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PERFORMANCE EVALUATION OF A MOBILE DRYER FOR FIELD CORN PRODUCTION

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BACHELOR OF ENGINEERING
(AGRICULTURAL AND BIOSYSTEMS)
FACULTY OF ENGINEERING
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PERFORMANCE EVALUATION OF A MOBILE DRYER FOR FIELD CORN PRODUCTION

By

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A project submitted in partial fulfilment of the requirement for the degree of

Bachelor of Engineering (Agricultural and Biosystems)

FACULTY OF ENGINEERING

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APPROVAL SHEET

This project report entitled Performance **Evaluation of a Mobile Dryer for Field Corn Production** prepared and submitted by Fatin Nabihah binti Juharidan to the Faculty of Engineering Universiti Putra Malaysia, in partial fulfilment of the requirement for the Degree of Bachelor of Engineering (Agricultural and Biosystems) is hereby accepted.

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ABSTRACT

The reduction of moisture content (MC) is important for the field corns to reserve the quality of the product. Typically the moisture content for harvest the field corn is around 25%. But to keep the quality of corn from the fungal problem, it need to be dry until 13% of MC. The fungal problem usually happen if the corns has higher of MC. Thus, the usage of mobile dryer is needed for the farmers to dry the corns from 25% of MC to 13% of MC. This preliminary research aimed to evaluate the performance of the mobile dryer in drying field corn at different operational conditions. Among the parameters to be measured are drying time, drying cost of MC and harvesting capacity for combine harvester. The drying time was measured to identify how much time is needed to reduce MC until it reach minimum MC which is 13%. From the result, the total drying time needed to reduce MC is around five hours. Besides, the total drying cost is measured for these dryer and tractor such as MATHARU dryer, Kubota tractor and New Holland tractor. It was found that the total drying cost for both dryer and tractor is RM223.62 per moisture reduction. Lastly, harvesting capacity of combine harvester such as Kubota and World Star also was measured. From the result obtained, the average harvesting capacity of Kubota is 2.76 tons/hr while for World Star is 2.32 tons/hr. It show that the average capacity of Kubota is higher than World Star combine harvester.

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ABSTRAK

Pengurangan kandungan kelembapan (MC) adalah penting untuk jagung bijirin bagi memelihara kualiti produk. Biasanya kandungan lembapan untuk tuaian jagung bijirin adalah sekitar 25%. Tetapi bagi menjaga kualiti jagung dari masalah kulat, ia perlu dikeringkan sehingga 13% MC. Masalah kulat biasanya berlaku jika jagung mempunyai lebih tinggi MC. Oleh itu, penggunaan pengering mudah alih diperlukan oleh petani untuk mengeringkan jagung dari 25% MC kepada 13% MC. Penyelidikan awal ini bertujuan untuk menilai prestasi mesin pengering jagung bijirin pada keadaan operasi yang berbeza. Antara parameter yang diukur adalah masa pengeringan, pengeringan kos MC dan kapasiti penuaian untuk mesin pengering jagung. Masa pengeringan diukur untuk mengenalpasti berapa banyak masa yang diperlukan untuk mengurangkan MC sehingga ia mencapai minimum MC iaitu 13%. Dari keputusan itu, jumlah masa pengeringan yang diperlukan untuk mengurangkan MC adalah sekitar lima jam. Selain itu, jumlah kos pengeringan bagi mesin pengering dan traktor juga diukur seperti pengering Matharu, Kubota traktor dan New Holland traktor. Ia telah mendapati bahawa jumlah kos pengeringan untuk kedua-dua mesin pengering dan traktor adalah RM223.62 per pengurangan kelembapan. Akhir sekali, kapasiti bagi jentera penuaian seperti Kubota dan World Star juga akan diukur. Daripada keputusan yang diperolehi, purata bagi kapasiti penuaian untuk Kubota ialah 2.76 tan / jam manakala bagi World Star ialah 2.32 tan / jam. Ia menunjukkan bahawa kapasiti purata Kubota adalah lebih tinggi daripada World Star.

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CHAPTER 1

INTRODUCTION

1.1 Background

Today, corn is the third important crop in the world after rice and wheat. Corn can be divided into two types such as sweet corn and field corn. Corn has very different of tastes, texture and used for different things. Usually sweet corn is used as ingredients in foods such as corn syrup and corn oil, while field corn is used as livestock feed and raw materials for industrial products. In Malaysia, field corn is one of an important feed ingredient for the livestock industry. But most of the field corn was imported from another countries such as US states, German, Thailand, Argentina and others because of shortage corn produced in Malaysia.

Recently, the Malaysian government has initiated a new national project to plant field corn on a big scale to cater the need for animal feed in the country. So mobile dryer had been introduce to give benefits for farmer which is easily used to dry the grain corn. The corns must be dried at maximum moisture content which is 13% to preserve in the storage for a long time.

A 13 % moisture content is considered to be the maximum value for the storage of wheat, corn, grain and rice during short periods, in spite of the fact that temperature and oxygen concentration also play an important part (Laca et al., 2006). Basically, acceptable moisture content (MC) by feed miller for safe storage of field corn is about 13%. (Laca et al., 2016). The ideal harvest moisture content for corn is between 22 to 25 % (Thomison., 2010). Since a typical MC of corn at a harvest is about 25%, an artificial dryer is needed to remove the excessive moisture from the grain. Moisture

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content of the crop is one of the factor that will affect the storage life of the corn. If the moisture content of the corn is too high, it will lead to physiological problem because it can stimulate a fungal problem, respiration and germination to the corn. During hot and humid condition, fungal also can easily growth on the corn. Temperature can also be spoilage of the safe storage which is promote the activity of fungal and insect problems. When the temperature is lower, the metabolic rate of fungi and insect will be decreases. Thus, it will affect the activity that can causing spoilage.

Apart from the problems, corn must be dried at maximum moisture content which is 13% to prevent from the fungal growth. Drying is important to keep the corn in good quality. As initiative, the corn above 21% moisture can be dried using natural air, low-temperature drying and also using mobile dryer. Using maximum drying temperature that will not damage the corn also can reduce energy consumption (Ken Hellevang., 2009). When the corns were dried using mobile dryer, it must use optimum temperature to decrease energy consumption. If the temperature is too high, it required more energy consumption and will cause the corn become damage. Thus, the cost of the mobile dryer also can be minimised if the dryer is operated at maximum drying temperature.

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1.2 Problem statement

Planting field corn is a new national project introduced in Malaysia. It must be dried at the suitable moisture content to prolong the storage life. Thus, a mobile dryer is proposed to be a solution due to Malaysian climatic condition which is higher density of rainfall. Due to the higher of rainfall, we need a dryer as alternative to reduce the moisture content from 25% to 13% which is acceptable for feed millers. Therefore, in this project the performance of the mobile dryer will be evaluated as the potential application to the farmers. The farmer need to identify the minimum of drying capacity of the mobile dyer if the corn were harvested at different moisture content. The optimum operating condition need to be determine for reduced the drying cost of the mobile dryer. If the grain is too long to be dried on the mobile dryer, it need more energy. The result of this study will be very important for drying service providers, farmers and also dryer manufacturer. The success of the drying operation certainly could reduce the drying cost thus increasing the profit of growers.

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1.3 Aim and Objectives

Aim

The aim of this study is to evaluate performance of mobile dryer in a field corn production at different conditions. Among the parameters to be measured are drying temperature, drying time, air flow-rate and loading amount. The drying cost will be calculated for each grain MC studied in this study. The optimum MC of the grain to suit the performance of the dryer will also be determined.

Objectives

The goal of this study is to evaluate the performance of mobile grain dryer in drying field corn at the field. Secondly, this study is also carried out to find the optimum drying cost for the grain harvested to be dried from twenty to thirteen percentage of moisture content. The specific objectives are:

1. To determine the drying time of field corns for recommended optimum drying temperature being dried until minimum moisture content which is 13% to 14%.
2. To determine the drying cost for moisture reduction of the corn.
3. To determine the harvesting capacity of different combine harvesters.

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CHAPTER 2

LITERATURE REVIEW

2.1 The Agronomy of Field Corn

Nowadays, corn are used as human food, biofuel, for livestock feed, and also as raw material in the industry. Thus, to get best product of corn some characteristic need to be considered for example the type of soil we used to plant the corn. Corn performs best on deep, well-drained, medium to coarse textured soils, but producers have successfully produced corn on a wide range of soil types (Smith et al., 2008). Some research are finding the suitable planting depth for the corn must be 1½ to 2 inches. When the seeds are planted deeper than 1½ to 2 inches and 2 to 4 inches apart, it will prevent from damage root system. If the seed planted less than 1 inches, it will leading to nodal roots at above the soil surface. That exposed roots will caused herbicide injury and insect predation. For the best grow of corns, pH soil must be between 5.8 until 6.8. Besides, corn crops also grow fast in the hot weather and needs 500mm of water per growing season to grow well. Corn growth and development responds primarily to temperature and is not controlled by day length (Smith et al., 2008). And for the best temperature of soil to be plant the corn at 60 °F to 95 °F. Corns can be harvested around 60 to 100 days and the seed can be germinated only 10 to 14 days.

2.2 Land Preparation and Plant Spacing

In the land preparation, plough and rotovator was used to carry out the primary tillage, secondary tillage and third rotary tillage. Primary tillage are the first steps used to loosen the soil with the object of improving structure and countering compaction. These include mouldboard ploughs, disc ploughs, and chisel ploughs. Secondary tillage is applied to control weeds and prepare a seedbed. This sequence of rotary

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tillage implementation is the standard practice for seedbed preparation before we plant the corn crops. Seedbed preparation is important to increase seed germination and prevent from the stunted growth of seeds. Aims of soil tillage are to reduce the weeds, improving the soil structure and increasing water erosion.

After land preparation, drainage system will be developed to ensure the irrigation system of the crops become smooth and to prevent from stagnant water. Drainage system also important to increase corn yield potential and the growth of plant. Then, the suitable plant spacing must be uniformly as in a row to make sure the maximum yield and population of plant. Uniformly plant spacing will causes the corn yield potential decreases and the growth of plant become slower. Seed should be spaced as uniformly as possible within the row to ensure maximum yields, regardless of plant population and planting date (Smith et al., 2008). If the seeds are planted closely to each other, it will compete to soil nutrients and will make the plant grow poorly. Thus, the suitable plant spacing that be used by farmers is 75 cm x 25 cm.

2.3 The Highest Field Corn Production Countries

The United States is the world's largest corn producer and currently exports between 10 and 20 percent of its annual production (USDA, 2018). Corn is the primary U.S. feed grain, accounting for more than 95% of total feed grain production and use (USDA, 2018). The available U.S corn output for 17% used for seed, food products, and industrial products. In 2001, corn accounted for 16% of U.S. crop cash receipts and 8% of total receipts from U.S. agricultural production (McElroy et al., 2002). Corn is grown in most U.S States for example, Iowa, Illinois, eastern portions of South Dakota and Nebraska, western Kentucky and Ohio.

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Iowa and Illinois, the top corn-producing States, typically account for slightly more than one-third of the U.S. crop, (USDA, 2006). Iowa where located at US states is a country that produce the largest number of field corn crop. In 2015, Iowa led the country in corn production then followed by Illinois and Nebraska. Iowa is one of the largest cereal mills and popcorn-processing plant in United States. Besides, it also the largest manufacturing industry for the industry of food processing. They are produce corn oil, corn-starch, corn sugar, and glucose. Iowa is states that has the most fertile topsoil on the planet. So, it is a great place to plant the corn in order to produce high quality corn crop as well as higher yield.

2.4 Field Corn Production in Malaysia

2.4.1 Climate change impact on field corn production

From the statistics of Department of Agriculture Malaysia in 2017, there are some states had planned to plant field corn as an alternative to increase crop production and intensity, reducing the cost of importing field corn and expanding the country's cultivation to achieve a target of 20,000 hectares shown as a table below. In 2017, there were 229 hectares of area provided to plant the field corn but only 89 hectares was used for planting the field corn. The main planting area in Malaysia are Terengganu, Kedah, Perlis, Kelantan, Johor, Negeri Sembilan and Melaka (DOA, 2017).

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Table 2.1. The location for planting the field corn at different states in Malaysia

Location	Area provided (ha)	Planting area (ha)
Kg. Dadong, Terengganu	39	30
Kg.Sg. Batu, Merbuk, Kedah	22	18
Laka Temin, Kedah	75	16
Chuping, Perlis	50	3
Kandis, Kelantan	22	1
Felda Cemplak, Johor	10	10
Ulu Bendul Dan Felda Serting, N.Sembilan	10	10
Gapam, Melaka	1	1
Total	**229**	**89**

Source from statistics of Department of Agriculture Malaysia (DOA), 2017

Researcher found that climate change commonly affects the agriculture in term of production as well as the impacting socio economics problem to the people involved. There are example of direct and indirect effect of climate change such as physical damage, loss of crop harvest, drop in productivity, vigour and others related to crop potentials. Other than that, floods is one of disasters that happened due to climate change which could damaging effect on the economy, and social and psychology of people affected.

Besides, rainfall is one of the most important climatic variables. Normally, rainfall over 25 mm per month is considered as heavy rainfall; whereas, among all harvesting sessions, the minimum rainfall is 57.4 mm, (Md. Mahmudul Alam, Mohd Ekhwan bin Toriman, Chamhuri Siwar and Basri Talib, 2011). Apart of these issues, when rainfall is higher in the wet period, it will cause floods while lack of rainfall in the dry period cause droughts. During the rainy seasons, the soil will become saturated and exceed the field capacity of the crops. Thus, this situation will causing the corn die due to the excessive amount of water in the soil. Besides, if the soil is saturated, it

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can deplete oxygen in the soil and increase disease infection as well as nitrogen losses. So, to overcome the stagnant water be formed, a good irrigation systems should be built.

2.4.2 Soil types that suitable for planting field corn

The soil requirements for com in Malaysia are summarized by MARDI, (1986a). Corn can be grown on variety of soils but performs best on well-drained, deep loam and silt loam containing abundant organic matter and nutrients. Riverine, marine terraces and flood plains are example of places that we can used to plant the corn because higher of nutrient and organic matter. Other than that, developed peat is also suitable for corn cultivation. But the crop performance is very poor on muck or peat soils. Peat soils will affecting suitability for crop production because high acidity and fertility. Waterlogging, low fertility and typically high acidity are challenges of agricultural production on peat soils. So due to this issues, deep loam or silt loam is most suitable for plant the corn crops. In addition, corn also can be grown on moderately acid soils, but the optimum pH of the soil must be about 5.3 to 6.0 to provide the best condition for growth. For the desirable for corn growth, soil bulk density is around 1.3 Mg m-3 or less than that.

2.4.3 Harvest and post-harvest practices

Harvest for silage can be done slightly earlier, but grain harvest will require more drying, (Joel Ransom, 2013). It require more drying to prevent the corn get disinfection by fungi. So the corn can be stored more longer if it dry at optimum drying. Corn harvested at 20 to 25 percent moisture need immediately drying to be stored at the storage for a long time. While corn that be dried at 13 or 14 percent moisture it can be shelled safely in the storage.

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Post-harvest handling can be characterized as the stage of crop production instantly taking after harvest. When the corn crop is removed or separated from its parent plant, process of deterioration will be started immediately. In Malaysia, they will make post-harvest treatment to ensure the quality of corn in good condition. After the final quality corn be checked they will used as an ingredient in a processed food product or whether it is sold for fresh consumption. Post-harvest treatment are functioning to slow down physiological forms of senescence and development, diminish advancement of physiological disorders and minimize the hazard of microbial development and defilement. So it will make the corn stay freshly after been harvested.

2.5 Corn production in Philippines

2.5.1 Climate change impact on field corn production

In Philippines, the second important cereal crops is corn. Corn is also a crops that is affected by climate change. Climate change not only affects the corn production system but also affects social and economic activities.

In Philippines, the effects of global climate change is one of the factor that causes the agricultural sector to decline especially corn crops. Some plants or crops that been planted can get damage because of the climate change. There are some example of the effects of global climate change that rarely happen such as temperature become higher, high in frequency, intensity increases, and duration of extraordinary climate events such as dry seasons, surges and tropical storms, spatial dispersion of rainfall, warming temperatures, ocean level rise coming about in saltwater interruption and loss of agricultural land. Researcher found that soil erosion also main factor that will lead to negative soil nutrients balance, soil efficiency decreases, and subsequently,

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crop yields become lower are a few of the impacts of climate change on Philippine farming.

Thus to overcome the losses on the agricultural sector, there are few strategy be used in Philippine agriculture like crop diversification, change of crop or crop variety, and crop insurance. Besides, another strategy be used is providing the subsidies. In conclusion, agriculture in one place requires strategies to overcome the problems faced.

Researchers also found that climate change is likely to have far greater influence on the volatility of corn prices over the next three decades than factors that have been recently blamed for prices swings (e.g., oil prices, trade policies, and government biofuel mandates) (Jordan 2012). The production of corn will be affected because of climate change and causes the corn prices become lower. During climate change like heavy rain, corn will easily get disease and affected by fungus. Thus, the quality of corn will be decreased and it is hard to get higher prices in the market. The quality of corns is important to the farmers to get higher prices from the seller. To conclude, the impact on climate change in the Philippines tends to bad effect such as causes corn prices to decline.

2.5.2 Soil types that suitable for planting field corn

Data collected in the area describe soil characteristics are very limited. Farmer give responds about advantages and disadvantages of each of five soil types based on fertility level, drainage characteristics, susceptibility to erosion, and suitability for crop production or other agricultural use. Farmers described that the most fertile soils generally suited to most crops such as clay loam and sandy loam soil. This is the most common soil types be used by farmers in the surveyed area. There are some farmers

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respond that even the sandy loams are not waterlogged but it more susceptible to drought, while clay loam soils can retain soil water better, but can be poorly drained and make land preparation difficult during wet seasons. But some place soils in the upland plain and hilly maize in Cotabato, Philippine are already slightly eroded, although still good for crop production.

Table 2. 3 Advantages and disadvantages of different soil types as reported by farmers in maize production areas of the Philippines.

Soil type	Local name	Advantages	Disadvantages
Clay loam	Malagkit or Pilit-pilit	• Good for cereal crops • Generally suitable for growing many crops, including high value crops • Fertile • Good water retention • Excellent for lowland rice production	• Land preparation is difficult in the wet season • Limited source of moisture for crops
Sandy loam	Buhaghag, Banlikan, or Balod	• Good for maize, legumes and vegetable production • Generally suitable for growing many crops • Does not become waterlogged	• Poor water holding capacity, drains easily • Susceptible to drought • Low fertility
Clay		• Good water retention • Good for contour farming and has potential to support forest trees • Generally suitable for growing many crops • Excellent for pasture	• Tendency to flood, not good for crops • Susceptible to soil erosion • Needs proper soil fertility management practices • Poor drainage
Sandy clay loam		• Good for crop production and pasture	• Slightly susceptible to soil erosion

2.5.3 Harvest and post-harvest practices

Grain corn that harvested in 25% to 20% of moisture content, the farmers will sell immediately the fresh grain corn at low prices at the market because fungi will

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easily attacks the fresh grain when it stored. Farmers stated that grain corn weight would be particularly diminished if stored too long, the increased costs acquired at a later date probably won't cover the loss of income because of the lower grain weight. So, for the farmers it is better to sell the corn earlier compared to the late date because to prevent any losses happen to them. Storage requires additional grain handling and management is also important for farmers. Meanwhile, grain corns that harvested about 15-20% moisture content, it can be stored or be sold immediately.

Some farmers sell their maize right after harvested and some of them keep the maize for a better quality and higher price to be sold in the market. But most farmer will be immediately sold the grain harvested in rainy seasons instead keep it in storage barn. Because when the grains were keep it in storage barn too long, its will causes fungus and make the price become lower. Thus, this practice allowed farmers to avoid the post-harvest problems.

2.6 Natural air drying

Natural air or low temperature drying refers to the process in which grain bins are filled or partially filled with grain and then natural air is moved through the grain with fans, (Sadaka et al., 2017). As dry air passes wet grain, moisture moves from the grain into the air. The addition of water to the air reduces its ability to dry the grain it passes through next. This process continues as the air moves through the column of grain until the air no longer dries the grain, or the air exits the grain. As the fans continue to run, a drying front moves from where the air enters the grain to where it exits the grain, (Sadaka et al., 2017) .The air flow rate depends on fan properties as well as the type and depth of the grain. As grain depth increases, air flow rates decrease. Therefore, the drying front will slows when increasing grain depth

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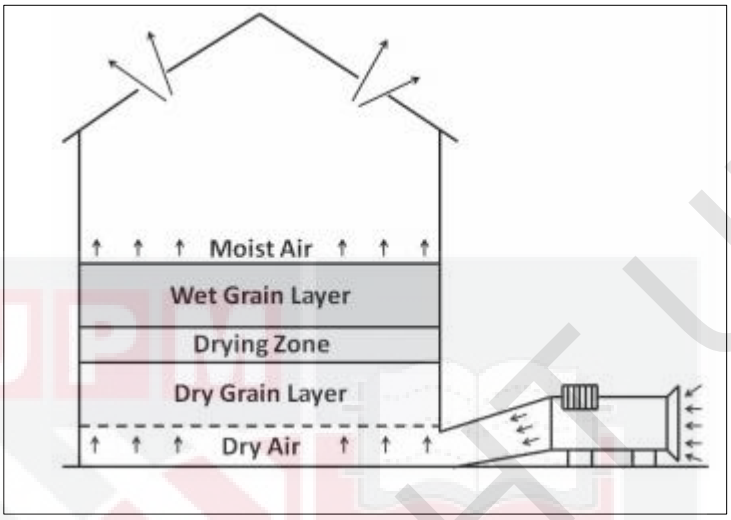
and increases the amount of time it takes for all the grain to reach equilibrium moisture content, (EMC) and the potential for grain quality losses.

Figure 2. 1. Grain bin utilizing natural air/low temperature drying



2.7 Cross- flow drying

One of the more popular continuous flow dryers is the cross-flow dryer, (Efficiency, 2012). In the circulating cross-flow dryer, grains flow through the drying chamber vertically by gravity, and drying air passes through the grain layers horizontally. The grains passing through the drying chamber are carried to the tempering chamber via a bucket elevator, (Kim et al., 2015). In crossflow drying is the differential grain flow dryer, which consists of tapered columns, dual variable-speed discharge augers, and a tempering hopper separating the first and second drying zones. The exhaust air from the second drying zone and from the cooling section are mixed and recycled. Due to the tapered column design and the dual discharge augers, the grain on the air inlet side of the columns moves more rapidly through the drying sections than the cooler grain near the air exhaust side of the drying zones. Thus, the moisture gradients across the width of the columns are significantly reduced, (Engineer and Education, 2002).

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2.8 Mechanism on Field Corn Dryer

Within the process of drying, heat is essential to evaporate moisture from the grain and a flow of air is required to carry away the evaporated moisture. There are two basic components included within the drying handle which are the relocation of moisture from the insides of an individual grain to the surface and the dissipation of moisture from the surface to the encompassing discuss. Grains will lose or pick up moisture until equilibrium is come to with the surrounding air. The equilibrium moisture content (EMC) is subordinate on the relative humidity and the temperature of the air. We can conclude that for the corn to dry it is important to remove the moisture in the corn to prevent them infected by the fungi.

Differential in moisture percentage across the column. The height and the width of the corn column do not affect the efficiency of the drier. The thickness of the column of corn, however, was found to be very important. The difference in moisture content of the corn from the inside and outside of the column was determined by making moisture determinations on samples of corn taken in grain sampling tube. From this article we can conclude that only the thickness of a corn dryer column is important in drying the corn as this machines are using high temperature. The thickness of the column will affect the temperature entering the drier.

The drying process involves simultaneous heat transfer from the surrounding to the surface of the product being dried combined with heat transmission within the material; and mass transfer from inside the product to its surface, followed by external transport of moisture to the surroundings (Crapiste & Rotstein, 1997). During the drying process, the parameters of corn such as the physical properties (size, density etc.), moisture content and mass–heat transfer coefficients between the air and the food product will be changed. Researcher found that external condition of product such as

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humidity, temperature and flow rate of drying air will changes the chemical composition of the food product. Dai & Lui (2017) expressed that the drying process is very important since it can decrease grain loss by controlling grain moisture and temperature to the specified level and it keeps up the quality, freshness and longer capacity life of grain

However, drying of corn is much more complex than drying of other cereals because corn has high moisture content during harvest time which are ordinarily 25% or higher. Typically, the drying of corn had two stages such as pre-drying and final drying. Pre-dying from the initial mean grain humidity basically from 25% to 19% and final mean grain storage from 16% of to the final mean grain storage humidity of 13% (Los et al., 2013). The grain is additionally more vulnerable to the mechanical harm if the temperature rapidly changing such as grain heat up to high temperature.

In this way, simulation programs describing the different drying strategies were commonly utilized to assess impacts of drying parameters such as drying temperature, column thickness, number of drying stages and cooling discuss recycling on the improvement of grain temperature and moisture content, immersion of exhaust air and energy requirement. With this recreations, the drying results can be related to comparable working conditions for all drier types, which is essentially impossible by taking estimations at commercial operations during the drying season (Leon, 2002).

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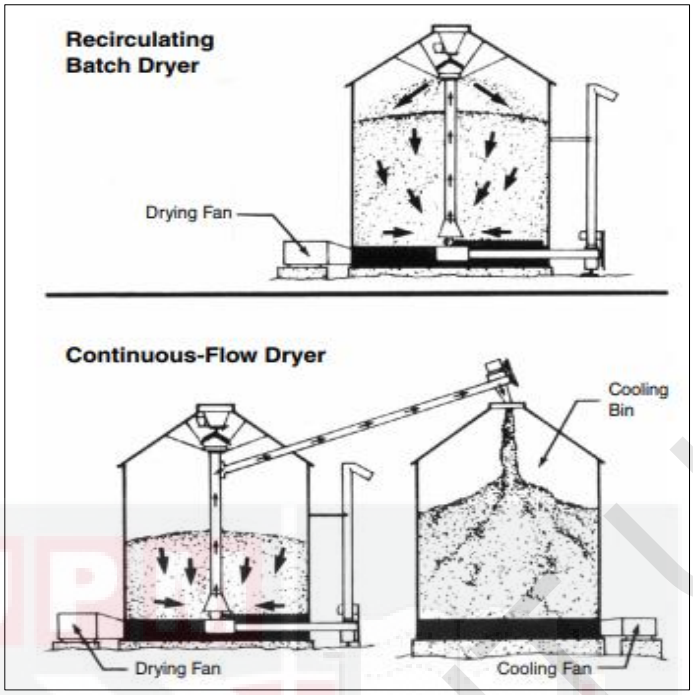

Figure 2. 2. Grain recirculators convert a bin dryer to a high speed recirculating batch or continuous flow dryer. (NDSU, 2013)

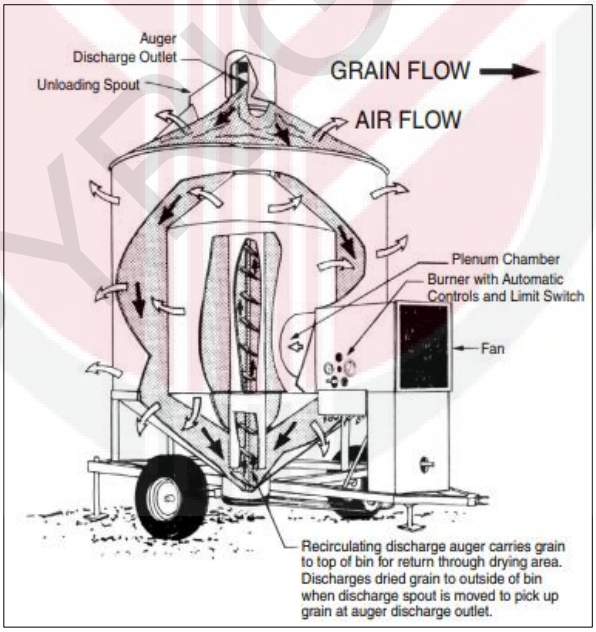

Figure 2. 3. Recirculating batch dryer (NDSU, 2013)

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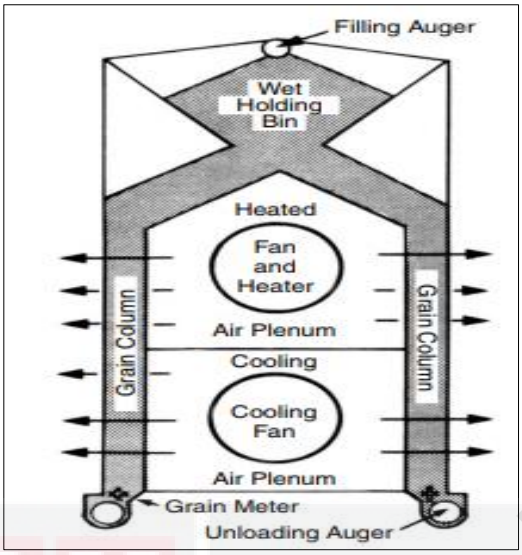

Figure 2. 4. Cross-flow dryer with forced-air drying and cooling (NDSU, 2013)

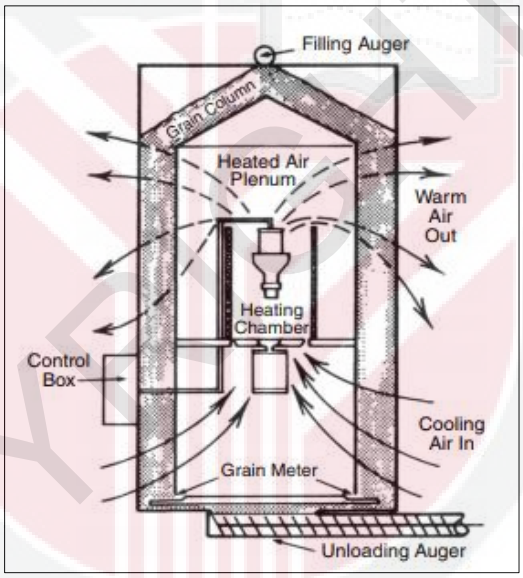

Figure 2. 5 Cross-flow dryer with reverse-flow cooling (NDSU, 2013)

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CHAPTER 3

MATERIALS AND METHODS

3.1 Study area

The experiments was conducted at the field corn plantation located in Felda Chemplak, Labis, Johor. The type of variety of field corns that was planted at the farm was Pasific Seed 339. The corn was planted in the field on 3rd October 2018. Then, it will be harvested at 100-110 days around 2nd January 2019 and expected time to complete the harvest process is on March 2019. This farm was recommended by Lembaga Pertubuhan Peladang (LPP) which is responsible in that district.

This farm was divided into three block namely as Block A, Block B and Block C. Each of block has different area, for example area of Block A is 19.03 hectares, area of Block B is 22.67 hectares and lastly for Block C is 8.10 hectares. Thus, the total area for alls the field corn plantation is about 50 hectare.

In Block A, the region were divided into four subplots which are Plot 2, Plot 6, Plot 20, and Plot 22. While for Block B divided into five subplots which are Plot 8, Plot 15, Plot 18, Plot 28 and Plot 29. Lastly, the region in Block C was divided into two subplots namely Plot 12 and Plot 13. The total plots at the field corn plantation are eleven plots as shown in Table 3.1. Figure 3.1 and Figure 3.2 shows the map at the field corn plantation at Felda Chempelak, Labis, Johor.

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Table 3. 1. Total area of field corn plantation.

Block	Subplots	Area (hectare)	Total area of yield (hectare)
Block A	Plot 2	4.05	**19.03**
	Plot 16	6.07	
	Plot 20	5.67	
	Plot 22	3.24	
Block B	Plot 8	4.05	**22.67**
	Plot 15	4.05	
	Plot 18	6.47	
	Plot 28	4.05	
	Plot 29	4.05	
Block C	Plot 12	4.05	**8.10**
	Plot 13	4.05	
Total			**49.80**

Figure 3. 1. Full 3D map of field corn plantation at Felda Chemplak Labis, Johor.

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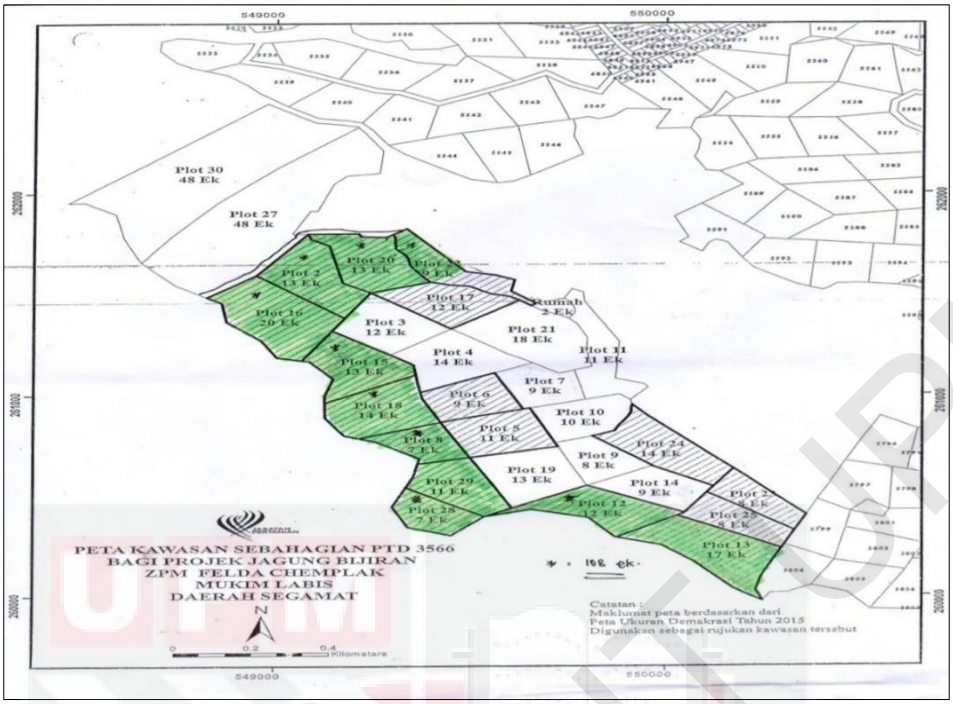

Figure 3. 2. Green color on the map is the eleven subplots that used for planting field corn.

3.2 Data collection

3.2.1 Moisture content of corn before harvested

The data on moisture content was collected before the field corn was harvested at the farm. The purpose was to determine the total average of moisture content before harvesting process. The moisture content of the corns will be measured by using Wile 78 Model grain moisture meter shown in Figure 3.3. Function of the device to measure level of moisture content and temperature of the grains.

Three samples of corn were plucked randomly at two different plots which are Plot 8 and Plot 28. Plot 8 labelled as Plot 1, Plot 2 and Plot 3, while for Plot 28 labelled as Plot 4 and Plot 5 in Table 4.1. Each of sample was collected randomly on the different row. The MC for every sample was tested for three times and its reading was

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recorded. Each sample of different plot has three sampling numbers. Thus, the total of three samples were produced nine sampling numbers as shown in Table 4.1.

There are some steps must be followed when using this device. Firstly, the corn kernels need to be separated from the cob. Then, put around 10 to 15 corn kernels inside the grain moisture meter and twist the caps of the grain mositure meter until a 'click' sound heard. After crushing the corn inside the grain moisture meter, press the green button. Lastly, the MC value will be displayed on the screen as shown in Figure 3.5.

Figure 3. 3. Wile 78 Model grain moisture meter

Figure 3. 4. Corn kernels were seperated from the cob.

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Figure 3. 5. The percentage of moisture content was measured and value of three replications was calculated for all samples.

3.2.2 Moisture content during drying process

After harvesting, the corn was transferred into the mobile dryer for making drying process. It is important the corn to be dried immediately to prevent from the infection of fungus. Usually the corn will be dried using mobile dryer until the percentage of MC reduce from 25% to around 13% -14%. At 13% of MC, the corn can be kept for a long period in the storage. In the field, the mobile dryer being used to dry the corn are MATHARU model. The MATHARU mobile dryer full tank can fit up to 3 tons of corn kernels.

The harvested corn kernels will be transferred direct into the inlet of mobile dryer until the tank is full. After that, the drying operation will be carried out until the corn reaches the percentage of MC which is 13% to 14%. The maximum temperature of air used in drying is 70° Celsius because if temperature is too high it will damage the corns. The reduction of MC of the corn will be measured for every half and hour after the corn being dried by using moisture grain meter as shown in Table 4.3.The

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samples of corn will be collected by climbing up on top of the mobile dryer as represent in Figure 3.6. to measure the reduction of MC. The samples need to be collect from on top of the mobile dryer because to get an accurate values of reduction MC of corn. The samples will be tested until it reaches 13% to 14% of MC and then the drying operation will be stopped. All the results of the sample will be collected and recorded.

Table 3. 2. Specification of MATHARU mobile dryer

Model	**Manufacturer's country**	**Burner fuel**	**Fuel consumption (litre)**	**Loading capacity (tons)**	**Tractor power (hp)**
Matharu MEP-20	India	Diesel	200	3	35 above

Figure 3. 6. The sample was collected on top of the mobile dryer.

Figure 3. 7. The percentage of MC was displayed around 13% to 14% and then the operation will be stopped.

3.2.3 Combine harvester operation

Before the corn being dried and transferred into the inlet of mobile dryer, harvesting process was performed by using a combine harvester. There were two types of combine harvester which are Kubota and World Star be used for harvest the corn on the field. The function of combine harvester is to separate the corn's kernel from its cob. The stopwatch will start when the combine harvester started to operate. After the combine harvester complete to harvest a row of plots, the time taken was recorded. The time will stop recorded until the storage of the combine harvester was full. The combine harvester was harvested the corn in 'zig zag' method. The loading capacity for each storage of Kubota and World Star Model is different. Kubota full storage capacity can fit up to 1.5 tons of corn while the World star can fit only for 1.0 tons. Thus, the total time operation for each combine harvester was different because both combine harvester had different capacity of storage. The table below shown the specification of both combine harvester to compare the performance between Kubota and World Star.

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Table 3. 3. Specification of Kubota and Word Star combine harvester.

Model	Engine power (kW)	Fuel tank capacity (litre)	Loading capacity (tons)	Engine rotation speed (rpm)	Overall dimension (mm)	Weight (kg)	Speed shift system
Kubota DC-105X	77.2	140	1.5	2600	Length= 5640 Width = 3045 Height= 3040	4630	HST
World Star WS7.0	80	115	1.0	2650	Length= 5100 Width = 2890 Height= 2700	3100	HST

Figure 3. 8. Kubota combine harvester was harvested corns in the field.

Figure 3. 9. World Star combine harvester was transferred the corn kernels into inlet dryer.

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3.3 Data analysis

All the data will be tabulated into a table and will be analysed by using Microsoft Excel. Data of drying time, reduction of moisture content, drying cost, harvesting capacity and time operation of combine harvester will be analysed and calculated by using ANOVA in Microsoft Excel. ANOVA was used to calculate the means, standard deviation, and variance, minimum and maximum value.

Besides, the results of drying time are analysed by plotting a graph drying time against reduction of moisture content as shown in Figure 4.1. The drying cost of dryer and tractor also are calculated to estimate the total drying cost of corn required to complete dry the corn. The calculation of fuel consumption of dryer and tractor are presented in Equation 3.1 respectively. The drying cost of the moisture reduction for every dryer and tractor are calculated by using Equation 3.2.

Total fuel consumption = initial fuel of dryer/tractor – final fuel of dryer/tractor (3.1)

$$\text{Drying cost} = \frac{total\ fuel\ consumption\ (litre) \times RM\ (per\ litre)}{MC\ reduction} \quad (3.2)$$

Lastly, the average harvesting capacity is analysed for both of combine harvester such as Kubota and World Star. These combine harvester has different of loading capacity. Thus, the average of harvesting capacity are calculated by divided full tank capacity with total time operation of combine harvester. The calculation of harvesting capacity are presented in Equation 3.3.

$$\text{Total harvesting capacity} = \frac{total\ loading\ capacity\ (tons)}{\begin{matrix} time\ operation\ of\ combine\ harvester \\ with\ fully\ tank\ capacity\ (hr) \end{matrix}} \quad (3.3)$$

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CHAPTER 4

RESULT AND DISCUSSION

4.1 Statistical characteristic of the MC for field corn

The statistical characteristics of the MC of the field corn were shown in the Table 4.1. The MC were described by mean and standard deviation of all nine sampling number as shown in Table 4.2.

Table 4. 1. Moisture content, MC (%) of field corn for five plots

		MC of field corn (%)				
Corn Samples	**MC readings**	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
1	1	25.8	25.6	25.5	25.8	25.8
	2	26.0	24.5	25.5	25.8	25.8
	3	26.0	25.4	25.5	25.7	25.7
2	1	25.6	25.5	25.4	25.5	25.5
	2	25.6	25.5	25.4	25.5	25.5
	3	25.5	25.5	25.4	25.4	25.4
3	1	25.7	25.5	25.4	25.7	25.7
	2	25.6	24.5	25.3	25.7	25.7
	3	25.6	24.5	25.4	25.7	25.7

4.1.1 Statistical characteristic of the MC of corn kernels before harvest

Table 4.1 show the average of MC of corn for nine corn samples collected from different plots. It shows that mostly the corn was harvested around 24% into 26% of the moisture content from the field.

Table 4. 2. MC analysis for 9 corn samples (%)

	Moisture content, MC (%)				
Plots	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**
Min	25.5	24.5	25.3	25.4	25.4
Max	26.0	25.6	25.5	25.8	25.8
Mean	25.71	25.17	25.42	25.64	25.64
Std. dev	0.18	0.50	0.06	0.14	0.14

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Table 4.2 shows that the lowest of MC was recorded 25.5% at the first plot. While the highest of MC out of nine corn samples was obtained 26% on the first plot. There was no huge gap between the values of the MC for the first day which is only 0.5%. On the first day, the mean of MC recorded was 25.71% and the standard deviation was 0.18%.

For the second plot, it shows that the lowest MC of the corn was 24.5% while the highest MC was 25.6%. The differences between of two MC was recorded of 1.1%. The mean of MC was recorded 25.17% with the standard deviation of 0.502%. For the third plot, the lowest MC was recorded 25.3% while the highest of the MC was 25.8%. There was no huge gap between these two samples which is 0.5% of difference. The mean was recorded 25.42% on the third plot and standard deviation show that the least amount of MC than other plots which is 0.06%.

On the fourth plot, the results obtained for the lowest of MC was 25.4% and the highest MC was 25.8%. For the nine corn samples, the result obtained for the mean of the MC was 25.64% with standard deviation of 0.14%. Lastly, the lowest MC at the fifth plot was recorded of 25.4% and the highest MC was obtained 25.8%. The mean and standard deviation value were recorded same with the fourth plot which are 25.64% and 0.14% of MC.

4.2 Data statistical of drying time for MC reduction of corns

Table 4.3 shows the drying time of the corn with reduction of MC by using MATAHRU dryer. There were eight loadings with difference drying time and MC reduction. The data were be described by means, standard deviation and minimum and maximum value as shown in Table 4.4.

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4.2.1 MC Reduction of corn kernels using MATAHRU dryer

Table 4. 3. MC reduction of corn of 8 loadings at different drying time using MATHARU mobile dryer.

MC reduction (%)								
Drying interval (hour)	**Loading 1 (%)**	**Loading 2 (%)**	**Loading 3 (%)**	**Loading 4 (%)**	**Loading 5 (%)**	**Loading 6 (%)**	**Loading 7 (%)**	**Loading 8 (%)**
0	25.6	25.7	25.8	25.7	25.7	25.7	25.6	25.5
0.5	25.5	25.1	25.1	25.7	25.2	25.7	25.3	25.5
1.0	24.8	23.2	24.6	23.7	24.4	25.6	24.9	25.5
1.5	23.1	20.3	23.8	23.6	23.1	25.0	23.5	25.5
2.0	21.7	19.2	21.2	23.1	22.1	24.8	22.5	25.4
2.5	19.1	18.4	19.5	21.3	20.8	22.1	20.7	23.1
3.0	18.1	17.7	17.1	18.7	19.2	22.4	19.3	21.8
3.5	17.8	16.9	15.2	16.0	17.9	19.2	14.7	19.6
4.0	13.4	13.5	12.5	14.1	16.8	18.0	14.0	18.0
4.5					13.7	14.0	13.5	16.0
5.0							13.1	13.4

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Table 4.3 shows that Loading 1 required four hours to reduce the MC from 25.6% to 13.4%. It take only four hours to reduce the MC because the operation of MATHARU dryer to dry the corns was started at noon of 12.15 p.m. until 4.20 p.m. in the evening. During this time the humidity in air was lower and the temperature of surrounding also higher. When the ambient temperature is higher it will help the dryer to burn the corns more easily compared to burn the corns during night. Thus, it causes the drying time for completely dried the corn be faster. For Loading 2, 3 and 4 also were required four hours for completely dried the corn. The time for Loading 2 started to burn the corns was around 1.40 p.m. until 5.40 p.m. and it is very suitable time to dry the corns because during this time the air humidity is lower. The same goes to Loading 3 and Loading 4 which were started to dry the corn at noon around 11.30 a.m. until 3.40 p.m. in the evening. Thus, from the observation that the dryer operated more efficiently to dry the corn start from the noon around 11.00 a.m. until 4.00p.m. in the evening.

When the dryer started to dry the corns in the evening which is around 4.00 p.m. above, the drying operation process of dryer are slower as the humidity in air becomes higher and the ambient temperature is lower. Therefore, the time to dry the corn is getting longer to reduce the MC from 25% to 13%. As shown from Table 4.3, Loading 5 and 6 were required four and half hours to complete dry the corn. The higher the air humidity, the longer time required to reduce the MC to 13%. While for Loading 7 and 8, the time for dryer were started to operate at around 3.00 p.m. until 8.30 p.m. in the evening. Thus, the drying time for both loading was needed five hours to dry the corn from 25% to 13% MC. From my observation, during night time is not an efficient time for corn drying process using mobile dryer because the rate of humidity is higher

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compared to day time. Other factor that make the time operation longer during night because the mobile dryer is located in the open area.

Table 4. 4. MC reduction analysis for 8 loading.

MC reduction (%)								
Loadings	**Loading 1**	**Loading 2**	**Loading 3**	**Loading 4**	**Loading 5**	**Loading 6**	**Loading 7**	**Loading 8**
Min	13.4	13.5	12.5	14.1	13.7	14.0	13.1	13.4
Max	25.6	25.7	25.8	25.7	25.7	25.7	25.3	25.5
Mean	21.01	20.00	20.53	20.78	20.89	22.25	19.15	21.32
Std.dev	4.19	4.02	4.77	4.11	3.95	4.01	4.71	4.38

Table 4.4 shows the MC reduction analysis for eight loadings with different of times. For Loading 1, the minimum value for the MC was obtained 13.4% while for the maximum value was 25.6%. For the mean of Loading 1, the result was obtained 21.01% MC with the standard deviation of 4.19% MC. Besides, the result obtained for the minimum value of Loading 2 was 13.5% MC and maximum value was 25.7% MC. While for the mean value was recorded 20% with standard deviation of 4.02%. For the Loading 3, the minimum and maximum value were recorded with 12.5% and 25.8% MC. The mean value for Loading 3 was 20.53% MC and the results obtained for standard deviation was 4.77%.

The results for the minimum value of Loading 4 was recorded with 14.1% of MC and the maximum value was 25.7%. For the mean value, the result was obtained 20.78% MC and the standard deviation was 4.11% MC. Next, for Loading 5 and 6 the minimum value of MC were 13.7% and 14% respectively. While the maximum value for both loading was 25.7% MC. The mean value obtained for Loading 5 was 20.89% MC and for Loading 6 was 22.25%. Other, the minimum value for Loading 7 was recorded with 13.1% MC and the maximum value was 13.4% MC. The lowest mean value recorded from the table was 19.15% MC for Loading 7. While the standard

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deviation was recorded 4.71% MC. Lastly, the result obtained for minimum value of Loading 8 was 13.4% MC while the maximum value was 25.5% MC. The mean of MC was recorded 25.42% for Loading 8 with standard deviation of 4.38%.

From the Figure 4.1 shows that the trend of graph for moisture reduction against drying time is slightly decreasing. When the moisture reduction of corn is higher, the drying time to reduce from 25% to 13% also higher. But if the dryer is operated during sunny day, shorter time is needed to reduce the MC from 25% to 13%. Because during sunny day temperature surrounding is higher and it will help the dryer to burn the corn efficiently as compared to rainy day. During the rainy day the combustion process of corn is ineffective because the humidity level of the air is high.

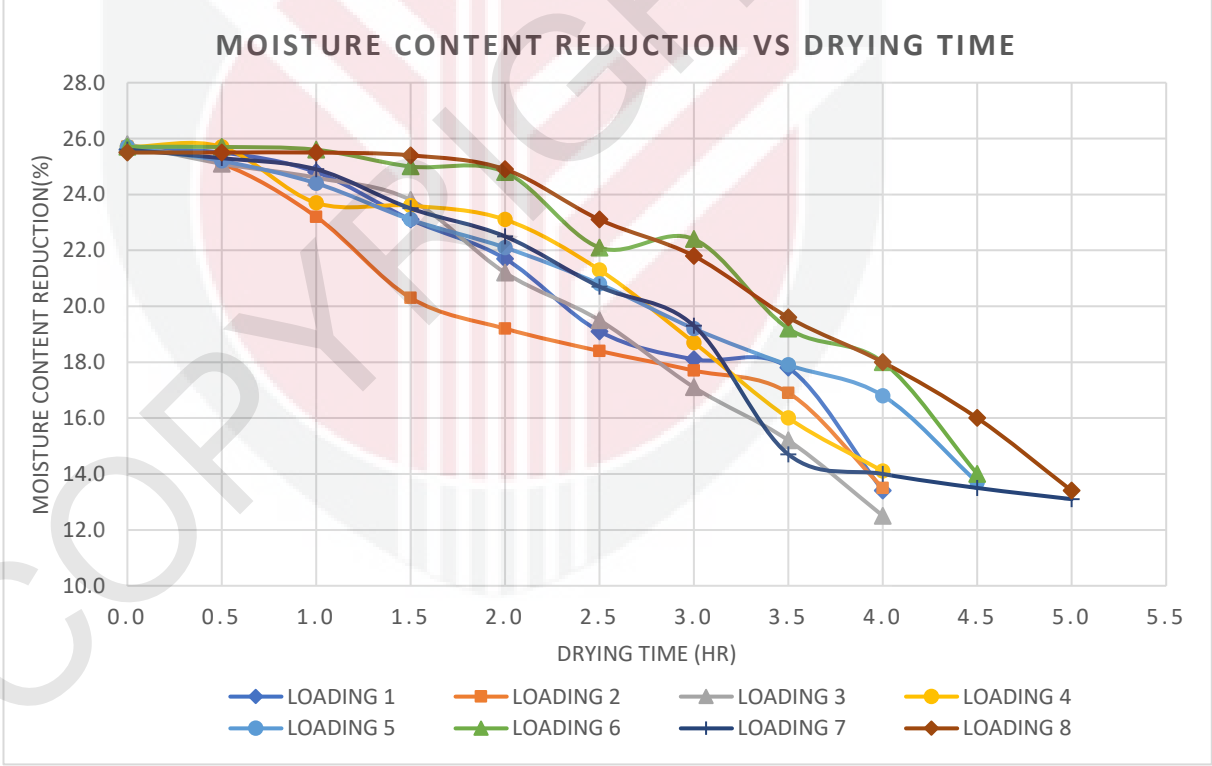

Figure 4. 1. Graph drying time versus moisture reduction for MATHARU mobile dryer

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4.3 Data statistical of drying cost for MC reduction of corns

Table 4.5 shows the drying cost for moisture reduction of corn for dryer and tractor. Drying cost was calculated to estimate the total drying cost per 1% of moisture reduction for both dryer and tractor. The data were be calculated such as moisture reduction, diesel price and total fuel consumption.

4.3.1 Drying cost for MC reduction of corn using MATHARU mobile dryer

Table 4. 5. Drying cost for moisture reduction of the corn using MATHARU mobile dryer for six loadings.

Samples	Moisture Reduction (%)	Fuel Consumption (Litre)	Drying Cost (RM/ Moisture Reduction)
Loading 1	11.3	136	26.24
Loading 2	11.5	155	29.38
Loading 3	11.7	164	29.30
Loading 4	12.1	128	23.06
Loading 5	12.2	146	26.09
Loading 6	12.2	145	25.91
Average	**11.8**	**145.7**	**26.66**

From Table 4.5, the drying cost for moisture reduction of corn by using MATHARU dryer was calculated. There was six loadings with different of moisture reduction and fuel consumption. But the price of diesel same for all samples which was RM2.18 per litre. From the result obtained, 136 litres of diesel was used to reduce the MC of 11.3%. Therefore to calculate the drying cost, price of diesel need to multiply with total fuel consumption and divided by 11.3% of moisture reduction as represented in Equation 3.2. The result was obtained RM26.24 per moisture reduction.

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While for reduction moisture of 11.5%, the fuel that have been used was 155 litres and the total drying cost after be calculated was RM29.38 per moisture reduction.

Besides, to reduce the moisture as much as 11.7%, the amount of fuel that have been used is 164 litre. Therefore, the drying cost that obtained is RM29.30 per moisture reduction. 128 litre of fuel was used to reduce 12.1% MC of corn and total drying cost was obtained RM23.06 per moisture reduction. To reduce 12.2% MC, the total fuel was needed 146 litre and total drying cost of these sample RM26.09 per moisture reduction. Lastly, 145 litres of fuel was used to reduce 12.2% MC. And the total drying cost obtained from the table was RM25.91 per moisture reduction.

Table 4. 6. Drying cost for moisture reduction of the corn using Kubota and New Holland tractor for six loadings.

Loadings	**Moisture Reduction (%)**	**Fuel Consumption (Litre)**	**Drying Cost (RM/ Moisture Reduction)**
Loading 1	11.3	43.0	8.30
Loading 2	11.5	68.0	12.89
Loading 3	11.7	61.5	11.46
Loading 4	12.1	50.0	9.01
Loading 5	12.2	61.5	10.99
Loading 6	12.2	61.5	10.99
Average	**11.8**	**57.6**	**10.61**

From Table 4.6, the drying cost for moisture reduction of corn by using tractor such as Kubota and New Holland were calculated. Therefore to calculate the drying cost, price of diesel need to multiply with total fuel consumption and divided by moisture reduction as represented in Equation 3.2. For Kubota tractor, the fuel that needed to reduce 11.3% MC is 43 litre. Total drying cost for Kubota tractor was

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RM8.30 per 1% moisture reduction. From the result obtained, by using New Holland tractor 68 litres of diesel was used to reduce MC of 11.5%. The result obtained for drying cost was RM11.46 per moisture reduction. While for reduction moisture of 11.7%, the fuel was used 61.5 litres and the total drying cost after be calculated was RM29.38 per moisture reduction. Besides, to reduce the moisture of 12.1%, the amount of fuel that have been used was 50 litre. Therefore, the drying cost that obtained was RM9.01 per moisture reduction. Lastly, 61.5 litre of fuel was to reduce 12.2% MC of corn. Thus, total drying cost obtained from the table 4.6 was RM10.99 per moisture reduction.

Table 4.7 shows that the drying cost for dryer was RM159.98 per moisture reduction. While for drying cost for both tractor Kubota and New Holland was RM63.64 per moisture reduction. Lastly, total sum of drying cost for both tractor and dryer was RM223.62 per moisture reduction.

Table 4. 7. Total actual drying cost for tractor and dryer.

Machines	Drying cost (RM/Moisture reduction)	Total actual drying cost (RM/Moisture reduction)
Dryer	159.98	RM223.62
Tractor	63.64	

Table 4.8 shows that the total average drying cost for dryer was RM26.66 per moisture reduction. While for average drying cost for both tractor was RM10.61. Lastly, total sum for both dryer and tractor was RM37.27 per moisture reduction.

Table 4. 8 Total average drying cost for tractor and dryer.

Machines	Average drying cost (RM/Moisture reduction)	Total average drying cost (RM/Moisture reduction)
Dryer	26.66	RM37.27
Tractor	10.61	

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4.4 Data statistical of harvesting capacity of combine harvester

Table 4.8 shows the harvesting capacity between Kubota and World Star combine harvester. Harvesting capacity is calculated by divided full tank capacity with time travel as represented in Equation 3.3.

4.4.1 Harvesting capacity between Kubota and World Star combine harvester

There are different of full storage capacity of Kubota and World Star. For Kubota the total full tank capacity is 1.5 tons while for World Star is 1.0 ton.

As shown in table 4.8, the total of harvesting capacity for Plot 1 was 2.73 tons/hr. The time required to fill up storage capacity of Kubota was 0.55 hours. For Plot 2, the time required to fill up 1.5 tons of storage capacity was about 0.56 hours. From the result obtained, the harvesting capacity for Plot 2 was 2.68 tons/hr. Besides, time required to fill up 1.5 tons of storage capacity of Kubota for Plot 3 was 0.52 hours. The result obtained for harvesting capacity was 2.88 tons/hr. Thus, the total average of harvesting capacity for three plots was 2.76 tons/hour.

Table 4. 8. Harvesting capacity between Kubota and World Star combine harvester.

	KUBOTA			**WORLD STAR**		
	Storage capacity (tons)	Operational time (hour)	Harvesting capacity (tons/hour)	Storage capacity (tons)	Time travel (hour)	Harvesting capacity (tons/hour)
Plot 1	1.5	0.55	2.73	1	0.66	1.52
Plot 2	1.5	0.56	2.68	1	0.61	1.63
Plot 3	1.5	0.52	2.88	1	0.67	1.49
	Average		**2.76**	**Average**		**2.32**

For World Star combine harvester, the time required to fill up 1.0 ton of storage capacity was about 0.66 hours. The total harvesting capacity for Plot 1 was obtained 1.52 tons/hour. While for Plot 2, time required to fill up storage capacity was 0.61 hour

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and total harvesting capacity was calculated 1.63 tons/hour. Lastly, to fill up 1.0 ton storage capacity of World Star for Plot 3, the time was needed about 0.67 tons/hour. Therefore, the total average of harvesting capacity for three plots by using World Star combine harvester is 2.32 tons/hour.

Lastly, table 4.8 show that the average of harvesting capacity by using Kubota was about 2.76 tons/hr while harvesting capacity by using World Star was 2.32 tons/hour. Its show that the average of harvesting capacity by using Kubota is higher than World Star.

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CHAPTER 5

CONCLUSION

From this study, the drying time of field corns for recommended optimum drying temperature being dried until minimum moisture content which is 13% to 14% was determined. It was found that average of drying time to reduce MC 25% to 13%-14% using MATHARU dryer was around 5 hours. In addition, the corn that dried at noon start from 11.00 a.m. until 4.00 p.m. was drying faster than dried at 4.00 p.m. above. So this was recommended for the farmers to start drying operation at noon rather than drying during night day. Besides, the drying cost for moisture reduction of the corn also was calculated. The drying cost was divided into two part which is drying cost for using MATHARU dryer and tractors such as Kubota and New Holland. For the total the drying cost, it required around from RM223.62 per moisture reduction to reduce the MC from 25% to 13%-14%. And the harvesting capacity of different combine harvesters also was calculated. There are two different of combine harvester such as Kubota and World Star been used to harvest the corns. Each of combine harvester has different of full storage capacity. From the result obtained, it also was found that Kubota has higher harvesting capacity which was 2.76 tons/hr as compared to World Star with 2.32 tons/hr.

5.1 Recommendation

At the present time, mobile dryer was developed for help farmers to reduce MC of corn as to control the quality of corn. The corns need to be dried immediately because to prevent from fungal problem. However, Malaysian weather which is frequent rainfall required the use of mobile dryer to dry the field corn. Unfortunately,

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the mobile dryer was placed in open area and drying process of corn can be disturbed if heavy rain is happen. During the rainfall, the drying process cannot be carried out as it may cause damages to the dryer. Thus, the Malaysian Government has to fixed up this problem by develop and build closed building to place the mobile dryer. This is important because to avoid any disturbance from weather such as heavy rain. By developing a new closed building, the drying process of the corn still can be carried out even though heavy rain is happen. It also will preventing from any broken system and reduce the cost for the maintenance of mobile dryer.

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APPENDICES

1. Calculation for drying cost

Fuel Consumption (litre)		
	Dryer (MATHARU)	Tractor (NEW HOLLAND)
Initial	200	77
Final	54	15.5
Total fuel consumption	146	61.5
MC reduction	12.2	

Drying cost for dryer = $\frac{146 \times 2.18}{12.2}$ = RM26.09 per 1% moisture reduction

Drying cost for tractor = $\frac{61.5 \times 2.18}{12.2}$ = RM10.99 per 1% moisture reduction

Fuel Consumption (litre)		
	Dryer (MATHARU)	Tractor (NEW HOLLAND)
Initial	200	77
Final	36	15.5
Total fuel consumption	164	61.5
MC reduction	11.7	

Drying cost for dryer = $\frac{146 \times 2.18}{12.2}$ = RM29.30 per 1% moisture reduction

Drying cost for tractor = $\frac{61.5 \times 2.18}{12.2}$ = RM11.46 per 1% moisture reduction

Fuel Consumption (litre)		
	Dryer (MATHARU)	Tractor (NEW HOLLAND)
Initial	200	77
Final	45	9
Total fuel consumption	155	68
MC reduction	11.5	

Drying cost for dryer = $\frac{155 \times 2.18}{11.5}$ = RM29.38 per 1% moisture reduction

Drying cost for tractor = $\frac{68 \times 2.18}{11.5}$ = RM12.89 per 1% moisture reduction

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Fuel Consumption (litre)		
	Dryer (MATHARU)	Tractor (NEW HOLLAND)
Initial	200	77
Final	54	15.5
Total fuel consumption	146	61.5
MC reduction	12.2	

Drying cost for dryer = $\frac{146 \times 2.18}{12.2}$ = RM26.09 per 1% moisture reduction

Drying cost for tractor = $\frac{61.5 \times 2.18}{12.2}$ = RM10.99 per 1% moisture reduction

Fuel Consumption (litre)		
	Dryer (MATHARU)	Tractor (NEW HOLLAND)
Initial	200	77
Final	72	27
Total fuel consumption	128	50
MC reduction	12.1	

Drying cost for dryer = $\frac{128 \times 2.18}{12.1}$ = RM23.06 per 1% moisture reduction

Drying cost for tractor = $\frac{50 \times 2.18}{12.1}$ = RM9.01 per 1% moisture reduction

Fuel Consumption (litre)		
	Dryer (MATHARU)	Tractor (KUBOTA)
Initial	200	64
Final	64	21
Total fuel consumption	136	43
MC reduction	11.3	

Drying cost for dryer = $\frac{136 \times 2.18}{11.3}$ = RM26.24 per 1% moisture reduction

Drying cost for tractor = $\frac{43 \times 2.18}{11.3}$ = RM8.30 per 1% moisture reduction

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2. Drying time of moisture reduction for mobile dryer

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
2/2/2019	Plot 8	0:00	70	25.6
		0:30	70	25.3
		1:00	70	24.9
		1:30	70	23.5
		2:00	70	22.5
		2:30	70	20.7
		3:00	70	19.3
		3:30	70	14.7
		4:00	70	14.0
		4:30	70	13.5
		5:00	70	13.1

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
3/2/2019	Plot 8	0:00	70	25.5
		0:30	70	25.5
		1:00	70	25.5
		1:30	70	25.1
		2:00	70	25.1
		2:30	70	24.9
		3:00	70	22.2
		3:30	70	21.3
		4:00	70	19.5
		4:30	70	17.9
		5:00	70	16.1
		5:30	70	13.1

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
3/2/2019	Plot 8	0:00	70	25.5
		0:30	70	25.5
		1:00	70	25.5
		1:30	70	25.4
		2:00	70	24.9
		2:30	70	23.1
		3:00	70	21.8
		3:30	70	19.6
		4:00	70	18.0
		4:30	70	16.0
		5:00	70	13.4

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Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
4/2/2019	Plot 8	0:00	70	25.6
		0:30	70	25.5
		1:00	70	24.8
		1:30	70	23.1
		2:00	70	21.7
		2:30	70	19.1
		3:00	70	18.1
		3:30	70	17.8
		4:00	70	13.4

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
4/2/2019	Plot 28	0:00	70	25.7
		0:30	70	25.7
		1:00	70	23.7
		1:30	70	23.1
		2:00	70	23.6
		2:30	70	21.3
		3:00	70	18.7
		3:30	70	16.0
		4:10	70	14.1

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
4/2/2019	Plot 28	0:00	70	25.7
		0:30	70	25.7
		1:00	70	25.6
		1:30	70	25.0
		2:00	70	24.8
		2:30	70	22.1
		3:00	70	22.4
		3:30	70	19.2
		4:00	70	18.0
		4:30	70	14.0

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Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
5/2/2019	Plot 29	0:00	80	24.1
		0:30	80	24.0
		1:00	80	23.8
		1:30	80	21.2
		2:00	80	19.0
		2:30	80	19.0
		3:00	80	18.5
		3:30	80	17.5
		4:00	80	17.0
		4:45	80	14.4

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
5/2/2019	Plot 29	0:00	80	24.6
		0:30	80	
		1:00	80	21.0
		1:30	80	
		2:00	80	17.6
		2:30	80	
		3:00	80	14.9
		3:30	80	
		3:35	80	13.1

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
5/2/2019	Plot 29	0:00	70	24.6
		0:30	70	
		1:00	70	21.0
		1:30	70	
		2:00	70	17.6
		2:30	70	
		3:00	70	14.9
		3:30	70	
		3:35	70	13.1

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Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
6/2/2019	Plot 12 + 29	0:00	80	25.7
		0:30	80	25.1
		1:00	80	23.7
		1:30	80	23.0
		2:00	80	19.5
		2:30	80	18.5
		3:00	80	18.1
		3:30	80	17.9
		4:00	80	17.3
		4:30	80	17.0
		5:00	80	16.4
		5:30	80	13.1

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
6/2/2019	Plot 12	0:00	70	25.7
		0:30	70	25.1
		1:00	70	23.2
		1:30	70	20.3
		2:00	70	19.2
		2:30	70	18.4
		3:00	70	17.7
		3:30	70	16.9
		4:00	70	13.5

Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
7/2/2019	Plot 12	0:00	70	25.8
		0:30	70	25.1
		1:00	70	24.6
		1:30	70	23.8
		2:00	70	21.2
		2:30	70	19.5
		3:00	70	17.1
		3:30	70	15.2
		4:00	70	12.5

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Date	Data collection	Time (hr:min)	Temperature (°C)	MC reduction (%)
7/2/2019	Plot 12	0:00	70	25.7
		0:30	70	25.2
		1:00	70	24.4
		1:30	70	23.1
		2:00	70	22.1
		2:30	70	20.8
		3:00	70	19.2
		3:30	70	17.9
		4:00	70	16.8
		4:30	70	13.7

3. Harvesting time travel for combine harvester

1. Kubota

Travel	Plot	Start (hr:min)	End (hr:min)	Time taken/travel (hr:min)
1	8	0:00:00	0:01:19	0:01:19
2		0:01:37	0:03:44	0:02:07
3		0:04:07	0:05:08	0:01:01
4		0:05:29	0:06:28	0:00:59
5		0:06:42	0:07:22	0:00:40
6		0:07:38	0:08:20	0:00:42
7		0:09:25	0:10:55	0:01:30
8		0:11:28	0:12:27	0:00:59
9		0:12:50	0:13:37	0:00:47
10		0:13:40	0:15:47	0:02:07
11		0:16:22	0:16:51	0:00:29
12		0:17:04	0:17:25	0:00:21
13		0:17:39	0:18:15	0:00:36
14		0:18:30	0:19:17	0:00:47
15		0:19:35	0:20:13	0:00:38
16		0:20:23	0:21:20	0:00:57
17		0:21:26	0:22:08	0:00:42
18		0:22:20	0:23:40	0:01:20
19		0:24:02	0:24:28	0:00:26
20		0:25:03	0:25:43	0:00:40
21		0:26:04	0:26:48	0:00:44
22		0:26:59	0:27:42	0:00:43
23		0:27:55	0:28:54	0:00:59
24		0:29:20	0:29:33	0:00:13
25		0:30:08	0:30:12	0:00:04
26		0:31:02	0:31:15	0:00:13
27		0:32:19	0:32:53	0:00:34
28		0:33:24	0:33:37	0:00:13

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Travel	Plot	Start (hr:min)	End (hr:min)	Time taken/travel (hr:min)
1	28	0:00:00	0:00:56	0:00:56
2		0:01:11	0:02:47	0:01:36
3		0:04:35	0:06:29	0:01:54
4		0:07:52	0:09:41	0:01:49
5		0:09:24	0:10:35	0:01:11
6		0:12:15	0:13:17	0:01:02
7		0:15:39	0:16:38	0:00:59
8		0:16:38	0:18:06	0:01:28
9		0:20:43	0:22:35	0:01:52
10		0:23:57	0:25:39	0:01:42
11		0:27:51	0:29:37	0:01:46
12		0:31:57	0:32:12	0:00:15
13		0:32:33	0:34:51	0:02:18

Travel	Plot	Start (hr:min)	End (hr:min)	Time taken/travel (hr:min)
1	29	0:00:00	0:03:15	0:03:15
2		0:03:21	0:05:32	0:02:11
3		0:07:24	0:09:18	0:01:54
4		0:10:10	0:11:25	0:01:15
5		0:11:56	0:14:04	0:02:08
6		0:14:46	0:16:15	0:01:29
7		0:16:36	0:17:17	0:00:41
8		0:17:36	0:18:40	0:01:04
9		0:18:52	0:19:56	0:01:04
10		0:20:05	0:21:23	0:01:18
11		0:21:43	0:22:25	0:00:42
12		0:22:37	0:23:57	0:01:20
13		0:24:17	0:25:01	0:00:44
14		0:25:27	0:26:00	0:01:26
15		0:27:12	0:27:52	0:00:40
16		0:28:01	0:29:17	0:01:16
17		0:30:03	0:30:39	0:00:36
18		0:30:56	0:31:39	0:00:43

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2. World Star

Travel	Plot	Start (hr:min)	End (hr:min)	Time taken/travel (hr:min)
1	8	0:00:00	0:02:34	0:02:34
2		0:02:53	0:05:38	0:02:45
3		0:07:06	0:08:13	0:01:07
4		0:08:30	0:12:45	0:04:15
5		0:12:59	0:16:53	0:03:54
6		0:17:26	0:20:28	0:03:02
7		0:21:06	0:29:50	0:08:44
8		0:30:09	0:32:29	0:02:20
9		0:32:54	0:35:01	0:02:07
10		0:35:08	0:36:45	0:01:37

Travel	Plot	Start (hr:min)	End (hr:min)	Time taken/travel (hr:min)
1	28	0:00:00	0:03:18	0:03:18
2		0:03:34	0:05:45	0:02:11
3		0:05:55	0:08:29	0:02:34
4		0:08:43	0:10:25	0:01:42
5		0:10:51	0:12:48	0:01:57
6		0:12:59	0:16:59	0:04:00
7		0:17:02	0:19:38	0:02:36
8		0:19:48	0:23:04	0:03:16
9		0:23:32	0:27:42	0:04:10
10		0:28:12	0:30:07	0:01:55
11		0:30:29	0:32:17	0:01:48
12		0:32:37	0:34:26	0:01:49
13		0:34:40	0:38:04	0:03:24
14		0:38:16	0:40:55	0:02:39

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Travel	Plot	Start (hr:min)	End (hr:min)	Time taken/travel (hr:min)
1	29	0:00:00	0:01:28	0:01:28
2		0:01:40	0:05:07	0:03:27
3		0:06:07	0:07:42	0:01:35
4		0:08:04	0:11:55	0:03:51
5		0:12:25	0:14:24	0:01:59
6		0:14:52	0:17:09	0:02:17
7		0:18:44	0:20:13	0:01:29
8		0:20:35	0:23:31	0:02:56
9		0:24:06	0:25:24	0:01:18
10		0:25:58	0:28:14	0:02:16
11		0:28:53	0:30:20	0:01:27
12		0:31:04	0:33:47	0:02:43
13		0:34:32	0:35:46	0:01:14
14		0:36:15	0:38:33	0:02:18
15		0:39:05	0:40:12	0:01:07

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