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EVALUATION OF THE DRYING PROCESS OF PADDY RICE WITH A BIOGAS CONTINUOUS ROTARY DRYER

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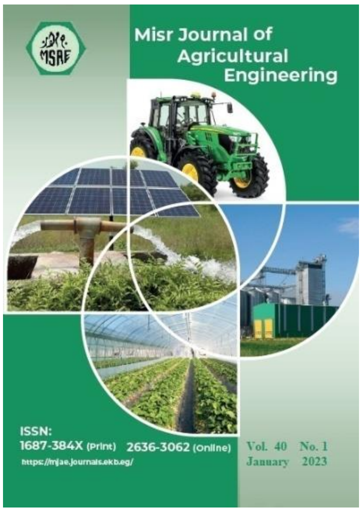


Keywords:
Paddy rice; Rotary dryer; Biogas.

ABSTRACT

A rotary drum dryer was designed and developed for drying paddy rice. A novel design thermal unit is designed and fabricated to provide the heat energy required for drying process. This thermal unit can be operated using liquid petroleum gas (LPG) or biogas as a renewable resource. Most of artificial drying systems contaminate the dried material by the exhaust gases and negatively affect the germination ratio. The advantage of this new thermal unit is that the exhaust gases are vented from the chimney and only clean hot air contacts the dried material. Also, a novel technique is used for transporting dried material depends on the venturi theory where the phenomenon of fluidized bed occurs and partial grain drying process happens. A set of preliminary experiments were conducted to arrive at suitable blower speed, hot air velocity and rotary drum speed. The main drying process happened in the rotary drum dryer where a great disturbance of dried material happened due to stirring and air velocity combined effects. The results showed that the air velocity of 10 m/s and feeding rate of 75 kg/cycle had the greatest effect on drying rate and lowest effect on specific energy consumption. Also, the rotary drum speed of 10 rpm was suitable regarding the drying rate and specific energy consumption at feeding rate of 75 kg/cycle. This drying system incurred a lower cost per kilogram compared to other methods.

1. INTRODUCTION

Rice has been distinguished as one of the oldest and most important foodstuffs for human, **Tumpanuvatr *et al*. (2018).** Therefore, it is one of the most important staple foods in the word. Todays, almost one-third of the world populations rely on rice as a main food source, **Jafari *et al*., 2018**. In Egypt, rice is the most important food besides wheat, therefore it can be found in almost all regions in the Egyptian Delta in the north of Egypt. Egypt is the country with the largest rice consumption in North Africa with 52.8 kg per year per capita, **Elbasiouny and Elbehiry**, **(2020).** It is deemed as a health food due to its abundance in nutrients such as fiber, vitamins, and minerals. It is the main source of carbohydrate for Egyptian people. According to statistics, in 2021 for a national planting area of 650,000 ha (1.55 million Faddan) which is 20% of total cultivated area. The total rice production is 4.8 million Mg per year, **Elbasiouny and Elbehiry, (2020).**

A large amount of rice production and the increasing need for rice make post-harvest handling of paddy very important. The main product of rice crop is paddy grain which must pass several stages in rice mills to change into edible form **(Khantong and Arnusan, 2018)**. The initial moisture content of the paddy grains in the harvest stage is about 28-35% which should be reduced to 7-11% using different drying methods. If the rice was harvested by combine machine, the grain moisture content could exceed 40%.

Drying is a typical process to reduce the moisture content of paddy to produce quality and to enable longer-term storage rice. In general, the factors that will affect the drying rate of paddy include drying air temperature, air flow rate, initial paddy moisture content, paddy temperature, distribution of water content in paddy core, paddy type and variety, paddy sickness pile and resident time, **Dina *et al.*, (2020) and Sitorus *et al*., (2021).**

The traditional method for rice drying in Egypt depends on spreading the paddy rice in a thin layer about 5-10 cm thick, on a clean surface under the sun in open air for a period on 4-6 days. The paddy rice is turned over every 4 hours during the day hours to mix top and bottom grains to avoid moisture accumulation in the bottom layer and over drying of the top layer. The paddy is covered during the night hours or in the unfavorite weather conditions. The cover is removed when the sun shines.

This process is tedious and time and labor consuming. Also, it needs a considerable land area. The grains are exposed to different weather conditions such as wind, rain, dew accumulation at night and early morning. This causes grains to re-absorb moisture thus resulting in cracked grains. Also, a considerable amount of grains are lost due to attacks of birds and astray animals or could be stolen.

Generally, in semi tropical regions, the period of the paddy harvesting is in September and October. This period of year is characterized by low temperature and high relative humidity and the chance of precipitation is high which are unfavorable conditions for traditional drying. Fossil-fueled dryers are now common as they can operate in any ambient conditions and readily controlled, and their operation and maintenance are well established. However, in many remote rural locations supplies of fossil fuels can be (I) in secure (II) expensive and require combustion equipotent and (III) their use incurs emissions.

There are a lot of alternative methods for paddy rice drying in Egypt, almost all drying systems used are of fixed-bed type which uses mostly fossil fuels **(Sorour 2006)**. The main problem pertaining to these traditional dryers is the high level of fossil energy consumption during the drying process so that more than 80% of the energy consumption in the rice processing operation is attributed to the drying systems. Also, the grains in the top layer are over-dried while moisture is trapped in the bottom layer **(Lisboa *et al.*, 2004; Kishta *et al.*, 2012)**.

The rotary drum dryer is one of artificial dryers that can be used for paddy drying (**Hanifarianty *et al.*, 2018; Farid *et al.*, 2019)**. The results shown that using this type of dryers has the lowest specific energy consumption (electrical) between 5.5-17.41 MJ/kg water evaporated, **Sitorus *et al*., (2021)**. Also, using rotary dryers helps to avoid moisture trapping in bottom layers.

In conclusion, paddy drying can be conducted naturally or mechanically using a dryer. Unfortunately, natural methods such as open sun drying, and solar drying can be irrelevant because they take longer time than mechanical drying **(Susanto *et al.*, 2021)**. The aim of this study is to develop a rotary drum dryer for paddy drying using a novel thermal unit which can use LPG or biogas as a renewable source of energy. Also, an important addition to this kind of dryers is the use of partially fluidized bed drying technique integrated with the conventional rotary drum dryer to increase the drying efficiency.

MATERIALS AND METHODS

Experiments were carried out through the autumn of 2021 at a private workshop store in Belbeis, Sharkia Governorate, Egypt. The experiments were conducted to evaluate a rotary dryer equipped with a thermal unit for drying freshly harvested paddy rice.

1. Materials

1.1. Raw Material:

Freshly harvested paddy (cultivar. 101) was selected and procured from Agricultural Research Station, Belbeis, Sharkia Governorate to conduct experiments. The paddy was passed through a cleaner to remove foreign matter, broken, chaff and immature grains.

1.2. The developed rotary dryer:

The 150 kg capacity prototype continuous rotary dryer was developed for on-farm paddy drying at a private workshop store at Belbeis, Sharkia Governorate, Egypt. The advantage of this hybrid-energized drying system is the drying process can take place continuously using heat energy from two different heat sources (LPG and biogas). The heat from the hybrid energy source is channeled to the drying machine. The following functional components of on-farm paddy dryer were fabricated and assembled according to the requirement. Fig (1) depicts a schematic diagram of the complete system.

A) Thermal unit:

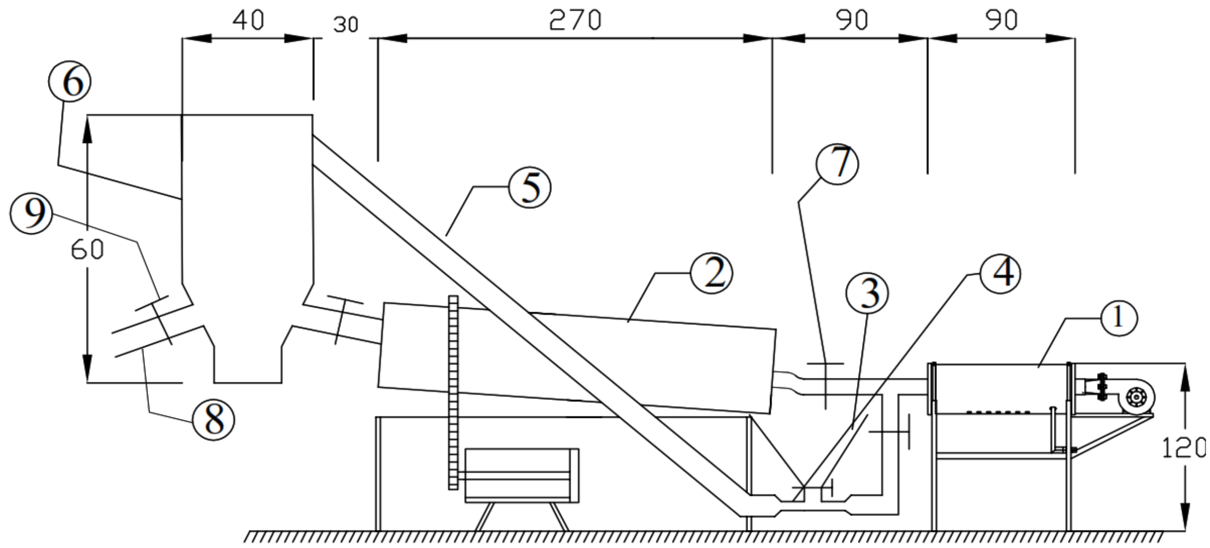
A multi-functional and multi-tasking thermal unit was designed and tested in the field. The unit was constructed from local material witch available in the local market. About 10% of the components are imported and available in the local market.

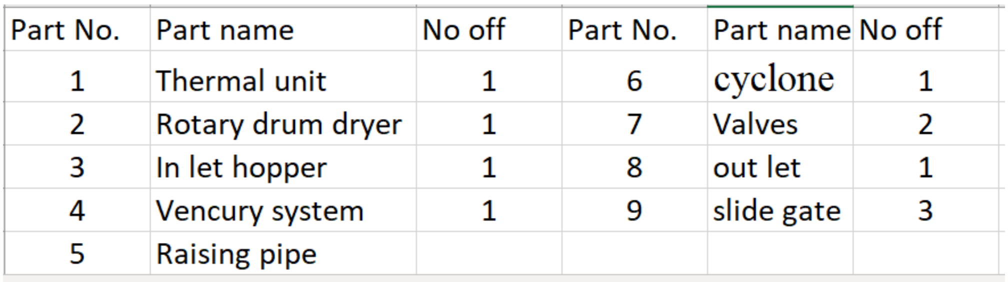
This thermal unit is consisted of four standard gas burners, 60 cm length, contained in an insulated steel cylinder, 40 cm diameter and 90 cm length. The cylinder has bottom holes to allow the fresh air in and a chimney to discharge the exhaust gases. An eccentric 10 cm diameter stainless tube, 2 mm thickness and 110 cm length, is passing through the upper part of the insulated cylinder to carry the air to be heated, from the air blower to the dryer rotary drum. This unit is equipped with a pilot light to keep the fire on during heat shut down according to the sensors signals. The unit has a 20 cm diameter air blower operated by a 2-phase electric motor, rated power is ¼ kW. Table (1).

Table (1): Air blower specifications

Model	Voltage	Input power	Highst speed	Volume	Pressure
DKT	220 V	0.25 kW	1360 rpm	900-1500 m^3/h	315-295 Pa

The blower flow rate is higher than the required flow rate through the system. Thus, a speed controller is used to reduce the blower speed into half, consequently, its discharge rate will be reduced into half.





Part No.	Part name	No off	Part No.	Part name	No off
1	Thermal unit	1	6	cyclone	1
2	Rotary drum dryer	1	7	Valves	2
3	In let hopper	1	8	out let	1
4	Vencury system	1	9	slide gate	3
5	Raising pipe				

Fig. (1) Detailed drawing of developed rotary dryer.

This thermal unit is operated using many different energy sources from traditional, new and renewable sources. The air is heated by two sources of energy, one of which is conventional (butane gas) and the other is renewable (biogas). Two solenoid valves were connected to the gas inlet to allow switching between LBG and biogas according to a signal from the thermostat.

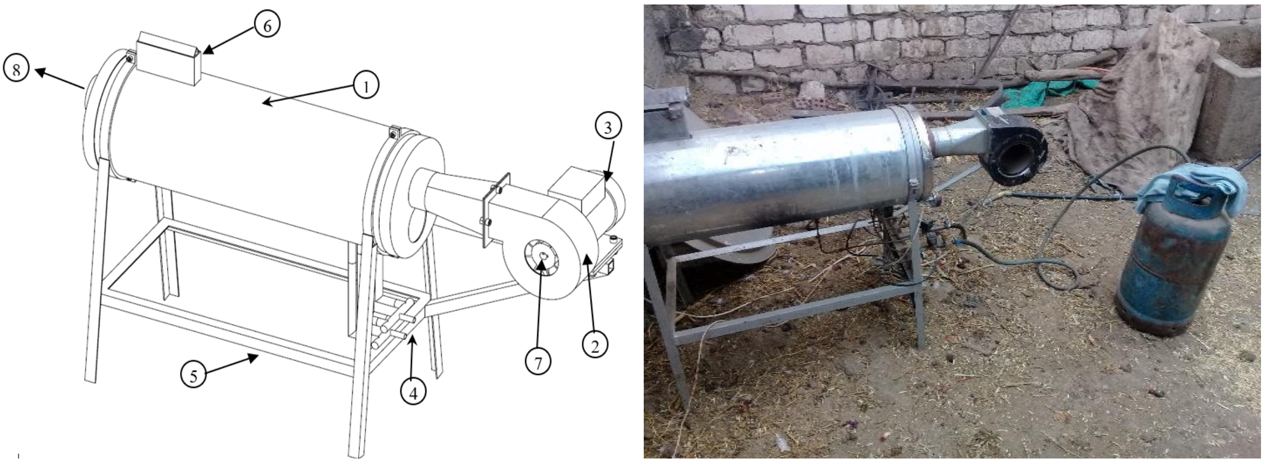


Fig. (2) Thermal unit parts: 1- insulated galvanized cylinder, 2- air blower, 3- electric motor, 4- gas burner, 5- frame, 6- chimney, 7- air inlet, and 8- hot air outlet.

B) Rotary dryer:

A Rotary drum dryer was designed and developed for drying paddy rice. The dryer has 57.5 cm diameter and 270 cm length. The size was similar to three of a 200-liter steel drum containers. The three drums were aligned longitudinally and welded using natural flame burner to produce one cylinder. A chain was welded circumferentially around the upper one third of the drum to serve as a driving gear. The external surface of the drum was thermally insulated. An electric motor (0.5 kW) and a reduction gearbox are used to rotate the drum by a sprocket (20 teeth) engaged to the driving gear (150 pitches).

The rotary drum is mounted horizontally and tilted 8° on 4 supporting bearings with the two top rollers located opposite the driving gear. This setup allows the drum to rotate in a fixed position by 5, 10 and 15 rpm.

The rotary drum is equipped with curved baffles distributed helically along the internal surface. Those baffles help in stirring the paddy to grantee homogenous drying and moving it forward to the outlet.

The hot air duct that coming from the thermal unit passes through the drum dryer concentrically. The duct is perforated to evenly distribute the hot air inside the drum.

C) Feeding System:

The feeding system consists of 3 main parts as follows:

- **Inlet hopper:**

A 100-kg capacity grain hopper is installed at the lower end of the drum dryer to initially hold the amount of paddy rice to be dried and to collect the dried grains after exiting the drum. The hopper is fitted with a sliding gate at the bottom to control the feeding rate.

- **Venturi**

The hot air duct (10 cm diameter) coming out of the thermal unit is divided into two paths 10 cm diameter each. The first goes directly to the dryer and the second goes to the venturi (5 cm diameter). The amount of hot air is controlled by two valves one for each path. The venturi reduces the air pressure and increases the velocity to exceed the critical velocity required to fluidize the paddy and carry it to the cyclone.

- **Cyclone**

A cyclone, 50 kg capacity, is installed to receive the elevated paddy by air stream that comes from the venturi. The grains swirl while falling from the top of the cyclone as a result of collision of air stream with the rotary element. This collision reduces the air velocity to allow the humid air to escape. The cyclone bottom has two gated paths, one to deliver the partially dried paddy rice to the rotary dryer drum and the other is to withdraw the fully dried paddy.

1.3. Instruments:

Portable moisture meter (M20P; Dickey John, USA) with accuracy of 0.25%, T-type thermocouples, hygrometer with range of 0-100%, Digital anemometer (AM-4202; Lutran, Taiwan) with accuracy of ±2%

2. Methods

2.1. Experimental conditions

A series of preliminary experiments were carried out to adjust the dryer working parameters. The appropriate blower speed was set by means of a speed regulating switch to about 5 m/s for heated air and controlled the discharge of heated air leaving the thermal unit to the drying system to 7.5 m^3/min. Where the amount of heated air entering the rotary dryer was controlled within 5 m^3/min and the amount of heated air entering the vent lifting device by about 2.5 m^3/min by two valves one on each track. Also, the grain feed rate above the intake hole for venturi was controlled to be 50, 75 and 100 kg/cycle by sliding gate at the bottom of inlet hopper. Thus, the air velocity 10 m/s at venturi nozzle is higher than 7.2 m/s. The rotational speed of the rotating dryer at speeds of 5, 10 and 15 rpm were controlled by installing a speed control switch for the dryer drive motor and the gearbox. The optimal height of the color and arrangement of the internal appendages on the inner periphery of the dryer wall were determined to perform their function in the movement of the grain. The drying process was arranged in four stages in the different parts of the system, and they were combined into two main stages.

The first stage: the initial drying is carried out in the venturi lifting device with the theory of fluidized bed by exposing the wet grains to a high temperature of 130° C degrees for a short period (high temperature for a short time).

The second stage: It is called the stage of rest, and it takes place during the presence of the grains with the hot air in the cyclone, so part of the moisture evaporates into the air, and the grains fall through the hole at the bottom of the cyclone, when the grains are exposed to relatively cold temperature and relieve pressure from the surface of the grains, evaporation of the water accumulated on the grain wall occurs. The previous two stages were merged in one stage where the theory of fluidized bed applied to it.

The third stage: This stage takes place inside the rotary dryer where the grains move from the cyclone to the cylinder of the rotary dryer. The grains are dried as they move in the cavity of the dryer against the hot air and mixed with it. The grains move to the exit hole to the feeder again.

The fourth stage: At that stage, drying is accomplished during the falling of the grains from the cavity of the main dryer to the feeding hopper, exposing the grain to the relatively cold air, so a rapid evaporation of surface moisture from the grain occurs. So, the final drying is done. The previous two stages can be combined into one stage, which is the main stage of drying. These stages can be repeated more than once before the grains are permanently removed from the system until the humidity required for safe storage of the grain is reached.

Experiments were carried out under the following treatments as follow:

- Three different hot air velocities (5, 10, 12 m/s)
- Three different feeding rates (50,75 and 100 kg/cycle)
- Three different speeds of rotary dryer (5,10 and 15 rpm)

2.2. Measurements

The following indicators were taken into consideration for evaluating the performance of manufactured unit as:

2.2.1. Moisture content of raw material.

The moisture content of paddy samples was determined by drying 10 g samples in an oven at 105±1°C for 24 hours (**Araullo *et al.,* 1976**). The samples were weighed on precision electronic balance having least count of 0.001 g. The moisture content was calculated by the loss in moisture per unit weight of paddy.

$$m.c = \frac{W_m}{W_m + W_d} \times 100$$

where,

m.c = Moisture content, % (w.b.)
Wm = Weight of moisture content, g
Wd = Weight of bone-dry material, g.

2.2.2. Bulk Density.

The bulk density was calculated as the ratio of paddy weight to the volume occupied **(AOAC, 1985)**. Bulk density was measured with 50 ml cylinder, which was filled with paddy up to 15 cm height. The excess paddy was removed, and the weight recorded.

2.2.3. Moisture ratio.

Moisture ratio (MR) of paddy during drying was calculated using the following equation:

$$MR = \frac{M - M_e}{M_o + M_e}$$

Where:

M = Instantaneous moisture content, % (d.b.)
Mo = Initial moisture content, % (d.b.)
Me = Equilibrium moisture content of the material, % (d.b.).

2.2.4. Equation of Mean Residence Time

For the calculation of drying time, mathematical models studied by **Soponronnarit, *et al.*(1997)**, were used to calculate the moisture ratio at set drying conditions to compute the drying time:

$$\tau = \frac{\rho A H}{F}$$

Where:

ρ = Density of paddy rice, $\frac{kg}{m^3}$
A = Area of dry chamber, m^2
F = Feed rate, kg/min
H = bed depth, m

2.2.5. Drying rate Equation

Based on experimental work by **Satayaprasert and Vanishsriwatana (1992)** moisture transfer in paddy rice kernels could be described well by Lewis' equation as follows:

$$\frac{M(t) - M_{eq}}{M_{in} - M_{eq}} = exp(-k\tau)$$

where:

$M(t)$ = average moisture content at time t, dry-basis decimal.
M_{in}= initial moisture content, dry-basis decimal.
M_{eq}= equilibrium moisture content, dry-basis decimal
K =drying constant
τ = drying time, min

This equation assumes that temperature equilibrium and internal mass transfer resistance in paddy is negligible. To determine moisture. equilibrium of paddy, the equation was developed by **Phudphong *et al.* (1990).** Drying constant is a function of inlet hot air temperature and bed depth, and can be depicted by the following equation:

$$k = 75.93\, exp\left(-\frac{2662.21}{T_{mix} + 273.16}\right) - 0.087H$$

where: T_{mix}= inlet hot air temperature, °C

2.2.6. Heat Utilization Factor (HUF)

HUF may be defined as the ratio of temperature decrease due to cooling of the air during drying and the temperature increase due to heating of air.

$$\text{HUF} = \frac{Heat\ utilized}{Heat\ supplied} = \frac{t_1+t_2}{t_1-t_0}$$

2.2.7. The Coefficient of Performance

The coefficient of performance (COP) of a paddy dryer is expressed mathematically as follows.

$$COP = \frac{t_2 + t_0}{t_1 - t_0}$$

Where:

t_2 = Dry bulb temperature of exhaust air, °C
t_0 = Dry bulb temperature of ambient air, °C
t_1 = Dry bulb temperature of drying air, °C

2.2.8.Specific Energy Requirement

The specific energy requirement (SER) was estimated by the following equation

SER = Total consumed power (kW) / dryer capacity (kg/h).

Total consumed power (kW) = Electrical power + Thermal power

The electrical power was estimated by using the following equation **(Ibrahime, 1982)**

$$\text{EP} = \frac{I.V.\eta}{1000} \qquad \text{(kW)}$$

Where, *EP*, electrical power, kW; *I*: Current intensity, Ampere and *V*: Voltage (220 V).

$$\text{TP} = \frac{m.c.\Delta t}{T} \qquad \text{(kW)}$$

Fuel Consumption (FC):

FC = (Qr/HVRC) x ηtu

Where,

FC = Fuel Consumption, kg
Qr = Total heat required, kJ
HVRC = Heating value of rice hull, kJ/kg
ηtu Thermal unit Efficiency = 65%

Where, *TP*, Thermal power*; m*, mass, kg; *C*: specific heat, cal/g.°c; *Δt*: temperature difference, °c

2.2.9. Operational cost

The operational cost can be determined by using the following formula:
Operational cost (L.E./Mg) = Hourly cost / dryer capacity
Hourly cost = fixed cost + variable cost

RESULTS AND DISCUSSION

Some preliminary experiments were carried out, from which the effective parameters of the drying system were determined. Where different speeds were selected for the hot air blower, and thus the discharge rates for the hot air leaving the thermal unit should be 7.5 m^3/min. The heated air is divided into two parts after leaving the thermal unit, where about 2.5 m^3/min goes to the Venturi to raise the wet grains and dry them initially with the fluidized bed theory and at a heated air speed ranging between 8, 10, 12 m/s., feeding rates of wet paddy rice were controlled by a sliding gate under the feed hopper, so that it is in the range of 50, 75 and 100 kg/cycle. The effect of those parameters was studied in the first stage of drying on each of: 1- Drying percentage. 2- Heat utilization factor. 3- Dryer performance factor. 4- Specific energy consumption. About 5 m^3/min of hot air goes to the second part of the drying system i.e., the rotary drum dryer. Also, the rotary speed of the rotary dryer has been adjusted by means of the drive motor speed switch so that it is in the range of 5, 10, 15 rpm with feeding rates of 50, 75, 100 kg/cycle. and its effect on the previous factors. Finally, the operating costs of the drying system were calculated in L.E/kg of paddy rice and compared with other conventional drying systems.

The obtained results will be discussed under the following heads:

1.a. Effect of hot air velocity and feeding rates on drying ratio:

The venturi increases the air stream velocity above the critical fluidizing speed, so the air carries the falling grains from the feeding hopper through a tube 5 m length and 10 cm diameter to the top of the cyclone. During this stage, the grains are exposed to a high temperature (130° C) for a short time. The grains temperature increases rabidly causing the internal moisture to migrate to the surface. Fig. (3-a) depicts the effect of air velocity on drying ratio at different feeding rates.

It is clear that the drying ratio has a direct proportion with air velocity at different feeding rates. This proportion is decreasing as feeding rates increase.

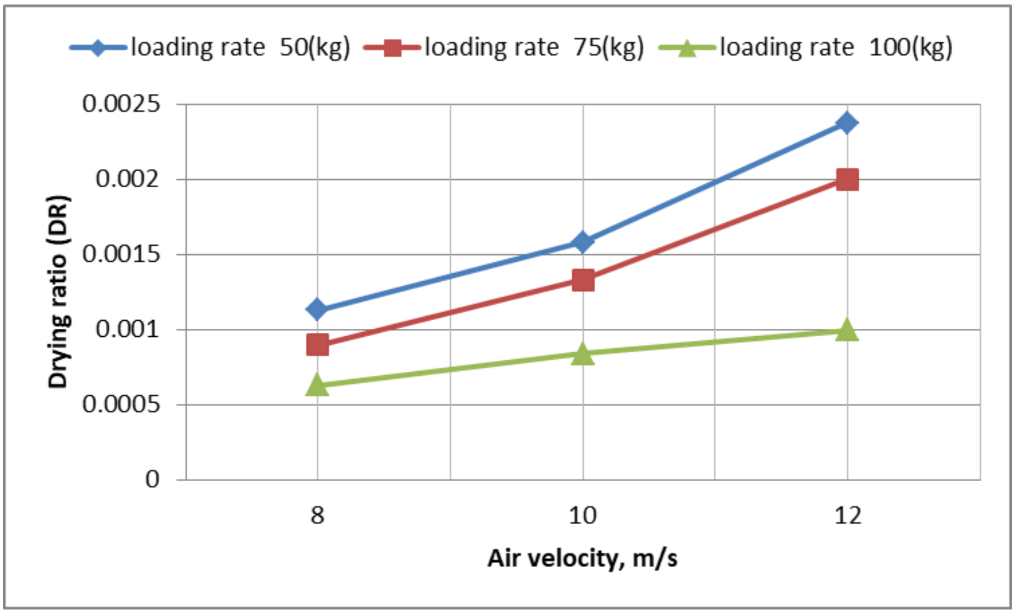


Fig. (3.a) Effect of air velocity on drying ratio at different feeding rates

1.b. Effect of rotary dryer speed and feeding rates on drying ratio:

The fast-moving air stream through the venturi tube elevated the grains to the top of the cyclone where the air collides with the blades of the rotary element causing the grains to swirl down the cyclone while the air temperature decreases. This causes the surface moisture to escape through the top of the cyclone. The grains enter to the rotary drum dryer and expose to the hot air stream coming directly from the thermal unit in cross flow, so the grains temperature increases gradually in the direction of the outlet. The baffles inside the drum stir the grains and mixed them with the hot air which decreases the speed of the grains downward. As a result of this, the residing time of grains inside the dryer increases. Consequently, the drying ratio increases in general, with agreement of **(Susanto *et al.*, 2021)**. Fig. (3-b) displays the relation between the drum speeds and drying ratio at different feeding rates.

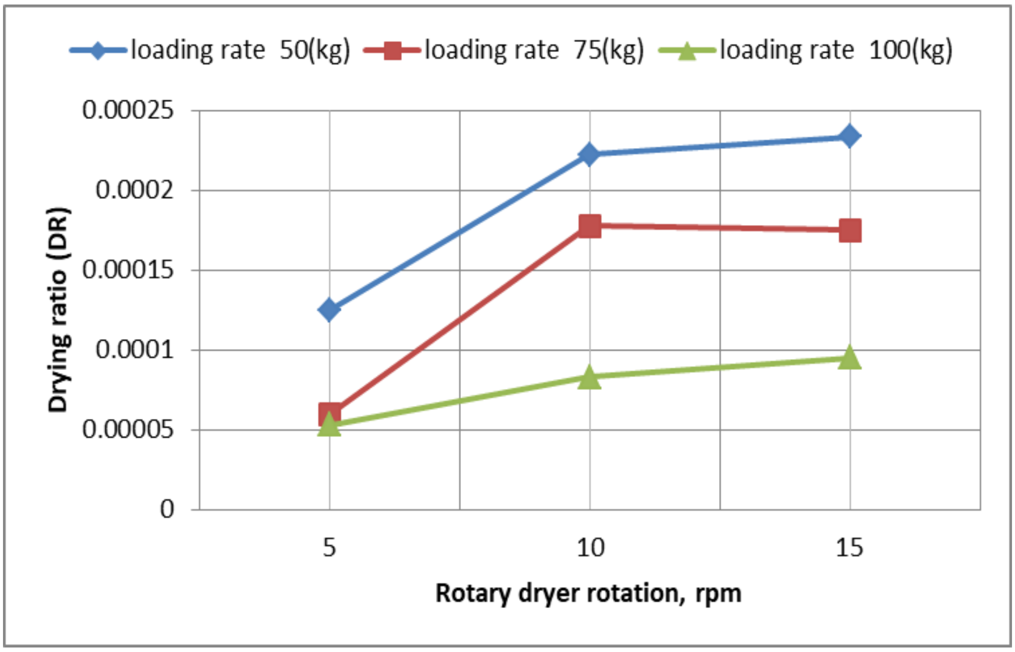


Fig. (3.b) Effect of rotary dryer speed on drying ratio at different feeding rates

2.a. Effect of hot air velocity and feeding rates on heat utilization factor (HUF):

Fig. (4-a) shows that HUF increased by increasing air velocity up to 10 m/s then decreased under 50 kg/cycle feeding rate, but this phenomenon disappeared with feed rate of 100 kg/cycle. This can be attributed to the fact that more grains consume more heat to dry.

2.b. Effect of rotary dryer speed and feeding rates on heat utilization factor (HUF):

Increasing drum rotary speed improved HUF under the different feeding rates due to the effect of stirring and mixing the grains with the hot air.

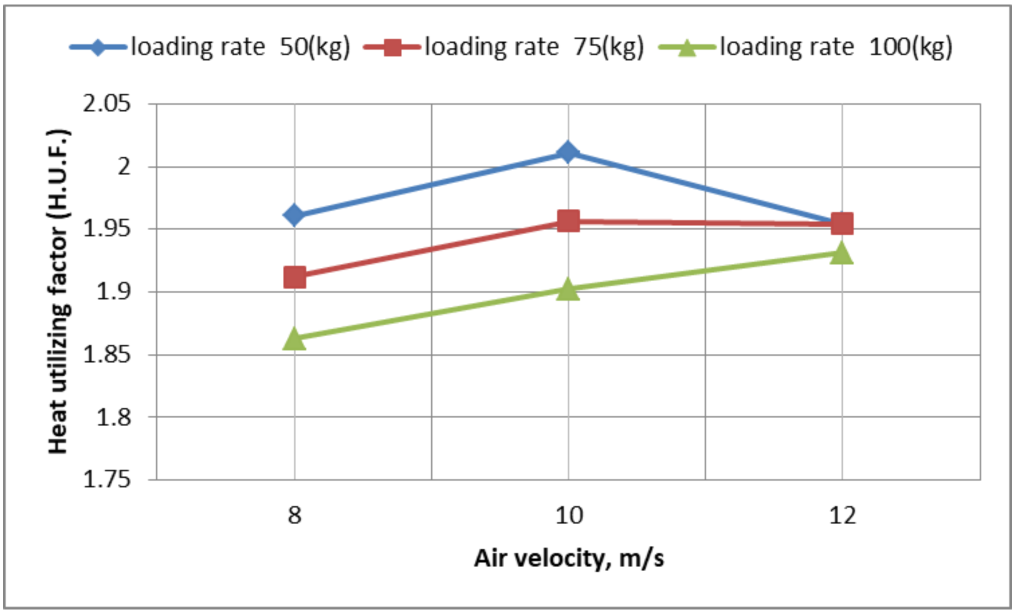


Fig. (4.a) Effect of air velocity on heat utilization factor at different feeding rates

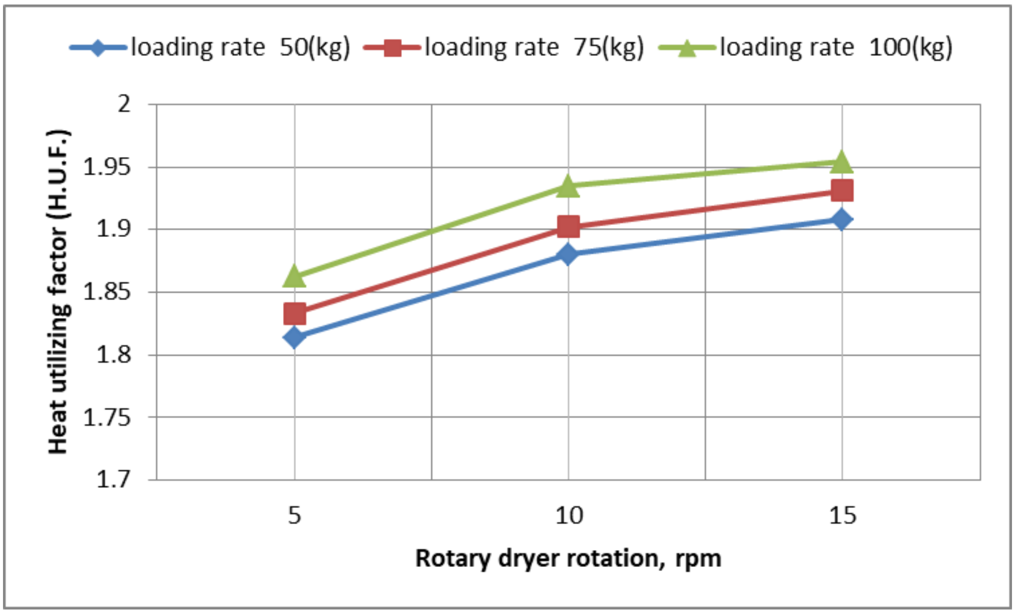


Fig. (4.b) Effect of rotary dryer speed on heat utilization factor at different feeding rates

3.a. Effect of hot air velocity and feeding rates on coefficient of performance (COP):

Fig. (5-a) illustrates the relation between hot air velocity on COP under different feeding rates. The same trend was similar to that found with HUF where the COP increased up to air velocity of 10 m/s then decreased under the lowest feeding rate, with agreement of **(Dina *et al.*, 2020)**.

3.b. Effect of rotary dryer speed and feeding rates on coefficient of performance (COP):

Increasing drum rotary speed improved COP under the different feeding rates due to the effect of baffles on stirring and mixing the grains with the hot air under different feeding rates, with agreement of **(Lisboa *et al.*, 2004)**.

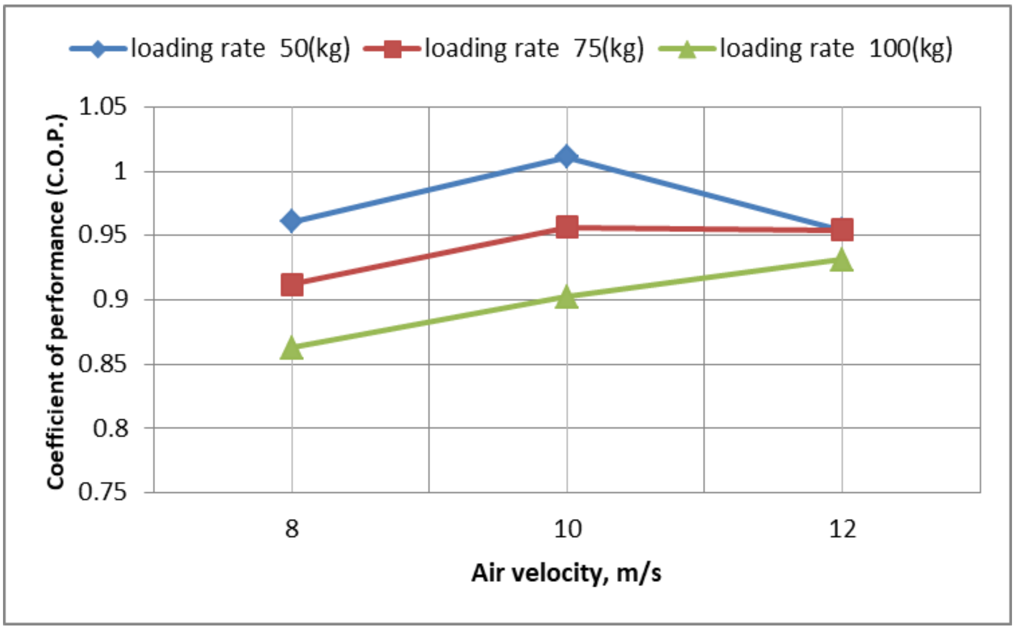


Fig. (5.a) Effect of air velocity on coefficient of performance at different feeding rates

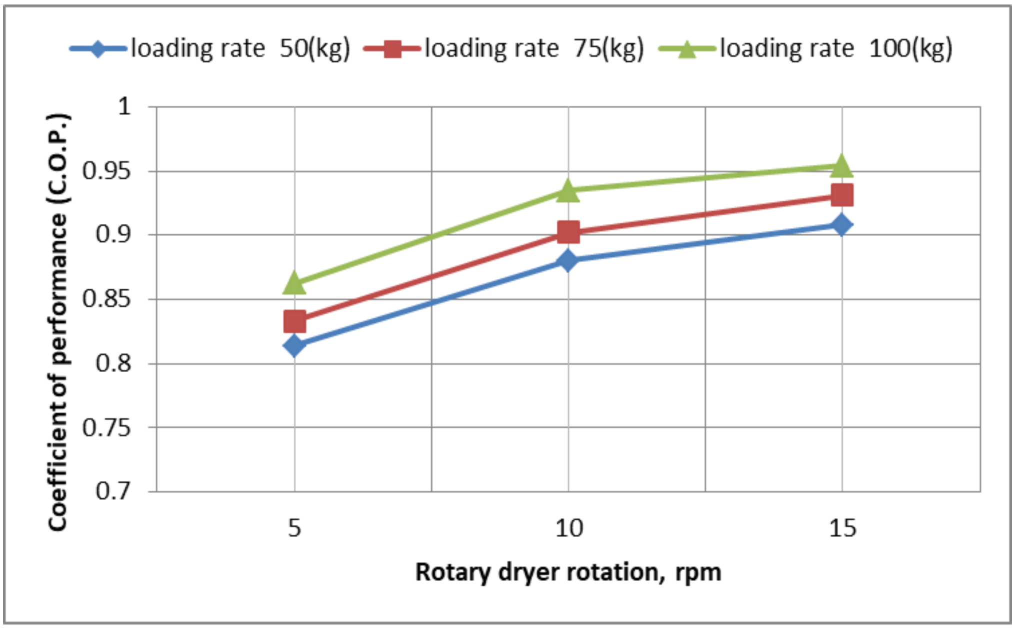


Fig. (5.b) Effect of rotary dryer speed on coefficient of performance at different feeding rates

4.a. Effect of hot air velocity and feeding rates on consumed specific energy (CSE):

Fig (6-a) portrays the relationship between different air velocities on the specific energy requirement at different feeding rates. It is evident that specific energy requirement directly proportional with air velocity due to increasing electric power consumption. But it has an inverse proportion with different air velocities due to increasing of drying rate, with agreement of **(Jafari *et al.*, 2018)**.

4.b. Effect of rotary dryer speed and feeding rates on consumed specific energy (CSE):

It can be concluded from Fig. (6-b) that rotary speed of the dryer has a slight effect on specific energy requirements for fixed feeding rates. Meanwhile, specific energy requirement increased by increasing feeding rate at a fixed drum rotary speed, with agreement of **(Tumpanuvatr *et al.*, 2018; and Susanto *et al.*, 2021)**.

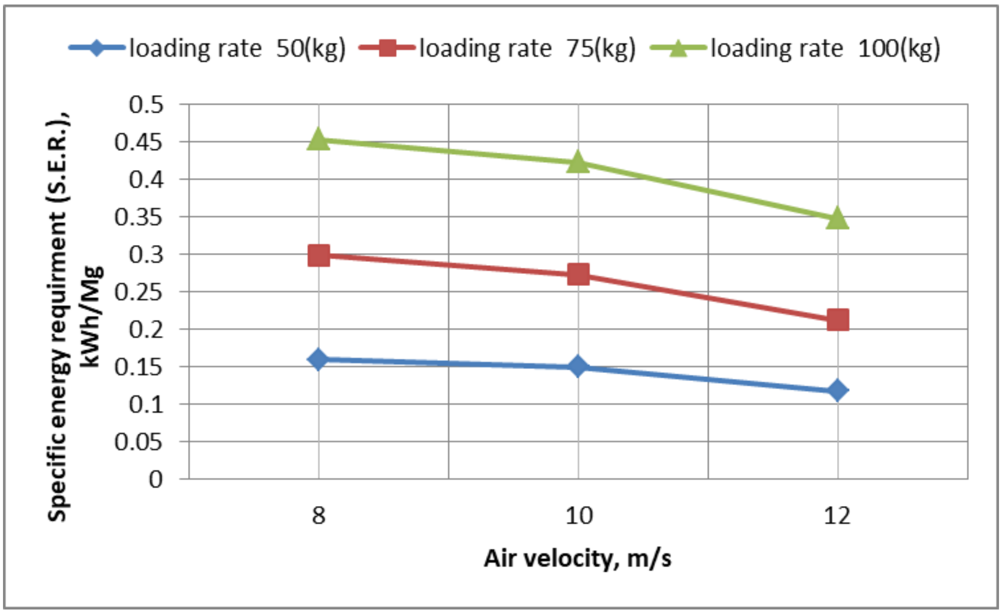


Fig. (6.a) Effect of air velocity on specific energy requirement at different feeding rates

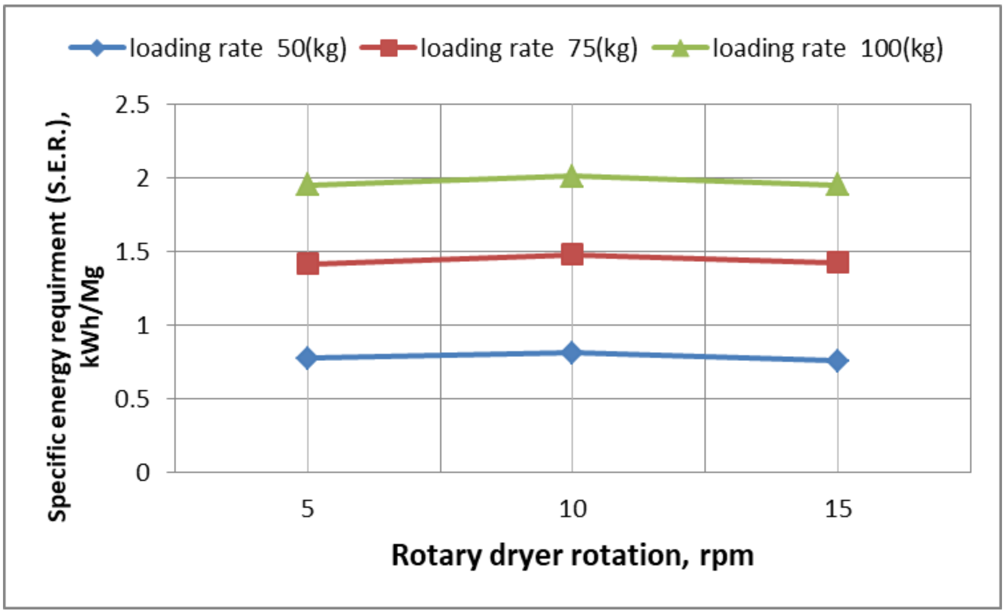


Fig. (6.b) Effect of rotary dryer speed on energy requirement at different feeding rates

5. System Cost Analysis:

Table (2) displays the incurred costs for the best treatment. This treatment variables were 75 kg/cycle feeding rate, 10 m/s air velocity, and rotary dryer speed 10 rpm. The cycle time was measured as 16 min/cycle. Accordingly, the system can dry 281.25 kg/h. The total productivity estimated to 2250 kg/day (assuming 8-hour day). Dividing total cost/day ÷ total productivity/day gives the drying cost L.E./kg. Total cost was found to be 0.104 L.E./kg. in other words, the cost for drying one Mg about 104.10 L.E.

Table 2 : Cost analysis of the manufactured equipment

Parameters	**Fixed cost**
Initial cost of thermal unit	15000 L.E.
Depreciation cost of machine (10 %)	1500 L.E.
Interest cost (12%)	1800 L.E.
Repair and maintenance cost (1%)	150 L.E.
Total fixed cost per year	3450 L.E.
Total fixed cost per day (180 operating day/year)	19.17 L.E.
Parameters	**Variable cost**
Labor cost (2 workers/day)	200 L.E.
Electricity cost (1 LE/kW.h)	10.00 L.E.
Thermal cost (0.5 LE/kW.h)	5.00 L.E.
Total variable cost per day	215.00 L.E.
Total cost per day	234.17 L.E.
Total cost per hour (assume 8 h operating hours)	29.27 L.E.

CONCLUSIONS

A drying system provided with clean biogas-thermal unit and a novel technique of venturi theory for dried material transportation was used continuously for drying paddy rice. A set of preliminary experiments were conducted to arrive at suitable blower speed, hot air velocity and rotary drum speed. The main drying process happened in the rotary drum dryer under three different hot air velocities (5, 10, 12 m/s), three different feeding rates (50, 75 and 100 kg) and three different speeds of rotary dryer (5, 10 and 15 rpm). The best drying treatment was found to be 10 m/s hot air velocity, 75 kg/cycle, and 10 rpm for rotary drum speed. This treatment was selected regarding the specific energy consumption and total cost per kg.

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تقييم عملية تجفيف أرز الشعير بمجفف دوراني مستمر يعمل بالغاز الحيوي

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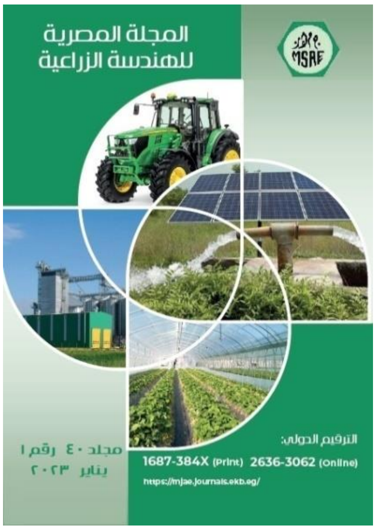

الكلمات المفتاحية:
الأرز الشعير؛ المجفف الدوار؛ البيوجاز.

الملخص العربي

تم تصميم وتطوير مجفف الأسطوانة الدوارة لتجفيف الأرز الشعير. تم تصميم وتصنيع وحدة حرارية ذات تصميم جديد لتوفير الطاقة الحرارية اللازمة لعملية التجفيف. يمكن تشغيل هذه الوحدة الحرارية باستخدام الغاز المسال أو الغاز الحيوي كمورد متجدد. معظم نظم التجفيف الصناعية تسبب تلوث للمادة الغذائية بسبب اختلاطها بغازات العادم مما يؤثر سلبيا على حيوية الجنين ونسبة الإنبات. ميزة هذه الوحدة الحرارية الجديدة هي أن غازات العادم تنفث من المدخنة وأن الهواء الساخن النظيف فقط يلامس المادة المراد تجفيفها. أيضًا ، يتم استخدام تقنية جديدة لنقل المواد المراد تجفيفها تعتمد على نظرية الفنشوري حيث تحدث ظاهرة الطبقة المميعة وتحدث عملية تجفيف الحبوب الجزئي. تم إجراء مجموعة من التجارب الأولية للوصول إلى سرعة المروحة المناسبة وسرعة الهواء المسخن وسرعة الأسطوانة الدوارة. حدثت عملية التجفيف الرئيسية في المجفف ذو الأسطوانة الدوارة حيث حدث اضطراب كبير في المادة المراد تجفيفها بسبب تأثيرات التقليب وسرعة الهواء معًا. أظهرت النتائج أن سرعة الهواء البالغة ١٠ م / ث ومعدل التلقيم ٧٥ كجم / ساعة كان لهما أكبر تأثير على معدل التجفيف وأقل تأثير على استهلاك الطاقة النوعي. أيضًا ، كانت سرعة الأسطوانة الدوارة البالغة ١٠ لفة/دقيقة مناسبة فيما يتعلق بمعدل التجفيف واستهلاك الطاقة النوعي بمعدل تلقيم يبلغ ٧٥ كجم / ساعة. سجل نظام التجفيف الجديد تكلفة أقل لكل كيلوجرام من المادة المجففة مقارنة بالطرق الأخرى.