CHAPTER 1 INTRODUCTION

1.1 Research Rationale

During drying moisture migrates from inner cells through the porous structure to the surface of food and then to the surrounding environment. Loss of moisture leads to deformation of food microstructure. Investigation of food microstructural changes is important because these changes are directly related to apparent physical characteristics of dried food, e.g., size, shape and texture, which directly affect its quality and consumer acceptance (Ramos et al., 2003; Mayor and Sereno, 2004; Mayor et al., 2007). Since the relationships between physical and microstructural changes could help design and identify an appropriate drying process and condition, several studies have been made to investigate such relationships of various food products undergoing different drying processes at different conditions (Riva et al., 2005; Askari et al., 2009; Yang et al., 2010; Gumeta-Chávez et al., 2011).

Although microstructural changes of food during drying (or any other processing) can be investigated using various microscopic techniques, e.g., light microscopy (LM), scanning electron microscopy (SEM) or stereomicroscopy (Marousis and Saravacos, 1990; Nussinovitch et al., 2004; Lewicki and Pawlak, 2005; Mayor et al., 2005; Kerdpiboon and Devahastin, 2007), these microstructural changes cannot be easily quantified without the use of appropriate evaluation algorithms. Recently, fractal analysis is among the techniques that have been proposed to tackle this difficulty. Quevedo et al. (2002), for example, conducted the fractal analysis of the microstructure of potato cells and used the calculated fractal dimension to describe the microstructural changes of potato during frying. Zhu et al. (2004) applied fractal analysis to monitor stress cracks in corn kernels, which were caused by rapid drying at high temperatures. Fractal dimension has indeed proved to be capable of being a quantitative indicator of the microstructural changes of many food products such as agar-fruit undergoing freeze drying, cane sugar undergoing crystallization, dough undergoing baking, protein gels prepared at different pH conditions (Nussinovitch et al., 2004; Dàvila et al., 2007; Pérez-Neito et al., 2010; Velazquez-Camilo et al., 2010).

Although there are attempts to use fractal dimension to quantify the microstructural changes of food products undergoing different processes, few studies have applied fractal dimension to correlate the microstructural changes to physical characteristic changes during processing. Kerdpiboon and Devahastin (2007) were among the first to propose the relationships between microstructural and physical changes of food during drying using fractal dimension. The results showed that the physical changes correlated well with the normalized changes of the fractal dimension ($\Delta FD/FD_0$) of the sample microstructural images. Fractal dimension has also proved to be a good structure-quality index of other food products undergoing other thermal processes, e.g., shrimp undergoing boiling (Niamnuy et al., 2008).

Despite some studies on the relationships between microstructural and apparent physical changes of various foods undergoing different drying processes at different conditions, such relationships have not yet been generalized and are specific to the tested drying methods and conditions. It is therefore desirable to develop a generalized indicator for monitoring the microstructural changes of a food product undergoing various drying processes and conditions. This indicator should be able to correlate the microstructural changes to some physical changes that take place during drying as well.

From the above-mentioned arguments it was the aim of this study to develop a generalized indicator that could be used to monitor microstructural changes of a test food material viz. carrot cubes undergoing three representative drying methods, i.e., hot air drying, vacuum drying and low-pressure superheated steam drying. Two types of indicators, i.e., normalized change of the fractal dimension ($\Delta FD/FD_0$) of the sample microstructure and normalized change of the average sample cell diameter ($\overline{\Delta D}/\overline{D_0}$), were tested. $\Delta FD/FD_0$ represents the normalized change of the shape of cell walls and intercellular spaces of a sample, while $\overline{\Delta D}/\overline{D_0}$ represents the normalized change of the cell volume (or, in other words, the cellular dimension) of a sample. The two indicators were compared because $\Delta FD/FD_0$ quantitatively represents both the irregularity of the cellular structure and of the intercellular space, while $\overline{\Delta D}/\overline{D_0}$ considers only the change of the sample cell volume. Further investigation was also made to verify the capability of the tested indicators as a generalized structure-quality indicator to correlate the microstructural changes to selected apparent physical characteristic changes, i.e., shrinkage and hardness.

1.2 Objectives

1. To study the effects of various drying methods and conditions on microstructural and some physical changes of a food material.

2. To verify the use of a generalized indicator to monitor microstructural changes of food undergoing different drying methods at different conditions.

3. To verify the capability of the tested indicators as a generalized structure-quality indicator to correlate the microstructural changes to selected apparent physical characteristic changes of a food material.

1.3 Scopes

1. Studying the effects of various drying methods, namely, hot air drying at temperatures of 60 and 80 °C, vacuum drying as well as low-pressure superheated steam drying at temperatures of 60 and 80 °C and an absolute pressures of 7 kPa, on the microstructural changes as well as selected apparent physical characteristic changes, i.e., shrinkage and hardness of a test food material viz. carrot cubes.

2. Verifying the use of two generalized indicators, i.e., normalized change of the fractal dimension ($\Delta FD/FD_0$) of the sample microstructural images and normalized change of the average sample cell diameter ($\overline{\Delta D}/\overline{D_0}$), to quantitatively monitor the microstructural changes and their relationship with the moisture content of a test food material viz. carrot cubes during various drying methods and conditions as outlined in Scope # 1.

3. Verifying the capability of the tested generalized indicators ($\Delta FD/FD_0$ and $\overline{\Delta D}/\overline{D_0}$) to correlate the microstructural changes to selected apparent physical characteristic

changes (i.e., shrinkage and hardness) of a test food materials viz. carrot cubes during various drying methods and conditions as outlined in Scope # 1.

1.4 Expected Benefits

1. Quantitative information on the microstructural changes of food as a function its moisture content during drying, which is useful for optimization of a drying process.

2. A generalized structure-quality indicator that can be used to monitor and control a drying process to obtain a high-quality food product.