The Design Concept of Rotary Tray Dryer Machine to Dry Gepuk Beef Patties

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Abstract— *Gepuk is a typical West Java Sundanese food made from cattle beef, tastes a little sweet and savory. Before being served, usually gepuk is fried first, so the effect of frying process can cause health problems due to the repeated use of cooking oil. This study aims to create a design concept for a rotary tray dryer for drying beef patties as an effort to replace the frying process. The research method used an engineering design approach which included design analysis, functional design and structural design of rotary tray dryer. From the results of the design analysis which found on problems identification in the field, the rotary tray dryer machine was designed with a capacity of 10 kg per each process which was adjusted to the production capacity of SME. The design components of the rotary tray dryer machine consisted of: (1) drying air inlet, (2) LPG-fueled heater, (3) distributor, (4) products trays, (5) rotary shaft, (6) drying chimney, and (7) exhaust fan (suction blower). The dimension of the rotary tray dryer machine was as follow: the tray dimensions 817 x 416 mm, the overall dimensions of the dryer construction, namely the side length 1.132 mm, the front width 1.496 mm and the height 1300 mm. Based on the simulation results, the rotary tray dryer machine can reduce the moisture content of the gepuk from 60 percent to 14 percent during the 10-hours drying process.*

Index Terms— -*Gepuk*, Drying Process, Design Concept, Rotary Tray Dryer

1 Introduction

Drying is one of food processing methods that has been known by people a long time ago. Drying is a process of reducing moisture content of a material to a certain limit of moisture content, in order to slowing down the product's deterioration due to biological and chemical activity. Meanwhile, the purpose of food drying is to reduce the moisture content thus the food can be stored longer, to reduce the volume in order for easier handling, saving transportation cost, packaging and storage. In other side, drying may cause losses such as changing in physical and chemical properties as well as quality deterioration [1].

Food drying involves simultaneous heat and mass transfer to and within the food material [2]. During the drying, all water vapor generated from the material is transferred to the surface and removed by the airflow on the surface. Heat which is transferred to the material by conduction, convection or radiation causes the moisture content changes from liquid phase to vapor and evaporate at the surface [3].

Therefore, the drying process involves mass transfer between phases from the wet material to the drying air (heat), which can be described as a transfer process of moisture content from the center of the material to the surface followed by evaporation on the surface of the material, and the water vapor is carriedby the drying air [2].

Gepuk is a typical West Javanese Sundanese food made from cattle beef, tastes a little sweet and savory. *Gepuk* processing business/industry is mostly carried out by SME (Small and Medium Enterprises) with simple processing technology. In general, the process of making *gepuk* is made from cattle beef, which is sliced in the direction of the meat fiber and half-cooked boiled, then beaten until it is slightly tender.

The soft meat is soaked in spices mixed with coconut milk, then boiled again until the coconut milk shrinks. At the time it will be served, fried in a little of oil until lightly browned. This beef patties (*gepuk*) menu is quite liked by public. The beef dish has a softer texture with a sweeter and more savory taste, so it fits perfectly with the tongue of Indonesian people.

Some problems occur in *gepuk* frying process, including: (a) cooking oil that is heated up to too high temperature and used

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repeatedly can cause bad saturated fat and carcinogenic free radical, which can cause the risk of cancer and other diseases, (b) causes loss/reduction of nutrients contained in food products, (c) increases trans-fat and calories in food products which is a risk to health, (d) poor quality of frying causes the inside of *gepuk* is not be fully cooked and affects the taste, (e) the moisture content of *gepuk* is still high enough, so the storage time is shorter. The content of free fatty acids (FFA) in the oil will increase with repeated frying by up to 50% [4].

As an effort to overcome those problems, the frying process of *gepuk* is replaced by drying. Drying is a cooking process and reducing the moisture content inside the product through hot air media, thus an even cooked *gepuk* can be produced with less moisture content and prevent health risk due to cooking oil consumption. Furthermore, in order to improve the effectivity of drying process it is necessary to design appropriate dryer machine namely rotary tray dryer where the working principle is a continuous system drying machine (the dried material is placed on a rotating trays), so that the drying process runs effective and efficient.

The purpose of this study was to analyze the design concept of a rotary tray dryer machine for drying beef patties "gepuk". At the initial stage, the design of the rotary tray dryer had a capacity of 10 kg of meat per process according to the production capacity of SME. It is expected that the rotary tray dryer machine can support the development of the SME business of *gepuk*, which are currently being developed by the community.

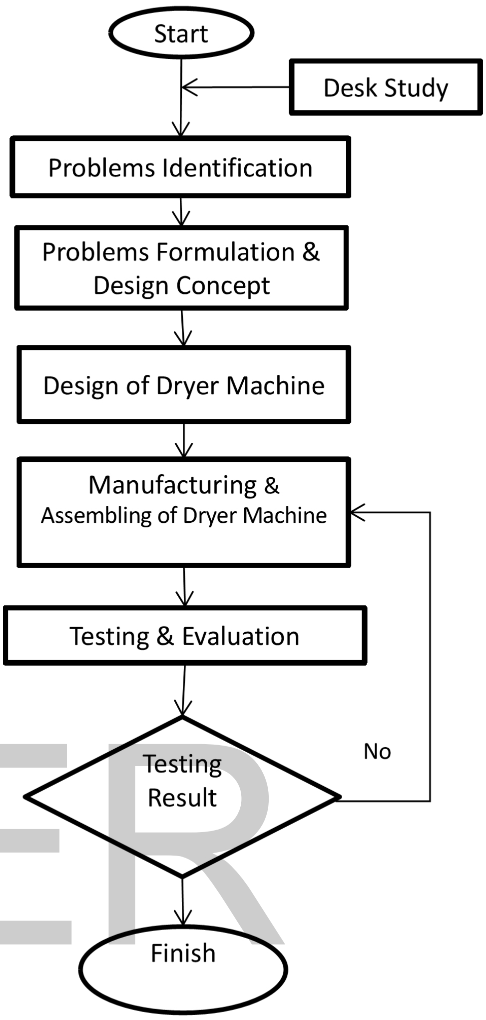

Figure 1. Research flow chart

2 MATERIALS AND METHODS

This research was conducted on May – August 2020 in Laboratory of Production Process, Study Program of Machine Engineering, Indonesian Institute of Technology.

Materials and equipments were AutoCad 2012 program, one set of wrenches, lathe machine, electric welding machine, grinding machine, drilling machine, elbow roll, hammer, acetylene welding, roll meter, cutting saw, plate shear, nut, bolt, thermometer, blower, stainless steel pipe with diameter 80 mm, stainless steel plate 304 with 1.5 mm thickness, and UNP iron 4x4 for the frame of dryer.

The method used in this research were engineering design approach that consisted of problems identification, problems formulation, design concept, manufacturing and testing of machine performance as shown in Figure 1.

2.1 Design Concept

The design concept of *gepuk* drying machine was conducted by improving the performance of dryer machine that produced un-uniform final moisture content and slow drying rate. Thus, the dryer machine was designed in continues system with rotation inside the dryer chamber in order to obtain uniform drying process and uniform final moisture content of *gepuk*.

2.2 Design Parameter

Design parameters were parameters that involved in the design of rotary tray dryer machine. Some of the parameters design were moisture content determination, products density determination, dimension of length, width and height, amount of moisture content to be removed, air rate to effect the drying process, air volume for drying, quantity of heat required to achieve effective drying process, heat mass transfer, sensible and latent heat used for drying, and determination of dryer component.

2.3 Dryer Machine Design

The design of rotary tray dryer machine was consisted of calculation and engineering drawing. The design was started by calculating and designing the construction and main parts of the dryer machine then followed by calculating the drying process through mathematic equations.

2.4 Construction Design

The construction calculation of the dryer machine was determined by the capacity of the machine

a. Determination of tray dimension (tray for drying *gepuk*)

$$V_g = \frac{M}{\rho_g} \quad (1)$$

Where:
M = weight of *gepuk*, kg
V_g= volume of *gepuk*, m^3
ρ_g = density of *gepuk*, kg/m^3

$$L_g = \frac{V_g}{t_g} \quad (2)$$

Where:
L_g = surface area of *gepuk*, m^2

$$L_{rl} = \frac{L_g}{P_r} \quad (3)$$

Where:
L_{t1} = Total area of tray, m^2
P_r = Tolerance percentage of clearance between *gepuk*

$$P_t : L_t = 2 : 1 \quad (4)$$

Where:
P_t = length of tray (drying place for *gepuk*)
L_t = width of tray, m

b. Determining the drying area dimension:

$$P_{dryer} = 40 + P_t \quad (5)$$

$$L_{dryer} = T_{dryer} = 3\, L_{dryer} \quad (6)$$

Where:
P_{dryer} = length of dryer machine, m
L_{dryer} = width of dryer machine, m
T_{dryer}= height of dryer machine,m

2.5 Heat and Air Flow Rate

a. Moisture content to be removed
Amount of moisture to be removed from the product, M_R (kg) was calculated by using Equation [5] :

$$M_R = M\left(\frac{Q_1 - Q_2}{1 - Q_2}\right) \quad (7)$$

Where:
M = drying capacity (kg)
Q_1 = initial moisture content (% wb)
Q_2 = final moisture content (% wb)

b. Amount of air required for drying, Q_a (kg) [5]

$$Q_a = \left(\frac{M_R}{H_{r1} - H_{r2}}\right) \quad (8)$$

Where:
H_{r1} and H_{r2} = initial and final ratio humidity, respectively (kg/kg dry air)
M_R = value derived from Equation (7)

c. Volume of air for drying, V_a (m^3) [5]

$$V_a = \frac{Q_a}{\rho_a} \quad (9)$$

Where:
. ρ_a = air density (kg/m^3)

d. Amount of calor required, H_r (kJ)[5]

$$H_r = \{(M * C_T * (T_2 - T_1)\} + (h_L * M_R) \quad (10)$$

Where:
M = dryer capacity per process (kg)
C_T = specific heat of the product (kJ/kg °C)
T_1 and T_2 = ambient and drying air temperature, respectively (°C)
h_L = latent heat of vaporization (kJ/kg)

2.6 Structural Design

Structural design was an analysis of rotary tray dryer machine's components which has been previously discussed in functional design. The shape, dimension and material from each component were determined in structural design. As given in the Figure 2, the design of rotary tray dryer machine was consisted of: (1) drying air inlet, (2) heater/LPG, (3) distributor, (4) trays, (5) rotating axle, (6) dryer chimney, and (7) suction blowe

2.7 Functional Design

The main components of dryer machine and functions to produce *gepuk* made from cattle beef is shown in Table 1.

Table 1. Functional design of rotary tray dryer machine

No	Dryer Machine Component	Specification	Function
1	Tray	Dimension 817x416x50 mm, SS 304	To place *gepuk* which will be dried
2	Main frame	1496x1132x1300 mm, SS304	Frame to support and place for drying process
3	Door	1200x1200 SS304 and glass	To feed in and withdraw products that need to be dried
4	Cover plat	1192x1496, 1192x1132 SS 304	To cover the main frame
5	Tray holder	1400 mm, D 30 mm	Axle for shaft
6	Engine	1 hp, rpm 1400, equipped with *reducer ratio* 1:70	To rotate axle
7	Heater	LPG fuel, high pressure regulator	To heat the air that will be distributed to *gepuk* meat
8	*Exhaust Fan*	Air suction 1151 CMH, which equipped with speed regulator	To remove air from drying chamber.

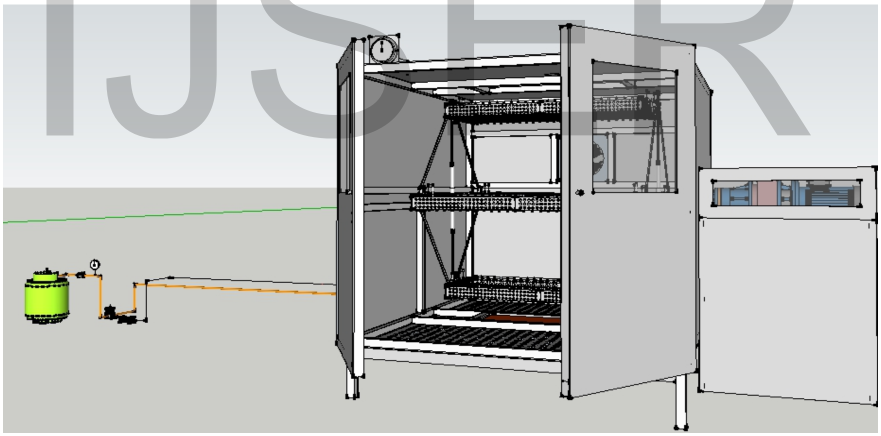

Figure 2. 3D picture of rotary tray dryer machine

3. RESULT AND DISCUSSION

3.1. Dimension and Density of *Gepuk*

The density of *gepuk* meat (cattle beef that has been boiled, sliced and seasoned) was needed as reference to determine the dryer machine. By using Equation 1 to 6, the trays dimension could be calculated. Based on the measurement of dimension and weight from 12 samples of *gepuk* meat as seen in Table 2, then the average density of *gepuk* meat 810 kg/m^3 was obtained.

Tabel 2. Calculation of *gepuk* meat density

Sample	Width (cm)	Length (cm)	Thickness (cm)	Volume (m^3)	Weight (gr)	Density (gr/cm^3)	Density (kg/m^3)
1	4,2	6	1	25,20	16,3	0,647	646,8
2	4,3	5,3	1,5	34,19	26,4	0,772	772,3
3	4,2	4,5	0,8	15,12	11,3	0,747	747,4
4	3,6	6,5	0,9	21,06	23,7	1,125	1125,4
5	4,4	6,2	1,6	43,65	24,4	0.559	559,0
6	3,9	4,8	1,1	20,59	19,3	0,937	937,3
7	4,2	4,3	1,1	19,87	15,2	0,765	765,1
8	5,2	5,2	0,8	21,63	15,8	0.730	730,4
9	4,4	5,0	1,5	33,00	24,4	0,739	739,4
10	4,2	5,2	0,5	10,92	10,7	0,980	979,9
11	4,7	4,9	0,4	9,21	9,6	1,042	1042,1
12	3,2	5,1	1,8	29,38	20,0	0,681	680,8
						Average	**810,5**

3.2. Tray Dimension and Construction of Rotary Tray Dryer Machine

Based on Equation 1 to 4, and initial density of *gepuk* meat 810 kg/m^3, thickness 10 mm, then tray width and length could be calculated i.e. 22.5 cm and 45 cm, respectively. In order to provide distance tolerance between products then trays were made wider i.e. width 40 cm and length 80 cm.

Basically, the capacity of trays could be made double i.e. 20 kg per each drying process if the feed products becoming 20 mm. However, the increasing of products' thickness will extend the drying process. Optimization of products' thickness and drying capacity was carried out after finishing the construction of the dryer machine.

The dimension of trays affected the dimension of this rotary tray dryer machine because the trays size had been determined to be 817 mm x 416 mm, with four numbers of trays. With a rotating scheme, there would be two trays in parallel position thus the width should be more than 800 mm, added with clearance between trays and left and right borders then the total width would be 1.496 mm, while the width was 1.132 mm (tray width was 800 mm, the rest would be used for left and right boundaries). The height was 1.300 mm (where the leg bars was about 200 mm).

3.3. Temperature, Air Flow Rate and Drying Time

Based on Equation 7 to 10, data as given in Table 3 were obtained.

With drying capacity 10 kg per each process, initial moisture of *gepuk* meat 60% (based on initial measurement), then the drying time could be computed i.e. 10 hours with final moisture content 14%.

According to Table 3, dryer could be operated at minimum temperature 50 ^oC and maximum air flow rate 2 m/second. For further research, a controller for drying temperature and air flow rate can be taken place.

Table 3. Parameters design analysis result for rotary tray dryer machine

No	Description	Value
1	MR dryer capacity (kg)	10.0
2	Q1, initial moisture content of the product (% wb)	60.0
3	Q2, final moisture content of the product (% wb)	14,0
4	Amount of moisture to be removed from the product (kg)	5,3
5	hr_2 = air humidity, 50 C (kg/kg dry air)	0
6	hr_1 = air humidity, 31 C dry basis	0,008
7	Amount of air to be distributed (kg)	668,6
8	Air density (kg/m^3)	1,1
9	Volume of air to be discharged (m^3)	599,6
10	Fan velocity (m/det)	2,0
11	Surface area (m^2)	0,008
12	Air debit (m^3/det)	0,016
13	Drying time (hour)	10,6
14	Fan power (watt)	13,1
15	Latent heat, hL (kJ/kg)	64,4
16	Latent heat of evaporation (kJ/kg)	1248,1
17	Required energy (kJ)	7319,9
18	Required energy (kcal)	1764,7
19	Calorific value of LPG (kcal/kg)	11220,0
20	Volume of gas needed (kg)	0,2

4. CONCLUSION

The design concept of this rotary tray dryer machine with drying capacity 10 kg per each process was suited with SME production capacity. Based on the calculation result, the dimension of this rotary tray dryer machine was 817 x 416 mm, with total construction dimension was side length 1.132 mm, front width 1.496 mm and height 1.300 mm. Based on the simulation, dryer machine could reduce the moisture content of product from 60% to 14% in 10 hours drying time.

ACKNOWLEDGMENT

The author would like to express his gratitude to the Head of Research Center and Community Empowerment of Indonesian Institute of Technology who provided fund for this research with Contract Number: 021/KP/PRPM-PP/VII/2020.

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