Experimental study of stale bread drying in a convective dryer using design expert

S. Heirani¹, S. Nanvakenari², K. Movagharnejad³,*

1. Bachelor student, Faculty of Chemical Engineering, Babol Noshirvani University of Technology.
2. Phd student, Faculty of Chemical Engineering, Babol Noshirvani University of Technology.
3. Professor, Faculty of Chemical Engineering, Babol Noshirvani University of Technology.

movagharnejad@yahoo.com

Abstract
The stale bread drying is one of the best economical ways to prevent wastage of bread and prevent cancer in animals. In this study, the effect of convective dryer on drying time, energy consumption and water activity of stale bread were investigated. For this purpose, the design expert software is used to design the tests and investigate the impact of the temperature and velocity of the inlet air in the convective dryer on drying time, energy consumption and water activity of samples. The results of these studies showed that the laboratory data are in good agreement with the predicted data.

Keywords: Stale Bread, Convective Dryer, Energy consumption, Water Activity, Design Expert.

1. Introduction
Food is one of the basic needs of living organisms, the main problem being the inability to maintain these products. Due to the low price and quality of traditional bread that is cooked in Iran, a large volume of bread waste is has been produced in recent years[1]. The drying process is one of the most important processes in the food industry. Drying is one of the common methods of preserving food and crops, preventing microbial growth, increasing shelf life, significantly reducing the crop weight, and reducing the costs such as warehousing, transportation, and packing [2,3]. Selecting the correct drying method is very important as it saves time and cost and improves the quality of the final product. Mustafa et al. used a combination of convective and infrared dryer in 2016 to dry stale bread. Their results showed that the infrared lamp improves the drying process [4]. In 2005, Tireki et al. conducted a study to investigate the feasibility of using microwave-infrared dryers to dry bread slices with the highest quality. The results of this study indicated that the reduction of drying time in microwave-infrared dryer was more than the reduction of drying time in each of these dryers individually [5].

Considering the importance of the need of stale bread drying and its impact on the health of livestock, poultry and humans and Since little research has been conducted to investigate the effect of drying methods on staling bread, This study was designed to evaluate the effect of convective dryers on drying time, energy consumption and water activity of dried bread as well as its drying kinetics.
2. Materials and Methods

2.1 Materials

In order to investigate the effect of convective dryers methods on the drying time, energy consumption and water activity of stale bread, experiments were designed with design expert software. Bread samples were purchased from a bakery in Babol. The bread was kept in the freezer bags for 50 to 60 hours after purchase to fully stale. After staling, we cut 30 grams of bread into square pieces with a 2.5 cm inclination by ruler and scissors. The initial moisture content of the bread was measured on a wet weight basis and as a percentage by the AND MX-50 moisture meter. The initial moisture content of all samples was approximately equal to 25-30% based on wet weight. The samples were dried until they reached 8% on a wet weight basis moisture content.

2.2 Methods

The samples were dried by convective drying methods. In the convective drying section, the ambient air flows by a suction fan passing through a heater that has various elements. Depending on the temperature and current intensity, the heating and the blower speed is manually changed. The airflow enters the sample chamber at the desired temperature and intensity and flows to the outlet valve after absorbing moisture. The outlet air flow from the sample chamber has a higher temperature than the ambient temperature and its humidity has increased due to the absorption of moisture from the samples. In order to use the outlet air flow heat, a shell and tube converter is used at the beginning of the inlet air flow. The outlet air passes through the converter and helps to heat the converter pipes and thus the inlet air flow. This helps to prevent heat loss of outlet air from the sample chamber and also saves energy. Humidity and temperature measuring sensors are embedded in the inlet and outlet pipes. The machine has a power panel and monitor to display humidity and temperature of inlet and outlet air. The whole machine is mounted on a stainless steel chassis.

2.3 Experimental design

The software used in this design is Design Expert Version 7. The independent variables are air inlet temperature and velocity. In this study the central composite design of response surface methodology was used for convective dryer. 13 experiments were designed which are shown in Table 1.

3. Results and discussion

3.1 Statistical Analysis

Quadratic models that are a function of inlet air temperature (A) and inlet air velocity (B) are predicted for process responses that are drying time, energy consumption and water activity that the results of which are reported in Table 2.
The data shown in Table 2 indicate that since p values are less than 0.05 for all models, then all models are acceptable. Lack of fit describes the variety of data appropriate around the model. Values greater than 0.05 p value for LOF indicate significant model correlations between variables and process responses. The higher the correlation coefficient R2, the closer it is to 1, it is desirable and Indicates that the laboratory and predicted data are in good agreement that As our data shows, R2 is an acceptable value for all models. Figure 1 shows the predicted data in terms of their actual values in the convective dryer. These figures show that there is good agreement between the laboratory data and the predicted data by the design expert.
Figure 1. Predicted versus actual data plot for a) drying time, b) Energy consumption, c) water activity in convective dryer.
3.2 Process Analysis
The 3D graphs of the process responses for convective dryer are shown in Figures 4.

As we can see in Figure 4, as the temperature increases, the drying time, energy consumption, and water activity decreases, increases and decreases, respectively. And as the velocity increases, the drying time decreases, the energy consumption at high temperatures increases,
and at low temperatures is almost constant, the water activity at low temperatures increases, and at high temperatures is almost constant.

4. Conclusion

In this study, the drying process of Sangak bread with initial moisture content of 25-30% based on wet weight was investigated in convective dryer to achieve final moisture content of 8% based on wet weight. The results showed that the drying time of the samples, the energy consumption and water activity decrease, increase and decrease, respectively with increasing the air inlet temperature. And with increasing the velocity, the drying time decreases, the energy consumption at high temperatures increases, and at low temperatures is almost constant, the water activity at low temperatures increases, and at high temperatures is almost constant.

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References