A Study on a High Efficiency Dryer for Food Waste

Bum-Suk Kim*, Chang-Nam Kang** and Ji-Hyun Jeong**†

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Abstract: The food waste that occurs in one year is very high in our country and disposal is expensive. However, disposers for food waste are not used wisely at real life. This is because most of them some kind of problem, for example big volume, complicated construction, high cost, lots of troubles, low energy efficiency and so on. In this study, we propose the new dryer system to decrease drying times by injecting hot air in down the side of the drying bucket. The designed drying bucket has inclined inlet holes down both sides. The inlet holes have variable gradients, we adjust the inlet velocity of the hot air to find a suitable vortex in the drying bucket. We verify the properties of the proposed system through simulation. The results show the proposed dryer system can improve the drying time and save energy for food waste disposal.

Key Words: Food waste, Disposer, Dryer, Drying bucket

1. Introduction

The food waste accounts for about 28% of all waste generated in our country each year. The cost of disposal is assumed to be over four hundred billion won per year. In times past, this food waste was foraged or used as manure. These days farmers dislike this practice because the waste has a lot of salinity and most of it is fermented food. So, a new method to deal with food waste has become necessary lately. Typically, food waste occurs in homes and restaurants and it contains a large volume of water. Furthermore, it often smells bad.

Therefore, it is difficult to handle. Also, the food wastes should be thrown out after it is collected in a bottle or plastic bag after a few days. In this way it goes bad easily and produces a horrible stench from bacteria. So, problems in terms of health and the environment arise. On the other hand, the cost of dealing with leachate, the bad smell that occurs due to the landfill of food waste, and securing sites for landfill of food waste is too expensive. If food waste is incinerated, some harmful materials are produced from incomplete combustion due to the high water content. The problem of dealing with food waste that occurs in homes and restaurants is an urgent issue because of the environmental pollution and high disposal costs.

In general, there are two types of food waste disposer, one is a compressing type that presses the food waste with a big screw, the other is a dehydrating type that remove the water from the food waste by revolving a waste bucket. These
types of food waste disposer are not widely used in real life, most of them have problems in terms of big volume, complicated construction, high cost, low energy efficiency and so on. There is a dryer for food waste that has been made to resolve these problems. It uses a method that removes the water in food waste by heating. It has a trunk type, drying bucket that has an inserted tube upper side to hold food waste. This system injects hot air into the drying bucket and one part of injected hot air is exhausted outside while one part of it is reheated in the heater. This machine also has some problems such as low drying efficiency, difficulty of production and assembly, low productivity, poor deodorization. This is because it only dries waste in the drying bucket though a heater and blower only.

In this study, we focus on the design of a drying bucket that will dry water of food waste efficiently. Specifically, we have designed a drying bucket in order to make the drying time shorter by injecting hot air down the side of the drying bucket. The designed drying bucket is composed of inclined inlet holes down both sides. There are various forms of inlet hole, we change the inlet velocity of the hot air to find a suitable vortex in the drying bucket. Therefore, we introduce and verify the properties of the proposed system through a simulation study using the ANSYS Workbench software.¹ ²

### 2. Modeling and Boundary Conditions

#### 2.1 Model design

As shown in Fig. 1, the common dryer system receives external air by the operation of an inside fan and the air is heated by being sucked through the heater. The hot air is thrown down the side of the drying bucket from the upper side through the inside air-duct. The hot air removes the water from the food waste in the drying bucket slowly. However, this dryer system has low drying efficiency because the hot air flows to down from the upper side of the drying bucket in a simple manner. If we can inject hot air down the side of the drying bucket and create a vortex, we would be able dry the food waste efficiently. Therefore, we propose a new dryer system to remove the water from food waste efficiently, as shown in Fig. 2.

Fig. 1 Dryer system for food waste

Fig. 2 Proposed model for drying bucket

(a) 1 hole (b) 2 holes (c) 3 holes

Fig. 3 Air inlet forms for proposed model
The proposed dryer system inserts hot air down both sides of the drying bucket through a guide pipe. The hot air inlets are designed to be inclined in such a way as to make hot air swirl counterclockwise. The air that dries the water in the food waste in the drying bucket is exhausted through the deodorization system.

2.2 Finite element model and boundary conditions

We have designed 3 types of air inlets down the side of the drying bucket for fluid analysis of the proposed dryer system, as shown in Fig. 3. We performed fluid analysis while changing the number of the air inlet degree of the inclined plane of the air inlet while keeping the same total area of the air inlet. The fluid area to analyze is inside the drying bucket and includes the physical properties of the air. The boundary conditions of the air inlet are that hot air is inserted with variable velocity (1~5 m/s) by a rotation motion of a fan and the intensity of the turbulent flow is 5%.

The upper side of the drying bucket has an open boundary condition to allow hot air to move freely. FEA (finite element analysis) for turbulent flow fields has 3 types: DNS (direct numerical simulation), LES (large eddy simulation) and RANS (Reynolds averaged Navier-Stokes simulation). We performed the FEA with the k-ε turbulence model of RANS. This has some inaccuracies in the prediction of the boundary plan exfoliation in viscosity low-rise areas, but it can precisely analyze the behavior of turbulence flow in free turbulence areas that have low-pressure gradients.
3. Results of the simulation

The analysis object has 3 types of air inlet designed in a cylinder form. The first has one air inlet, the second has two air inlets and the third has three air inlets. In the case of the one air inlet, the inlet width is 10 mm and height is 30 mm. In the case of the two air inlets, the inlet width is 5 mm and height is 30 mm. In the case of three air inlets, the inlet width is 3.3 mm and height is 30 mm. The hot air inlets have a gradient of 35°~50° and are designed to make hot air swirl counterclockwise. After supplying air of variable velocity (1~5 m/s), the result of the analysis is shown in Fig. 4–6.

The velocity and vortex form of hot air from the most variable inlet gradient, with one air inlet, is shown in Fig. 4. The hot air was inserted at a maximum of 5.0 m/s from 1.0 m/s and was increased gradually by 0.5 m/s. In the case of an inlet gradient of 50° and a velocity of 2.0 m/s (Fig. 4(a)), a vortex was generated well in the center and edge part of the drying bucket. However, the velocity of 2.0 m/s was not sufficient for drying of food waste in a short time. In the case of an inlet gradient of 45° and a velocity of 1.0 m/s (Fig. 4(b)), a vortex was generated well in the center part of the drying bucket. However, the velocity of 1.0 m/s was not sufficient for drying of food waste in a short time. In the case of an inlet gradient of 40° and a velocity of 3.0 m/s (Fig. 4(c)), a vortex was generated very well in the center and edge part of the drying bucket, also the velocity was appropriate for drying food waste in a short time.
The velocity and vortex form of hot air from the most variable inlet gradient, with two air inlets is shown in Fig. 5. The hot air was inserted to 5.0 m/s from 1.0 m/s by the same method. In the case of an inlet gradient of 45° and a velocity of 1.0 m/s (Fig. 5(b)), the vortex was generated very well in the center and edge part of the drying bucket, but the velocity was not sufficient for drying food waste in a short time. In the case of an inlet gradient of 40° and a velocity of 3.5 m/s (Fig. 5(c)), the vortex was generated well in the center and edge part of the drying bucket, and the velocity was appropriate for drying food waste in a short time.

The velocity and vortex form of hot air from the most variable inlet gradient, with three air inlets is shown in Fig. 6. The hot air was inserted to 5.0 m/s from 1.0 m/s by the same method. In the case of an inlet gradient of 35° and velocity of 2.0 m/s (Fig. 6(d)), the vortex was generated very well in the center and edge part of the drying bucket. In the case of an inlet gradient of 40° and a velocity of 3.5 m/s (Fig. 6(c)), the vortex was generated well in the center and edge part of the drying bucket, and the velocity was appropriate for drying food waste in a short time.

4. Results of the simulation

In this study, we proposed a new dryer system to reduce drying time by injecting hot air down the side of the drying bucket. The designed drying bucket is composed of inclined inlet holes down both sides. There are various forms of inlet holes, we changed the inlet velocity to find a suitable vortex in the drying bucket. The main contributions
of this work can be summarized as follows.

1) We have designed the form of hot air inlets for a drying bucket and injected air through these inlets creating a counterclockwise swirl.

2) In the case of the same form and total area of the hot air inlet, the vortex of hot air was not influenced greatly by the number of inlets.

3) In the case of an inlet gradient of 40° and a velocity of 3.0~4.0 m/s, a vortex was generated very well in the center and edge part of the drying bucket.

4) This new dryer system is expected to improve the drying time and save energy in food waste disposal.

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References


