Effect of storage time on the drying process of restaurant food waste

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Introduction

To date, there are no physic models to describe exactly the drying process. Drying is a complex physic process which depends on diffusion and convection phenomena. It is very important to model the stages in the drying process effectively. For that, drying curves are usually fitted with empirical, semi-empirical or semi-theoretical mathematical functions. Modelling the dehydration process is essential due to the complexity of the various physical processes that take place and because each feedstock has its own unique physical complicated structure (Jeong et al., 2014). Modelling is critical especially in full scale plants where significant amounts of feedstock are used leading to elevated energy demands. The most critical parameter that should be described during an air drying process within an integrated biowaste valorisation treatment train are the retention time necessary for the efficient dehydration of waste. Thus, tailored design of biowaste dryers is essential for the viability of such plants. To this end, given that the dehydration process of food waste has not been extensively reported in literature, mathematical models were developed. The effect of waste storage time was also evaluated.

Materials and Methods

Restaurant Food Waste

The raw material utilised in the present study was collected from the university restaurant in the National Technical University of Athens, Greece. It mostly contained losses and wastes of raw food during food making plus food scraps, leftover foods and rotten raw foods. It was source-separated and transferred to UEST (Unit of Environmental Science and Technology) in the Chemical Engineering School, NTUA, Greece.

Storage

Before drying, the collected food waste was stored in closed bins of 50 L, at room temperature (17-20ºC).

Dehydration

The restaurant food waste delivered was milled and dehydrated using a rotary drum dryer (GAIA GC-100) upon arrival or after the predetermined storage time (5-30 days with a 5-d step). Dehydration was carried out at 120°C until a final moisture content of 0.8±0.2 kgH_2O/kg TS was achieved aiming to avoid microbial development and alterations in the feedstock's composition. Homogeneous coarse powder feedstock was produced after this process. The volume of the produced condensate was measured at regular time intervals. After the dehydration process, both the dried food waste and the collected moisture condensate were characterized.

Analytical methods

The volatile fatty acid (VFA) concentration was measured by using the Spectroquant Volatile Organic Acids Test Kit of Merck Co. In addition, Total organic carbon (TOC) was measured by applying the Solid Sample Module (SSM5000A) of the SHIMADZU TOC-VCSH (total organic carbon analyser). All analyses were performed in triplicate.

Results and discussion

Figure 1 illustrates the evolution of normalized moisture content X_R versus time obtained on the sampling day and after the predefined storage times. The dimensionless moisture ratio X_R is defined as:

$$X_r = \frac{X_t - X_e}{X_0 - X_e} \qquad \text{Equation 1}$$

where X_0 is the initial, X_e the equilibrium and X_t the moisture content at time t.

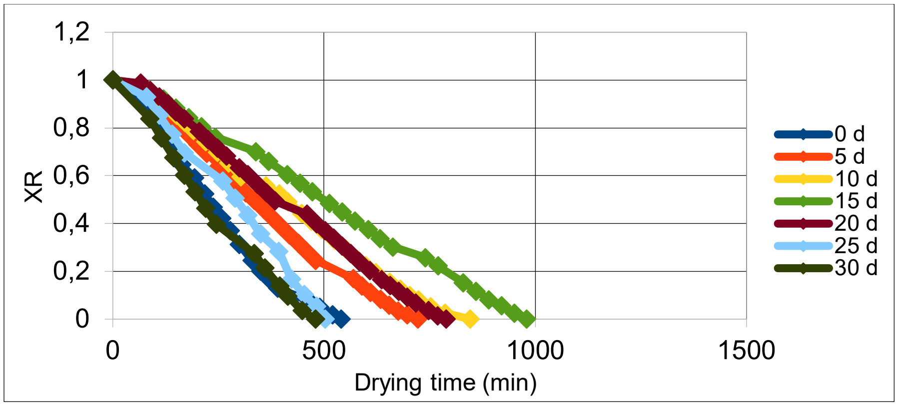

Figure 1. Effect of storage time on the normalized moisture content X_R versus time during drying of restaurant food waste

It is evident that the moisture content of the samples decreases with time. The drying kinetics are clearly affected by storage duration: from fresh waste and up to 15d of storage time, the older the waste, the slower the loss of mass, while longer storage times (from 15 to 30d) resulted in increasing rates of mass loss. The loss mass rate decreased while moving from the fresh waste (0.002min^{-1}) to 15d storage reaching a minimum of 0013min^{-1}. Longer storage times (over 15d) led to a faster loss of mass reaching 0.021min^{-1} for 30d storage time.

The drying curves were fitted with the main mathematical models proposed for the drying of agricultural products (Gómez-De La Cruz et al., 2015). Ten mathematical models were used to approximate the drying curves by non-linear regression analysis. The criteria such as coefficient of determination, R^2 was used to verify the quality of fit. In all cases R^2 was over 0.88 and mathematical models can be described as satisfactory. Nevertheless, the mathematical model that provided the best fit for all storage times was Gauss with R^2 over 0.994 for all cases. Up to 5d storage time, the modified Page model could describe the drying kinetics efficiently, while for longer storage times the logarithmic model was a better choice. Sotiropoulos et al. (Sotiropoulos et al., 2016) also studied the kinetics of household food waste drying and concluded that Midilli model and Page equation presented the optimum fitting results. This could be attributed to the different drying equipment or the different conditions applied.

Conclusions

The current practices applied in the collection schemes of source-separated food waste in most cases include a varying storage time under uncontrolled conditions. Additionally, it has been acknowledged that a dehydration step is necessary within an integrated valorisation of food waste. The drying kinetics of food waste was studied in this work. The drying curves were fitted in mathematical models proposed in literature and Gauss model proved to describe best the drying process. The results of this work can stand as a pillar in the design of large scale food waste drying systems.

Reference

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