ISSN: 2688-8645

Study on the Thermal Efficiency of Rotary Flash Dryer at Different Temperatures in Fishmeal Drying Process

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Abstract

The purpose of this paper is to study the operational thermal efficiency of the rotary flash drying equipment when it is used for drying fishmeal, to study the time for fishmeal to reach below the specified moisture and the drying rate of the rotary flash drying equipment under different temperature conditions, and to study the effect of the rising drying temperature on the main nutrients of fishmeal. The results showed that the thermal efficiency of the dryer gradually increased with the increase of drying temperature, the time required for drying became shorter, and the percentage of energy required for heating air and fishmeal warming decreased. However, the quality of fishmeal deteriorated with the increase of temperature. According to the operating parameters measured in the drying process, it is calculated that the drying temperature of 110℃ can meet the quality of finished fishmeal products and ensure that the drying thermal efficiency is maximized.

Keywords

Thermal Efficiency; Cyclone Flash Dryer.

1. Introduction

Fishmeal, as a high-level feed for animal (livestock, poultry, fish) breeding industry, as well as an important raw material for medical, pharmaceutical and fermentation industries, is rich in a variety of proteins and nutrients, and the demand for fishmeal has been increasing year by year in China. The drying process of fishmeal is an important process step that affects its productivity and the content of its internal nutrients, but excessive drying temperatures not only result in the loss of a large number of internal nutrients, but also have an impact on the appearance of fishmeal and on the taste.

Rotary flash drying technology is a kind of hot air drying, for fishmeal type of high humidity, paste easy to bond the heat-sensitive raw material drying is very suitable, and its more and more applications in the actual production of fishmeal. Foreign Hilmarsdottir on fishmeal processing air drying efficiency and optimization of steps to make research, to improve fishmeal production has reference value. Li Ge made a study on the nutrient content of fishmeal under different hot air temperature drying, which has a guiding role in temperature control of the drying process. However, there is no research on the thermal efficiency of hot air drying applied in the field of fishmeal drying, the purpose of this paper is to use different temperatures under the rotary flash drying equipment for drying wet fishmeal, to study the thermal efficiency of fishmeal drying under different temperature conditions, and the nutrient content of fishmeal to detect the drying of fishmeal production has a reference value of energy-saving and consumption reduction.

2. Experimental Materials and Methods

2.1. Materials and Equipment

Fishmeal material to be dried: the use of anchovy-based fresh miscellaneous fish as raw material fishmeal, after steaming, pressing, steam drying, its moisture content of 30% ~ 40%, infrared moisture rapid detector, rotary flash drying test bench, gas flow meter, protein automatic analyzer, Soxhlet extractor, thermometer and soon.

2.2. Experimental Methods

2.2.1. Detection Method

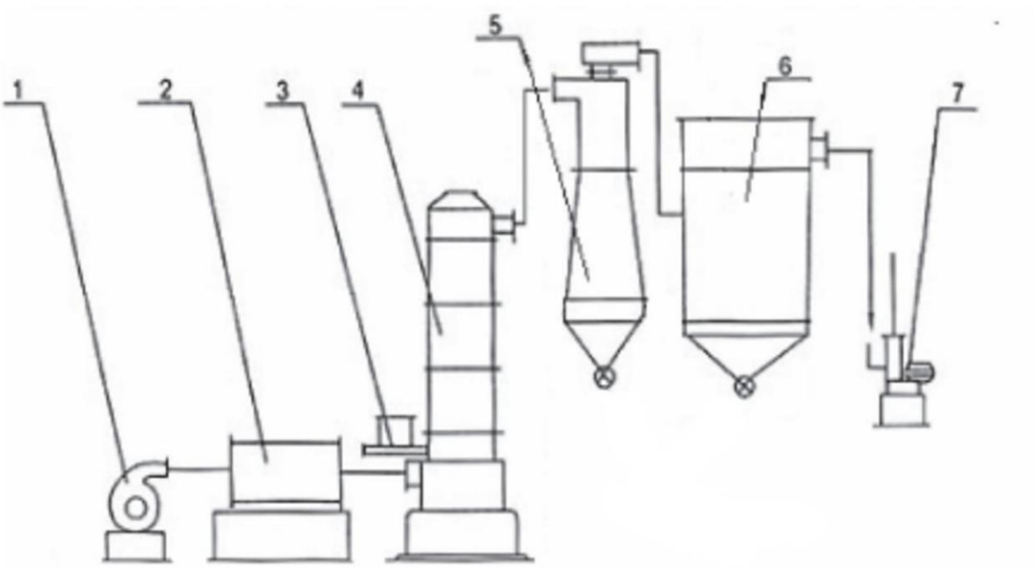
Moisture determination: moisture infrared rapid dryer was used to determine.

Determination of crude protein content: Determination by protein automatic analyzer.

Determination of crude fat content:Soxhlet extraction method.

2.2.2. Drying Process and Heat Exchange of Cyclone Dryer

In the part of drying host, using steam heat exchanger to heat the treated clean air to the drying temperature, the heated hot air enters into the bottom of drying host with suitable speed, enters into the inside of drying host according to the tangential direction and is in the spiral state, and the fan blade stirrer at the bottom drives the entering hot air to produce high-speed rotating airflow in the spiral ascending state, and the fishmeal material enters into the drying host directly through the spiral doser and is rapidly dispersed under the impact and driving of the spiral airflow and makes high-speed rotating ascending movement with the airflow. The fish meal material enters into the drying main machine directly through the spiral feeder, and is quickly dispersed under the impact and drive of the spiral airflow, and makes high-speed rotating upward movement with the airflow, and carries out full and efficient mass-heat transformation with the hot air. For the larger and wet fishmeal particles, the high-speed airflow is not enough to make it blow apart and rotate, so in the gravity drop to the bottom of the host, set at the bottom of the high-speed rotation of the fan blade cutting and crushing, and then chopped fishmeal particles and then with the high-speed rotation of the airflow up for drying, and then discharged by the separation of dust removal. The drying process is shown in Figure 1.



1. Induced draft fan; 2. Steam heat exchanger; 3. Screw feeder; 4. Drying main machine; 5. Cyclone separator; 6. Dust collector; 7. Exhaust air induced draft fan.

Fig 1. Rotary Flash Vaporization Dryer Drying Flow Chart

2.2.3. Calculation of the Thermal Efficiency of the Drying Process

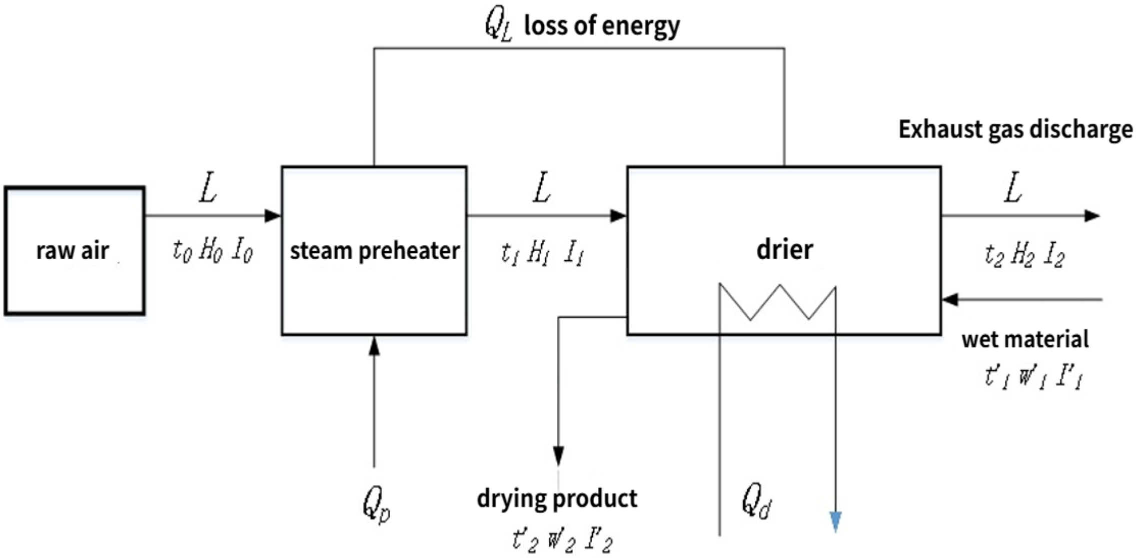


Fig 2. Two or more references

The energy exchange in the drying process is shown in Fig. 2, with reference to the basic formula of heat accounting for continuous drying system, the total heat consumed by the drying system is:

$$Q = Q_p + Q_d = L(I_2 - I_0) + G_c(I'_2 - I'_1) + Q_L \tag{1}$$

In the above equation : Qp : heat exchanger energy consumption, kJ; Qd : supplementary energy to the dryer, kJ. kcal/kg. QL: heat loss in drying process, kJ; L: dry air flow rate, kg/h; Gc: absolute dry material, kg; I2, I0: enthalpy of air in and out of the main machine, kcal/kg; I'2, I'0: enthalpy of enthalpy in and out of the fishmeal material, kcal/kg.

The enthalpy of the gas entering the heat exchanger up to its discharge is analyzed as follows.

I_2-I_0:

$$I_2 - I_0 = 1.01\,(t_2 - t_0) + (2492 + 1.88\,t_2)(H_2 - H_0) \tag{2}$$

As in the above equation : t2,t0: air temperature at the inlet and outlet of the dryer, ℃; H2, H0: humidity content of the gas at the inlet and outlet of the dryer, kg (water)/kg (adiabatic air).
Enthalpy analysis of wet material entering the dryer to exclusion:

I'_2-I'_1:

$$I_2^{'} - I_1^{'} = c_m(t_2^{'} - t_1^{'}) \tag{3}$$

As in the above equation : t'2,t'0: import and export temperature of fishmeal material, ℃; Cm: specific heat of fishmeal material, kJ / (kg-℃)

Since the amount of water evaporated from the material is equal to the increase in the moisture content of the air, the amount of water vaporized is:

$$W = H_2 - H_0 \tag{4}$$

As in the above equation :H2,H0: Moisture content of inlet and outlet gases, kg (water)/kg (adiabatic air);

Then the heat required to evaporate the moisture vaporization of the material:

$$Q_{\text{vaporization of water}} = W\left(2492 + 1.88t_2\right) - 4.18t'_1 W \quad (5)$$

As in the above equation : W: vaporization amount of moisture in drying process, kg (water)/kg (adiabatic air); t2: temperature of discharged gas, ℃; t'1: temperature of material to be dried, ℃.

Heating dry air calories are:

$$Q_{\text{heating air}} = 1.01L(t_2 - t_0) \quad (6)$$

As in the above equation : L: Air flow rate, kg/h; t2, t0: Dryer inlet and outlet air temperature, ℃;

Heating fishmeal material heat:

$$G_c = \frac{G}{\left(1 + \frac{\omega'_2}{1-\omega'_2}\right)} \quad (7)$$

$$Q_{\text{heated fishmeal}} = G_c c_m (t'_2 - t'_1) \quad (8)$$

As in the above equation :G: output of finished fishmeal, kg; Gc: absolute dry material, kg; ω'2: material discharge moisture content, kg (water)/kg (fishmeal material); Cm: specific heat capacity of fishmeal material, kJ / (kg-°C).

The total heat of drying is:

$$Q = Q_{\text{vaporization of water}} + Q_{\text{heating air}} + Q_{\text{heating fishmeal}} + Q_L \quad (9)$$

The thermal efficiency of the drying process is the ratio of the heat required to evaporate the moisture of the material to the total heat input to the drying equipment, viz:

$$\eta = \frac{Q_{\text{vaporization of water}}}{Q} \times 100\% \quad (10)$$

3. Results and Discussion

3.1. Drying Curves of Fishmeal at Different Temperatures

As shown in Figure 3, in 90 ℃ ~ 140 ℃, with the increase of drying temperature, fishmeal drying to the target moisture the shorter the time required, from 35% of the moisture content down to less than 5%, corresponding to the time required for 17.5,16,13.5,10,8.5,7.5s. It can be seen that, improve the drying temperature can effectively shorten the drying time, this is because the drying time between fishmeal material and hot air, the greater the temperature difference, the greater the heat transfer impetus, the faster the heat conduction. The larger the temperature difference is, the larger the heat transfer driving force is, and the faster the heat conduction is. In 0~4s, the higher the temperature, the faster the drying rate, i.e., the first 4s for the ascending drying stage, and then the higher the drying temperature, the faster the time to enter the descending drying, this is due to the continuous high-temperature drying so that the fishmeal within the various parts of the moisture gradient difference is large, sustained high-temperature drying of the fishmeal surface hardening, scorching.

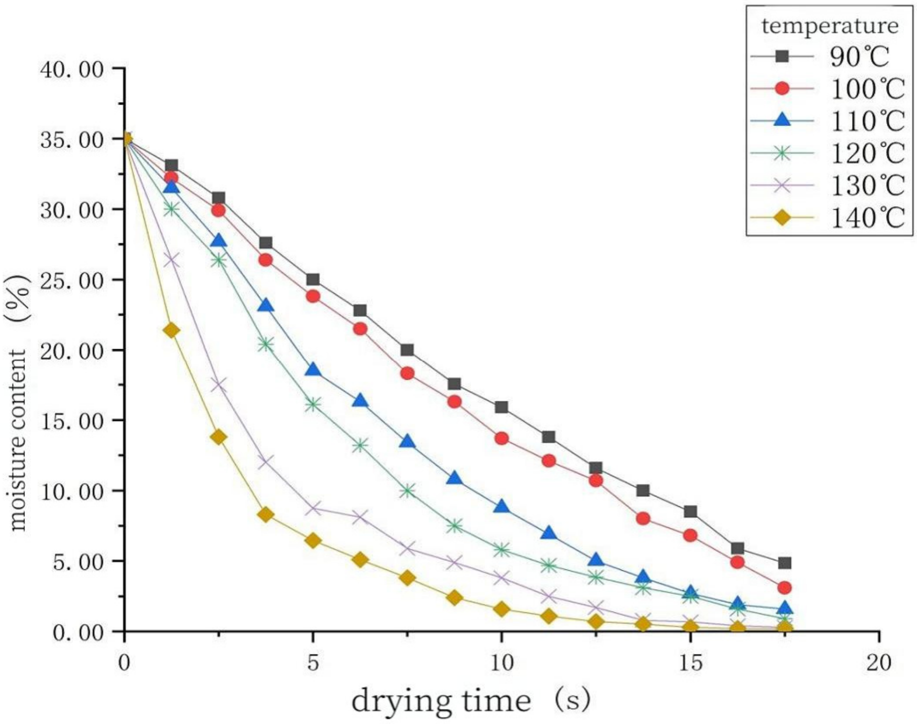


Fig 3. Drying curves of fishmeal at different temperatures

3.2. Thermal Efficiency of the Drying Process at Different Temperatures

To control the moisture content of fishmeal below 5%, the exhaust gas temperature, finished product temperature and feed volume after drying using different temperatures were measured, and the obtained data were shown in Table 1, which were calculated according to the measured values and physical parameters of fishmeal in accordance with the formulae of Eqs. (1) ~ (10).

Table 1. Drying operating parameters at different temperatures

drying temperature / ℃	air outlet temperature / ℃	Discharge temperature / ℃	Finished product moisture content/ %
90	59	44	4.85
100	67	47	3.26
110	78	50	2.85
120	95	52	2.65
130	101	59	1.79
140	112	63	1.62

Derived from the cyclone flash dryer at different temperatures on the drying of fishmeal thermal efficiency of the operation of the Figure 4, indicating that for fishmeal materials, without taking into account the conditions of its nutritional composition, in the temperature range of 90 ~ 140 ℃, the higher the temperature of drying, drying the rate of the more rapid, the higher the thermal utilization of the equipment operation. The reason is that as the temperature rises, the proportion of heat provided by drying in the heating air and the heating of the fishmeal material itself decreases. According to the formula to calculate the proportion of energy consumed by the two, in the case of a certain energy loss, the results are shown in Figure 5.

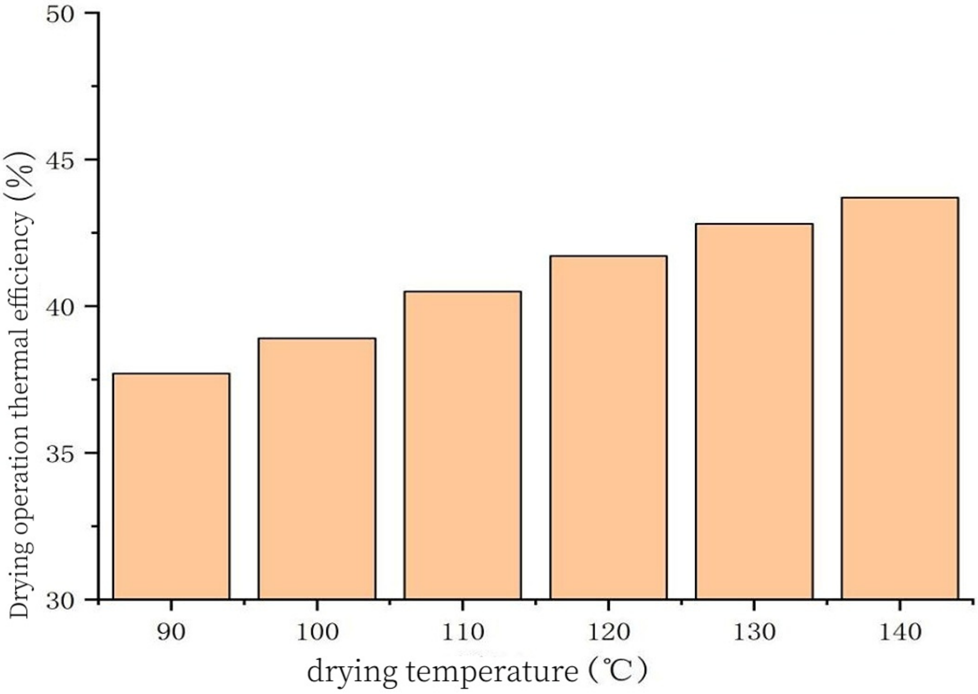


Fig 4. Thermal efficiency of fishmeal drying at different temperatures

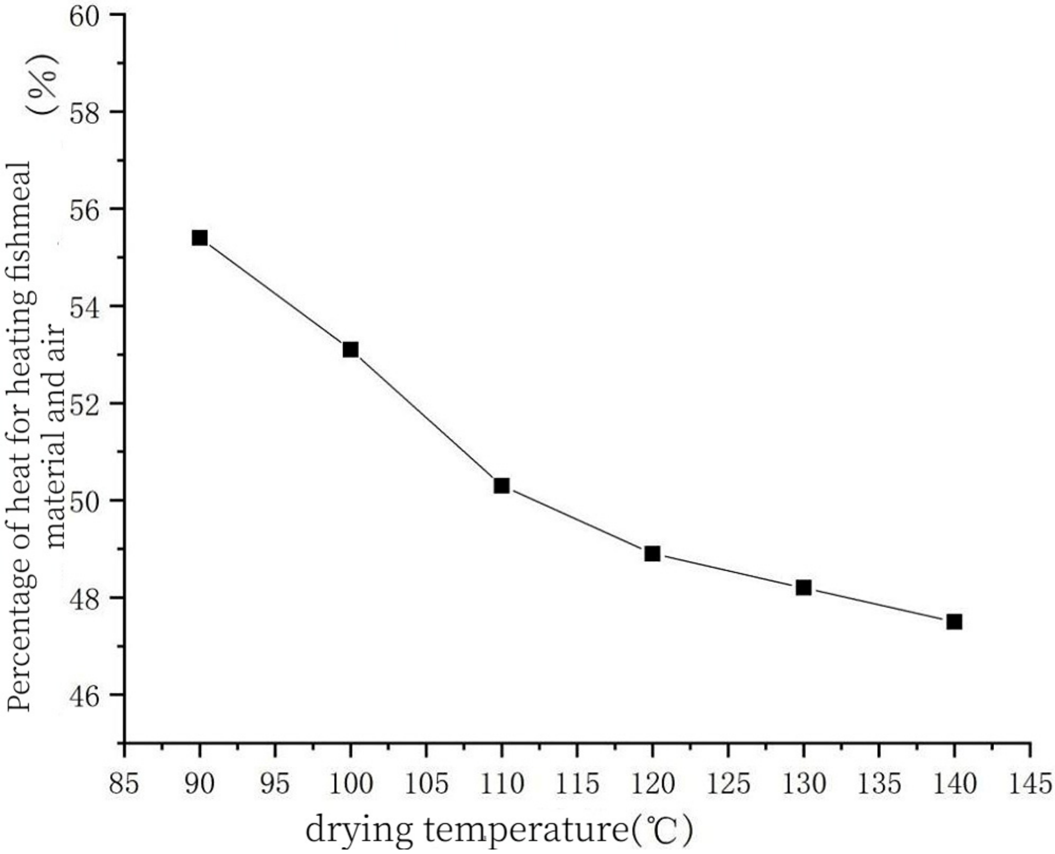


Fig 5. Thermal efficiency of fishmeal drying at different temperatures

3.3. Main Nutrient Contents and Sensory Changes of Finished Products Dried at Different Temperatures

Nutritional composition of fishmeal was determined as in Table 2, the crude protein content of fishmeal was basically unchanged under the drying temperature of 90-140 ℃, and the drying temperature did not affect the crude protein content. And with Li Ge and other experimental results are consistent . However, the content of essential amino acids such as histidine, lysine, valine and methionine decreased after the temperature exceeded 100 ℃, and these four amino acids were obviously destroyed when the temperature exceeded 120 ℃, and the digestibility of fishmeal pepsin decreased gradually with the increase of temperature . The initial pepsin content was more than 95.6%, and after the drying temperature exceeded 120℃, the content decreased to 92.2%, which reached the definition of first-grade fishmeal. After exceeding 140℃, its content was only 86.8%. It meets the standard of feed grade second grade fishmeal. The crude fat content decreases with the increase of temperature because the lipid in fishmeal undergoes oxidative decomposition with the increase of temperature.

Table 2. Main nutrient contents of fishmeal at different drying temperatures

	90℃	100℃	110℃	120℃	130℃	140℃
overstatement	4.85±0.07	3.26±0.03	2.85±0.02	2.65±0.02	1.79±0.03	1.62±0.02
crude protein	66.5±0.62	67.3±0.57	66.9±0.78	67.2±0.44	67.8±0.68	67.5±0.76
crude fat	11.42±0.07	11.38±0.04	11.36±0.36	11.09±0.13	9.8±0.15	8.7±0.27

In the drying temperature of 90 ~ 100 ℃ between the fishmeal did not produce significant changes, but after more than 110 ℃, the finished fishmeal has an obvious burnt taste, the temperature rises to 130 ~ 140 ℃, the fishmeal color becomes darker. Burnt taste aggravated, and with a slight irritating odor, this is due to high-temperature drying than low-temperature drying can accelerate the fat oxidation, fat oxidation produced such as hydroperoxides, fat polymers, aldehydes, ketones, acids and hydrocarbons, so that the fishmeal produces a nasty taste of the halo, and the hydrocarbons and other heterocyclic substances is the reason for the deepening of the color of the fat in the Melad reaction of the characteristics of the material .

Therefore, the increase in temperature is accompanied by an increase in thermal efficiency, but it also continuously reduces the nutritional value of fishmeal and the taste of the finished product. According to the definition of national standard feed-grade fishmeal , the fishmeal produced at 90~100℃, the nutrients and moisture content can reach the national feed fishmeal level 1 standard, but in the drying process, the heat consumed for heating the air and warming up the fishmeal material is about two times of the energy consumed for evaporating the moisture of fishmeal. Drying temperature 130 ~ 140 ℃, thermal efficiency of about 43%. However, the fishmeal produced is defined as feed grade secondary fishmeal due to the decrease of fat oxidation quality and serious loss of pepsin.

4. Conclusion

In this paper, the thermal efficiency of elevated rotary mill flash drying on fishmeal drying at different temperatures was investigated, and the effect of drying temperature on drying time was studied, from 90 to 140 ℃, the drying efficiency was 37.7%, 38.9%, 40.5%, 41.7%, 42.8% and 43.7%. With the increase of temperature, the drying rate is accelerated and the drying thermal efficiency is increased. And the temperature increases, air heating and fishmeal material heating energy accounted for 55.7% of the total drying heat, 53.8%, 50.5%, 49.2%, 48.6%, 47.8%, but the loss of nutrients in the fishmeal is also getting bigger and bigger.

ISSN: 2688-8645

Therefore, the choice of temperature, that is, to take into account the thermal efficiency of the dryer, but also take into account the quality of fishmeal products, according to the national standard for feed-grade fishmeal, the temperature of 110 degrees Celsius or so, you can maximize the assurance of the quality of fishmeal stabilized at the first level, and drying thermal efficiency of about 40%. In order to ensure the quality of fishmeal under the premise of improving the thermal efficiency of drying, can be added to the drying process exhaust gas recovery system, heating air accounted for up to 17 ~ 24% of the thermal energy, and the temperature of the exhaust gas is at least 30 ℃ higher than the temperature of the material to be dried, if it is applied to the drying of wet materials or drying process recycling, the thermal efficiency can be increased to more than 60%.

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