due to this reduction of volume, water required to fill the cell volume is comparatively low. Therefore, at higher dehydrated temperature levels, food material gets saturated with comparatively less amount of water and further addition of water results the breakage or bursting of the food material.

For this kind of studies try to quantify the extent of damage of the structure need to be quantified. The common practice of modelling several isotherms (eg. Freundlich, Temkin and Langmuire isotherms) are used to fit the experimental data for discussing observations (Tunc and Duman 2007; Taiytano yet al., 2012 and Hunt and He, 2015). Also need to link SEM pictures to dehydration -rehydration curves. This may be a prospect for future work

4. CONCLUSIONS

This study shows that the structural damage caused by the dehydration cannot be restored by rehydration. Therefore, rehydration can be used as a tool to quantify the internal damage of the food structure. This fact is also suggested by (Krokida and Marinos-Kouris, 2003). Further, according to the SEM images it can be concluded that shrinking of cells during dehydration limits the water recovery capacity to the food material. However, it should be noted that, in case of the development of porous structure while dehydration, this observation may change as the porous structure is also capable of absorbing water.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Hunt, J. F. and Z. Hee, 2015. Characteristics of plant-derived water-extractable organic matter and its effects on phosphorus sorption behaviour., p. 99-118, In Z. He and F. Wu eds. Labile Organic Matter-Chemical compositions, Function, and Significance in Soil and the Environment.SSSA Spec. Publ. 62. Soil Science Society f America, Madison, WL.
2. Krokida, M. K. & Marinos-Kouris, D. 2003. Rehydration kinetics of dehydrated products. Journal of Food Engineering, 57, 1-7.
3. Krokida, M. K. and Philippopoulos, C., 2005, Rehydration of dehydrated foods, Drying Technology, 23, 799-830.
4. TAIZ L. & ZEIGER E. 2002. Plant Physiology, Sinauer Associates,Inc.,.
5. Marabi, A. and Saguy, S. 2004, Effect of porosity on rehydraton of dryy food particulates, Journal of the science of Food and Agriculture, 84: 1105-1110
6. Ngamwonglumlert, L.; Devahastin, S., 2017, Microstructure and Its Relationship with Quality and Storage Stability of Dried Foods; Elsevier Ltd.: Amsterdam, The Netherlands,;
7. Prothon, F.; Ahrné, L.; Sjöholm, I., 2003, Mechanisms and Prevention of Plant Tissue Collapse during Dehydration: A Critical Review. Crit. Rev. Food Sci. Nutr., 43, 447–479.
8. Karunasena, H. C. P., Gu, Y. T., Brown, R. J. and Senadeera, W. 2015, Numerical investigation of case hardening of plant tissue during drying and its influence on cellular level shrinkage, Drying Technology 33(6), 713-734
9. Senadeera, W., 2008, The drying constant and its effect on the shrinkage constant of different-shaped food particulates, International journal of Food Engineering 4(8), 1-16
10. Taitano, L., Singh, R., Lee, J. and Kong, F. (2012) Thermodynamics analysis of moisture adsorption isotherms of raw and blanced almonds. Journal of Food Process Engineer., 35, 840-850.
11. Tunc, S. and Duman, O. (2007) Thermodynamic properties and moisture adsorption isotherms of cottonseed protein isolate and different forms of cottonseed samples. Journal of Food Engineer., 81, 133-143.