Heat Energy Balance Test Of Mango Puree Dryer Machine Capacity 5 Kg / Day Using A Hot Air Furnace System

Ahmad Maulana K.[1], Ade S. Margana[2], Sunanto Sunanto[1], Triaji Pangripto P.[2]

[1] Jurusan Teknik Pendingin dan Tata Udara
Politeknik Negeri Indramayu
Indramayu – Jawa Barat, Indonesia
[2] Jurusan Teknik Refrigerasi dan Tata Udara
Politeknik Negeri Bandung
Bandung – Jawa Barat, Indonesia
ahmadmaulana@polindra.ac.id, adesmargana@polban.ac.id, sunanto@polindra.ac.id, triajipangripto@polban.ac.id

Abstract. Mango puree is a semi-finished product processed from mangoes. This mango puree is usually preserved using the freezing method or the method of adding preservatives. But actually this mango puree can also be preserved by the drying method. The advantage of the drying method over the freezing method is that it saves electricity and is more economical in manufacturing and operational costs. For this reason, in this research a mango puree drying machine will be created and tested using an LPG gas stove heating medium with a drying capacity of 5 kg / day. The air flowrate (debit) from blower was variated about halfly opened (HO) test and fully opened (FO) test. The research was carried out with the aim of knowing the heat balance of the drying machine and knowing the operational costs in the mango puree drying process. From the test results obtained, the amount of input energy in the LPG gas combustion process is 190.4 kJ and the amount of energy wasted is 133.29 MJ or around 77.6% of the input energy. The energy that is passed on to the heat exchanger is only 56.67 MJ or about 45.4% of the input energy. The total energy used in the mango puree drying process in the cabin is 29.38 MJ or about 22.4% of the input energy.

Keywords: hot air; furnace; heat balance;air flowrate.

1 Introduction

Mango fruit is an agro-industrial product that is abundantly available in the coastal areas of West Java, especially the Indramayu, Cirebon, Kuningan and Majalengka areas. However, the existence of mangoes in this area still relies on the harvest season, where during the harvest season mangoes are widely available in the area, but if the harvest season has passed, they will be difficult to obtain. As a result of this season, mango fruit has fluctuating prices, sometimes expensive and sometimes cheap.

M. U. H. Al Rasyid and M. R. Mufid (eds.), *Proceedings of the International Conference on Applied Science and Technology on Engineering Science 2023 (iCAST-ES 2023)*, Advances in Engineering Research 230,
https://doi.org/10.2991/978-94-6463-364-1_63

Every harvest season there are many mangoes that are small or have an abnormal shape, or are classified as off grade. In fact, fruit like this still has economic value because it can be processed into various products, such as dried mango, puree, juice, jam/jam, jelly, dodol, fruit bars, mango leather, mango in cans, and mango candy. Puree is an intermediate product that can be further processed into various food and beverage products such as juice, jelly, dodol, candy and ice cream [1].

In order to avoid the risk of losing yields due to damage or being too ripe (rotten), which in turn can be detrimental to farmers, many processing companies now use gedong gincu mangoes as their main raw material. Some of the products produced include mango roll cake, mango strudel, processed puree and so on. In Cirebon itself, there is a cake company that orders 1 quintal of mangoes every day which it buys from farmers in Sedong Sindang village and its surroundings. From this main raw material, it is possible to produce 50 boxes of mango cake rolls, 50 boxes of mango strudel and lapis legit [2]. However, considering that crushed mango (puree) has a lot of nutrition and nutrition, this product is very popular with microorganisms as a place to live. Therefore, purees must be preserved to extend their shelf life [3]. One way to preserve the puree can be done by using a drying machine. These dried mango products are generally made from mango puree and dehydrated using various methods such as hot air dryers and solar dryers. Vacuum dryer and freeze dryer. to remove the water content so as to make a concentrated puree that lasts longer [3].

For this reason, on this occasion, a mango puree drying machine will be tested using a dryer using LPG fuel. It is hoped that the use of the drying boiler can provide a solution for storing mango puree on an industrial scale in several mango micro-industries in the Indramayu area and surrounding areas. So the theme that will be raised in this research is "Performance Test of the Puree Mango miniature boiler dryer with a capacity of 5 kg with variations in air flow rate".

2 Research Method

This research began by first making a miniature mango puree dryer using a hot air furnace system according to the design scheme in Figure 1 below.

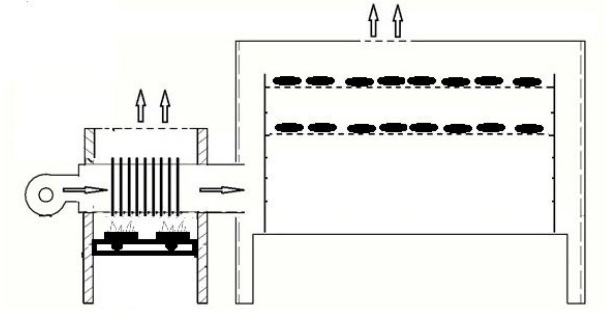

Fig. 1 design of a miniature mango puree dryer with a hot air furnace system

The design of the hot air furnace system uses LPG gas fuel so that it can be easily operated and the cabin temperature can be controlled. Burning LPG gas using a 2-burner gas stove is also used in this system so that the drying process can be more optimal. The heat transfer process from burning LPG gas to the air occurs in a gas to gas heat exchanger which is designed in such a way that the exhaust gas from burning LPG does not mix with the hot gas supplied to the dryer cabin. A blower is placed at the input of the heat exchanger to blow air into the heat exchanger until it reaches the drying cabin. In the drying cabin there are 2 shelves to place the mango puree to be dried. A total of 5 kg of mango puree will be placed on the shelves while hot air is blown from the bottom to the top of the cabin so that the drying process will occur on the mango puree on the shelves.

The mango puree drying process begins by turning on the LPG gas stove below and simultaneously turning on the blower to blow air through the heat exchanger to the drying cabin. The air heated in the heat exchanger will experience an increase in temperature to a temperature of 80 - 90 oC and then be blown into the drying cabin until the air temperature in the drying cabin also experiences an increase in temperature. The temperature in the drying cabin is controlled using a thermocontroller in the range 45 – 55 oC. As a result of heating the air in the cabin, the mango puree inside will undergo a drying process until the water content of the mango puree will decrease.

The test was carried out for 8 hours (480 minutes) and there were 2 (two) tests with different blower flow rates, namely flow with damper openings half / halfly open (HO) and flow with damper openings half / fully open (FO). During the test, several temperature data on the system were collected to determine the performance of the hot air furnace. The types of temperatures found in the drying process consist of: heat exchanger input and output air temperature, cabin temperature 1 (bottom) and 2 (top), and exhaust temperature. The five temperature points are measured using sensors connected to data acquisition type GSP-6 brand EXTECH and immediately record the data automatically and can be displayed on a computer/laptop device.

A digital scale is also used to determine the mass of LPG fuel supplied to the combustion chamber so that the fuel consumption rate (FCR) can be determined. Data regarding the mass of LPG fuel is recorded separately manually in another table. The following is a scheme of the testing process carried out in the mango puree drying process that has been carried out.

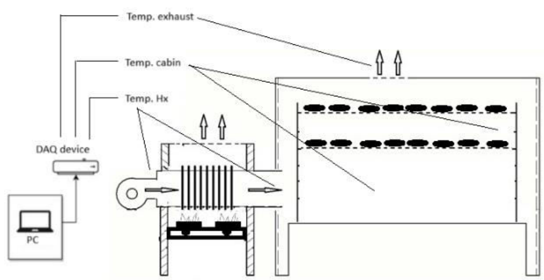

Fig. 2. heat balance test scheme for the drying process of mango puree

Once the test equipment is ready to be used, the next step is to prepare mango puree (pulp) made from ripe mangoes. The ripe mango is then peeled and chopped using a blender until it is smooth like puree (mango). A total of around 10 kg of mango fruit to produce 5 kg of mango puree. The following is a picture of the process of making mango puree that has been completed.

(a)

flue gas
(heatloss)

(b)

(c)

Fig. 3. process of making and drying mango puree in a hot air dryer, (a) blender process, (b) drying process, (c) results of dried mango puree.

3 Calculation Formula

The simple principle of the process of drying kumbung using a furnace dryer is actually a series of processes of changing/transferring heat from LPG fuel energy to hot air energy through a heat exchanger and then transferred to the cabin to dry the mango puree media. This process can be considered as a heat transfer process in accordance with the concept of energy balance in the furnace dryer.

Heat balance analysis in a furnace dryer is useful for estimating the values of heat wasted and used on each side of the heat transfer process that occurs during the drying process. The energy balance analysis starts from the heat energy of LPG used as fuel (Qfuel) as input energy, the heat energy in hot air (Qair) and up to the heat energy / product drying load (Qdryer) in the cabin as output energy. This is done to find out how much potential energy is produced at the end of the output when compared to the total energy input. The general scheme of the energy balance in the furnace dryer for the mango puree drying process is as shown in the following figure [4]:

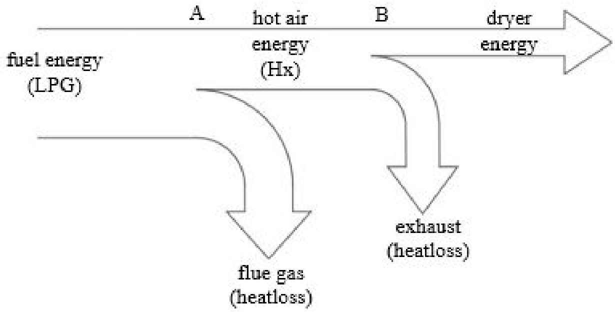

Fig. 4. Energy balance scheme in the mango puree drying process.

It can be seen in the picture above that the input energy originating from LPG fuel is transferred twice, namely energy transfer on the side of the combustion reactor and heat exchanger (side a), and on the cabin side (side b). During the energy transfer process there is waste energy (heat loss) that is not utilized so the efficiency is also doubled. And to calculate the total efficiency of the gasification furnace in the drying process by adding up the three existing efficiencies [5].

Eff. total = eff. a x eff. b .... (1)

Where :

eff. total = overall process efficiency

eff. a = efficiency in the combustion chamber and heat exchanger

eff. b = effisiensi in the cabin dryer

The formula used to determine total efficiency according to the energy balance scheme above is as follows [5].

$$\text{Efisiensi total} = \frac{Q_{output}}{Q_{input}} = \frac{Q_{dryer}}{Q_{fuel}} \quad \text{.........................} \ (2)$$

$$Q\ output = Q\ input - \sum Q\ losses \quad \text{.....................} \ (3)$$

$$\sum Q\ losses = Q\ loss\ a + Q\ loss\ b \ \text{.............................} \ (4)$$

Dimana :

$\sum$Q losses = heat loss throughout the process

Q loss a = heat loss in the combustion chamber

Q loss b = heat loss in the dryer cabin

The potential heat energy contained in LPG fuel (input energy) can be calculated using the following formula, namely [6]:

$$Q_{fuel} = m \ x \ GCV \ \text{..} \ (5)$$

Dimana :

Q_{fuel} = heat energy resulting from burning fuel LPG, (kJ)

m = mass of LPG fuel burned during combustion, (kg)

GCV = The calorific value of burning LPG fuel per unit mass, (kJ/kg), is known GCV LPG = 50 MJ/kg [7]

To calculate the amount of heat received on the air side is to calculate the amount of sensible heating heat. To calculate the rate of sensible heat in the air, you can use Black's basic equation, namely:

$$Q_{air} = m_{air} \ cp \ (T_2 - T_1) \ \text{.....................} \ (6)$$

Dimana :

Q_{air} = the amount of sensible heat used for heating the air (kJ)

m_{air} = heated air mass, (kg)

cp = air specific heat, (1,005 kJ/kg^{o}C)

T_1 = inlet air temperature hx (environment condition), (^{o}C)

T_2 = heat exchanger exit air temperature, (^oC)

Apart from taking into account boiler performance, dry air conditions during the air heating process in the heat exchanger (Hx) also need to be analyzed. The higher the hot air produced on the Hx output side, the lower the air humidity and this will result in the faster drying of the dryer cabin [8]. To determine the drying rate in this process, you can calculate the drying loss during the process. The term drying loss is generally called LOD (loss on drying), which is a statement of the humidity/water content of a product relative to the wet weight or initial weight of the product itself. If formulated using a standard formula, the drying rate of the product can be calculated using the following formula [9].

$$LOD = \frac{massa\ kadar\ air}{massa\ produk\ awal\ (basah)} \times 100\%$$

$$= \frac{m_{moisture}}{m_1} \times 100\%$$

$$= \frac{m_1 - m_2}{m_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where :

LOD = loss on drying, (%)

$m_{moisture}$ = the amount of water vapor lost, (kg)

m_1 = initial product mass (wet mass), (kg)

m_2 = final product mass (dried mass), (kg)

4 Result and Discussion

Figure 5 or Graph 1 below shows the temperature fluctuations from cabin temperature point in the system test. Meanwhile, table 1 is a table of the results of further data processing to calculate the heat balance that occurs during the drying process.

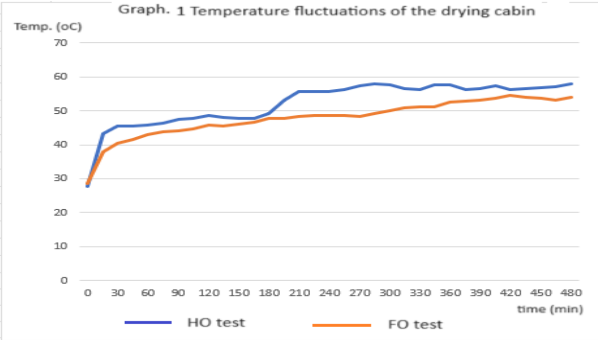

Fig.5. Average temperature of dryer cabin

It can be seen in graph 1 above and table 1 below that the different HO tests and FO tests in the drying process will result in different system performance. This is because there are different mass flow rates with different air flow discharges, namely the HO test and FO test. For the HO test, the mass flow rate is 0.031 kg/s, while for the FO test the mass flow rate is 0.047 kg/s. With a large air mass flow rate value in the FO test variation, it actually results in the efficiency of the drying process being smaller (total efficiency around 20.6%) while the efficiency in the HO test is around 22.4%. It can be concluded that the greater the air mass flow rate, the smaller the efficiency of the drying system. However, even though the efficiency is small, the FO test can actually produce better dry product quality when compared to the HO test. It is known that the loss on drying (LOD) for the HO test is only around 63.4%, while the LOD for the FO test is around 68.2%.

Tabel 1. energy calculation of hot air furnace sistem

No	Calculation parameter	Debit variasions	
		Halfly op. (HO)	Fully op. (FO)
1	Air conditions :		
	temp in Hx, (°C)	31.3	31.5
	temp out Hx, (°C)	97.8	91.5
	temp kabin, (°C)	57.7	54.3
	temp exhaust, (°C)	49.2	43.8
	laju al. massa (kg/s)	0.031	0.047
2	Total experiment time, (min)	480	480
3	Massa puree mangga awal, (kg)	5.2	5.4
4	Massa puree mangga akhir, (kg)	1.9	1.7
5	LOD puree mangga, (%)	63.4	68.2
6	Hot air energy, Qair (MJ)	56.67	81.62

7	Dryer energy, Qdryer (MJ)	29.38	38.31
8	Mass LPG used (kg)	3.81	3.84
9	Energi kalor LPG (MJ)	190.4	192.2
10	Eff. Hx, η a (%)	45.4	43.9
11	Eff. kabin, η b (%)	49.2	46.9
12	Effisiensi total, η tot (%)	22.4	20.6

Apart from being in tabular form, an energy balance scheme can also be created from a hot air furnace system type drying machine. The aim of creating this energy balance scheme is none other than to better understand the heat loss (waste energy) in the system in detail so that it can be optimized in subsequent tests. And the following is an example of an energy balance scheme for an existing hot air furnace with variations on the HO test.

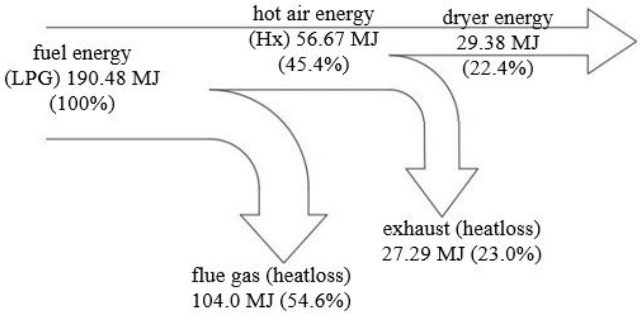

Fig. 6. Energy balance value scheme for the mango puree drying process using a hot air furnace system

It can be seen in Figure 6 and in accordance with Table 1 above that the highest amount of unused energy (heat loss) is found in combustion and heat transfer in the heat exchanger. The amount of heat loss is around 104.0 MJ or around 54.6% of the input energy. Meanwhile, the second heat loss on the exhaust side is around 27.29 MJ (or around 23.0% of the total input energy). The total of these two losses reached 133.29 MJ (77.6% of the input energy) while the amount of energy used for drying mango puree was only around 29.38 MJ (22.4% of the input energy).

5 Conclusions

Based on the experiments that have been carried out, several conclusions can be drawn as follows, namely:

1. The mango puree drying cabin temperature that can be achieved in this test is 57.7oC for the HO test and 54.3oC for the FO test.

2. The total efficiency value of the drying process is around 22.4% in the HO test and 20.6% in the FO test. Where the amount of energy used to heat the mango puree kumbung is around 29.38 MJ for the HO test and 38.31 MJ for the FO test.
3. The highest amount of heat loss is found in the combustion furnace and heat exchanger where the percentage value of heat loss in these parts can reach 77.6% of the total input energy or around 133.29 MJ in the HO test.

References

1. Dewandari KT, dkk. Pembekuan cepat puree mangga arumanis dan karakteristiknya selama penyimpanan. Jurnal Pascapanen Vol. 6(1) 2009. Balai Besar Penelitian dan Pengembangan Pascapanan Pertanian. Bogor
2. Tribunnews.com. Rabu, 14 November 2018. Mangga Gedong Gincu di Kabupaten Cirebon yang Tak Pernah Henti Produksi, https://www.tribunnews.com/nasional/2018/11/14/mangga-gedong-gincu-di-kabupaten-cirebon-yang-tak-pernah-henti-produksi.
3. Owino, W.O.; Ambuko, J.L. Mango Fruit Processing: Options for Small-Scale Processors in Developing Countries. Agriculture 2021, 11, 1105. https://doi.org/10.3390/agriculture 11111105
4. Maulana K, Ahmad, Aa Setiawan. Uji kesetimbangan kalor proses sterilisasi kumbung jamur merang kapasitas 1.2 ton media tanam menggunakan tungku gasifikasi. TURBO Vol. 5 No. 2. 2016 p-ISSN: 2301-6663, e-ISSN: 2477-250X. Jurnal Teknik Mesin Univ. Muhammadiyah Metro, Lampung. 2016.
5. Pedoman Efisiensi Energi untuk Industri di Asia. (2006) United Nations Environment Programme (UNEP)-www.energiefficiencyasia.org.
6. Keating, Eugene L. Applied combustion, Second Edition. Taylor & Francis Group, LLC. New York USA. 2007
7. Perbedaan LHV dan HHV: Pengertian dan Dampaknya terhadap Efisiensi Bahan Bakar - Localstartupfest.id
8. Maulana K, Ahmad, etc. TEST PERFORMANCE OF MINIATUR BOILER FOR DRYING KERUPUK WITH VARIOUS PRESSURE AND VARIOUS DIRECTION OF AIR CIRCUITS. TURBO Vol. 6 No. 2. 2017 p-ISSN: 2301-6663, e-ISSN: 2477-250X. Jurnal Teknik Mesin Univ. Muhammadiyah Metro, Lampung. 2017
9. Rankell AS, Lieberman HA, Schiffman RF. 1986. Drying, The Theory and Practice of Industrial Pharmacy. Philadelphia, Lea & Febiger.