FINAL YEAR PROJECT II: DISSERTATION

Study on Minimum Ignition Energy of Dust Fire/Explosion

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CERTIFICATION OF APPROVAL

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by

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A project dissertation submitted to the
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Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(HAZWAN FARID BIN MUHMMAD PUZI)

Abstract

Dust explosion is one of the most massive disasters in the process industries. When the company process plant involve with dust it is difficult to handle as the dust is very fine particle and hard to contain. In this project, it refer to incident happened in Imperial Sugar Refineries, where dust explosion had happened in 2008. In conjunction with dust explosion incident, this project will study on the minimum ignition energy for dust fire and explosion. Mainly, the study will be focusing on the food dust samlples. The study will be done by conducting several experiments on the factors which can initiate the dust fire and explosion. The factors will be studies in this project are the size of the dust and type of the dust. The dusts used in this study are from the food processing industries which is flour and sugar. At the end of study, the minimum ignition energy from each type of dust sample will be determined.

Acknowledgement

I would like to take this opportunity to express my sincere thanks and appreciation to the following persons and organizations who have directly or indirectly given generous contributions towards the success of this project.

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Chapter 1: Introduction

1.1 Background

The hazard of dust explosion is difficult to avoid in processes, especially when that company handles with the combustible powders. Many fines materials such as, coal, wood, flour, starch, sugar, pharmaceuticals, plastics and some metal can easily get burned. According to U.S. National Fire Protection Association there are differences between dust and combustible dust. Dust is any finely divided solid 420µm or 0.017in. or less in its diameter. While combustible dust is defined as combustible particulate solid that present a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape. So essentially, 420µm boundary should not be view as a sharp delineation between explosible dusts and non-explosible dusts. What will determine whether that certain particulate material represents dust explosion hazards are its actual chemical composition in addition to physical parameters such as particle shape and particle size. Dust explosion may occur in many industries, not just to the chemical process industries. It occurred in the petrochemical plant that produce chemical as the desired product and it also occurred in powder metallurgy manufacturing facilities product. In the other hand, it occurred in a coal mine where the coal dust was not viewed as the hazardous chemical.

According to Eckhoff dust explosion generally arise from the reaction of a fuel with oxygen to generate oxides and heat. So material such as silicates and carbonates will not experience dust explosion as they are already stable oxides. This explains why limestone finds use as explosion inertant in coal mines. When subjected to high temperatures, limestone will act as a heat sink and may decompose into calcium oxides and carbon dioxides. In this project, it will discuss on the minimum requirement of ignition energy for dust fire/explosion.

1.2 Problem Statement

Since the beginning of this century, there are many incident happened caused by dust explosion. The impact of this dust explosion almost destroyed the entire plant facility once it occurred. According to incident of dust explosion at Imperial Sugar Refinery on February 7, 2008 at 7:15 p.m. had resulted in 14 workers fatalities and thirty six workers were treated for serious injuries and burns. The impact of the explosion, it has destroyed the sugar packaging building, palletizer room and silos, and severely damaged the bulk train car loading area and parts of sugar refining process areas.

According to The U.S. Chemical Safety and Hazard Investigation Board (CSB), they had conducted an investigation on the incident. From the investigation they have identified the causes of the explosion. There were 6 possible causes of the incident which are sugar and cornstarch conveying equipment was not designed or maintained to minimize the release of sugar and sugar dust into the work area. The company did not have adequate housekeeping practices resulted in significant accumulations of combustible granulated and powdered sugar and combustible sugar dust on the floors and elevated surfaces throughout the packing buildings. Then, the explosion occurred because airborne combustible sugar dusts accumulate above the minimum explosible concentration inside the newly enclosed steel belt assembly under silos 1 and 2. CSB also had identified an overheated bearing in the steel belt conveyor most likely ignited a primary dust explosion. The primary dust explosion inside the enclosed steel conveyor belt under silos 1 and 2 triggered massive secondary dust explosions and fires throughout the packing buildings. Lastly, accumulated sugar dust and spilled sugar fueled the secondary explosions and fires. All the 14 fatalities were the result of this secondary explosion.

From this incident, we can notice dust which is the finest things that almost neglected can lead to a massive explosion. So, in this project will be further discussed on the minimum ignition energy for dust fire/explosion.

1.3 Objectives

The aim of this project is to investigate and identify the minimum ignition energy of food samples to initiate the dust fire and explosion. The parameters will be changed to find the minimum ignition energy throughout laboratory experiment.

1.4 Scope of Study

The study will involve researching and experimenting the possible factors that can initiate the dust fire and dust explosion. There will be several parameters will be tested and changed which are:

1. Size of the dust
2. Type of dust

Chapter 2 : Literature Review and Theory

2.1 General concept

From the explosion pentagon we may know many aspects on a fundamental level about dust explosion causation. The dust explosion may happen if explosion pentagon is satisfied. Within the explosion pentagon requirements are fuel, an oxidant, an ignition source, augment by mixing of the fuel and oxidant as well as confinement of the resulting mixture. In dust and air mixture, dust particle are strongly influenced by gravity. An essential prerequisite of dust explosion is the forming of a dust/oxidant suspension. When the suspension combustion occur, confinement creates an overpressure to arise, thus enabling a fast burning dust flame to transition to dust explosion.

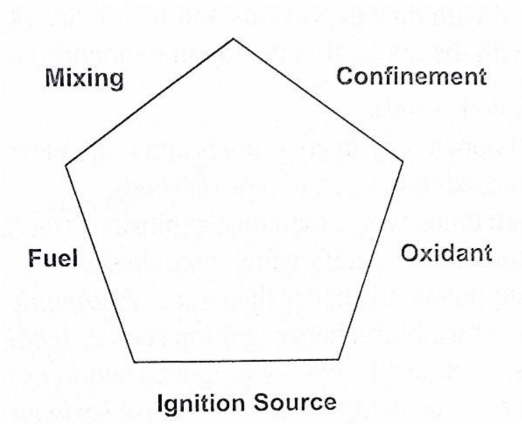


Figure 1: Explosion Pentagon diagram

Besides that, a dust explosion can take place if it satisfied with several conditions where the dust must be explosible. The dust also must have particle size distribution that will allow the propagation of the flame and the atmosphere where the dust disperse as a cloud or forming a suspension must contain sufficient oxidant to support combustion. Then, the dust suspension or cloud must have a concentration within the explosion range according to the upper and lower explosive diagram. The most important is the dust cloud must be in contact with an ignition source of sufficient energy to cause an ignition.

2.2 Possible hazards

There are several factors can bring hazard to the explosion by concerning both dust and the environment where it dispersed and suspended. According to the John Barton in his writing there were nine factors are highlighted where hazard of an explosion might happen. The first factor is the dust itself. Every dust has different variation of their explosibility and the consequent explosion violence generated. The violence generated from each explosion can be determine through two parameters which are the maximum explosion pressure that can be generated and the maximum rate of explosion pressure rise or explosion speed that is related to the *Kst* value. The second factor is about the composition of the dust. For example, coal dust mainly is highly explosible and emits higher explosion violence as the greater its volatile content. Then for the anthracite is non-explosible because it's have low volatile content.

Next highlighted factors are about the particle size and particle size distribution. If the particle is finer, it have bigger surface area and thus more likely to be explosible. For the distribution when the dust is made up from a series of particle ranging from fine to course, the fines particles will play the most prominent role in an ignition and in the propagation of an explosion. The fourth factor is the concentration of the dispersed dust. The concentration of the dispersed dust is depending on the lower explosion limit and upper explosion limit. The explosion will not propagate if the concentration is below the lower explosion limit or beyond the upper explosion limit. At the optimum concentration, the dust will give the most violence explosion.

In the fifth factor, the moisture content will affects the impact of explosion. As the moisture of the increase, the explosion violence will fall and may become explosible. The sixth factor to be considered is the ambient temperature and pressure. It is because a decrease in the maximum explosion in an enclosed explosion resulted by an increase in ambient temperature. Increase in the ambient temperature will cause a very little effect on the rate of pressure rise.

The turbulence of the dust cloud is another factor which can caused hazard for an explosion. In order for the dust cloud to happen, there must be some air movement for the dust to remain dispersed. Explosion violence of a dust cloud at the low level of turbulence is relatively mild but the explosion will propagate more vigorously at high state of turbulence when the flame front is broken up and its effective area are much increased. In addition with the presence of flammable gas, the dispersed dusts' explosion violence increases markedly if admixed with even a low concentration of flammable gas to give a so called 'hybrid mixture'.

The last factor is about the scale of the vessel. When mention about the scale of a vessel, a large vessel will give more explosion impact compare to the smaller vessel, but for a large vessel it will take more time for the pressure to arise. One of the simplest scaling laws is the cubic law, which relates the rate of pressure rise in an explosion to the cube root of the vessel volume.

2.3 Ignition sources

Ignition can be defined as the process where propagation is started or initiated. An ignition will be useful if it was applied to the substance which able to propagate a self-sustained combustion or exothermal decomposition wave. Scientifically, ignition will occur when the heat integration in some volume of a substance exceeds the amount of heat dissipation from the volume. It will be worst if the process continue to do so and increase the temperature. The characteristic dimension for ignition and no ignition of a volume is decided is on the order of the thickness of the front of a self-sustained flame through the mixture. This because self-sustained flame propagation causes a continuous ignition wave to the new part of the cloud which experienced the same condition where the heat generated is more than the heat dissipated.

The most common ignition sources are smoldering or burning dust, open flames, hot surfaces, heat from mechanical impact and electrical discharges and arcs. Ignition caused by smoldering or burning dust happened when combustible dust deposited in heaps or layer, in under certain circumstances may develop internal combustion and high temperature.

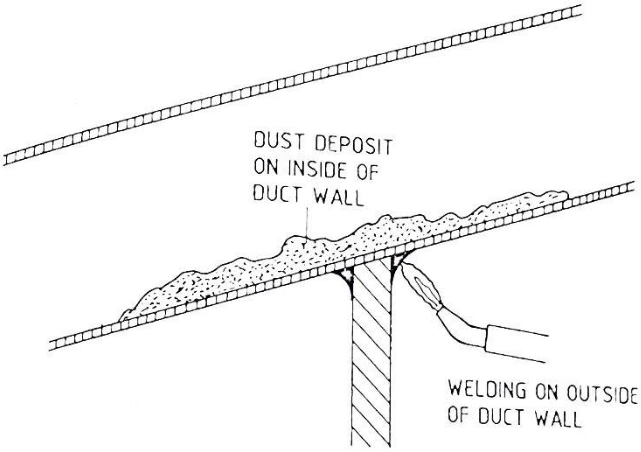


Figure 2: A hidden dust deposit inside a duct can bring to ignition by heat supplied to the duct wall from the outside.

The combustion could happen because of the porosity of the dust deposit, which can allow the oxygen access to the dust particles surface throughout and make the heat conductivity of the deposit become low. According to Eckhoff, heat developed due to comparatively slow initial oxidation at moderate temperature inside the dust deposit may not be conducted into the surroundings sufficiently fast to prevent rising temperature in the reaction zone. The temperature of the particles will increase further if the oxygen still available around the particles. For example if a dust deposit containing a hot reaction zone or known as smoldering nest, is disturbed and dispersed by mechanical action or air blast, a dust explosion can be easily initiated by the dust if it contact with combustible dust cloud. On the other hand, a dust deposit on a heated surface, which supplies the heat needed to trigger the self-ignition in the dust.

Open flames will be the most obvious source of ignition. For example during hot work such as welding and cutting, the flames from welding and cutting burners are more than enough to initiate any dust explosion to any dust cloud. The cutting burner flame is hazardous towards the dust is because its supply excess oxygen to the working zone. Besides that, smoking should be prohibited in areas where combustible dusts exist and a wooden match develops about 100J of thermal energy per second where it's enough to initiate the explosion.

Ignition created by hot surfaces is because of direct contact of dust layer with the surfaces. However, for hot surface to initiate an ignition, the temperature of the surface should be in the range of 400^0C to 500^0C.

Heat from mechanical impact is sometimes also created an ignition for a dust explosion from its friction. For friction to create an ignition, it will be a long duration process where two surfaces will rub onto each other and caused heat to accumulate. While for a short duration process could give out enough heat if the bodies is under large transient mechanical forces. Small fragments of solids materials maybe torn off, and if the body made of metal, it may start burning in air due to the initial heat absorbed in the impact process.

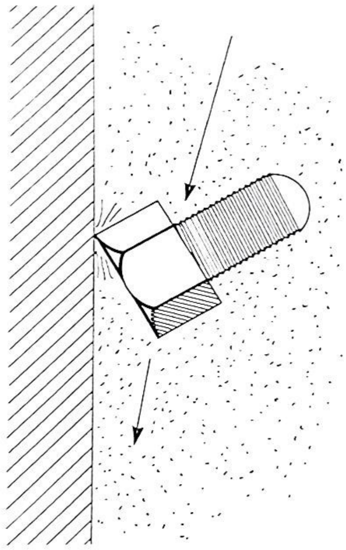


Figure 3: A steel bolt falls into a tall silo for corn and collides with the concrete silo wall at high velocity.

Lastly, electric sparks and arcs are very famous from past century about its ability to initiate dust explosion. The minimum sparks energy required for ignition varies with the type of dust, the effective particle size distribution in the dust cloud, the dust concentration and turbulence, and the spatial and temporal distribution of the energy in the electric discharge or arc. Generally, it is now accepted that many dust can be ignited by sparks energies in the range of 1-10mJ. Some dust may ignite at even lower energies. It may be useful to distinguish between discharges caused by release of accumulated electrostatic charges and sparks or arcs generated when live electric circuits are broken either accidentally or intentionally. According to Luttgens and Glor, electrostatic discharge can be held in six different ways which are spark discharge, brush discharge, corona discharge, propagating brush discharge, discharge along the surface of the powder or dust in bulk and lightning-like discharge. In between this six ways, spark discharge and brush discharge is the most hazardous.

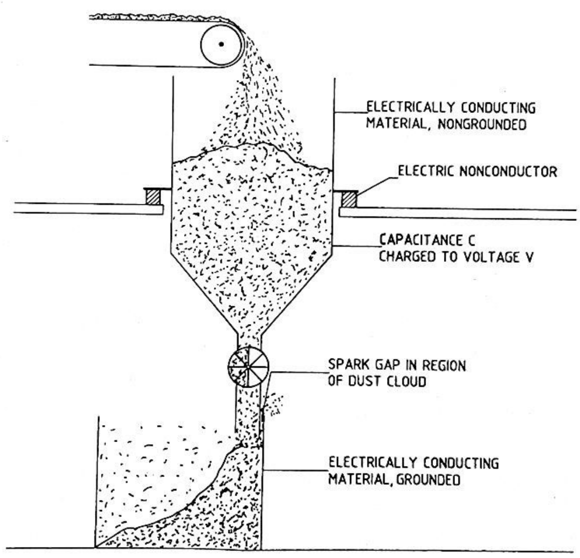


Figure 4: A practical situation that could lead to a dust explosion initiated by an electrostatic spark discharge.

2.4 Method to study the minimum ignition energy

According to Dufaud O. et all, had conducted an experiment to study the minimum ignition temperature for layers of metal powder mixtures. In order to study the characteristic of metal powder mixtures, the dusts have been chosen with regard to two main criteria which is their minimum ignition temperature must be significantly different and these materials must have distinct “thermal signature”. The experiments have been conducted on a heating plate consisting on an Inconel square plate of 280 mm length. Powder beds of 5mm thickness were put on the plate and heated at a rate of 40^0C/minute to a maximum temperature of 480^0C.

At first, various powders have been tested with a maximum diameter of 44 μm (Table 1). However, only zirconium and niobium powders ignited at a temperature close to 300^0. Then powder with lower particle size distribution ranging between 1 and 6 μm was used for the test. As a result only four powders ignited during such test which is iron, niobium, tantalum and zirconium as shown in Table 1.

Table 1 : Characteristic of tested metal powder

Powders	Particle size (µm)	Main Oxide	$T_{ignition}$ (^{0}C)	Observation	Providers
Aluminum	44	Al_2O_3	-	No ignition	Alfa Aesar
Iron	1-6	Fe_2O_3	155	Ignition	Goodfellow
Iron	44	Fe_2O_3	-	Self-heating	Sigma-Aldrich
Magnesium	44	MgO	-	No ignition	Alfa Aesar
Niobium	1-5	NbO	293	Ignition	Alfa Aesar
Niobium	44	NbO	304	Ignition	Alfa Aesar
Tantalum	2	Ta_2O_5	334	Ignition	Alfa Aesar
Tantalum	44	Ta_2O_5	-	Self-heating	Alfa Aesar
Titanium	44	TiO_2	-	No ignition	Alfa Aesar
Tungsten	44	WO_2	-	No ignition	Alfa Aesar
Zinc	44	ZnO	-	Self-heating	Merck
Zirconium	2-3	ZrO_2	181	Ignition	Alfa Aesar
Zirconium	44	ZrO_2	290	Ignition	Alfa Aesar

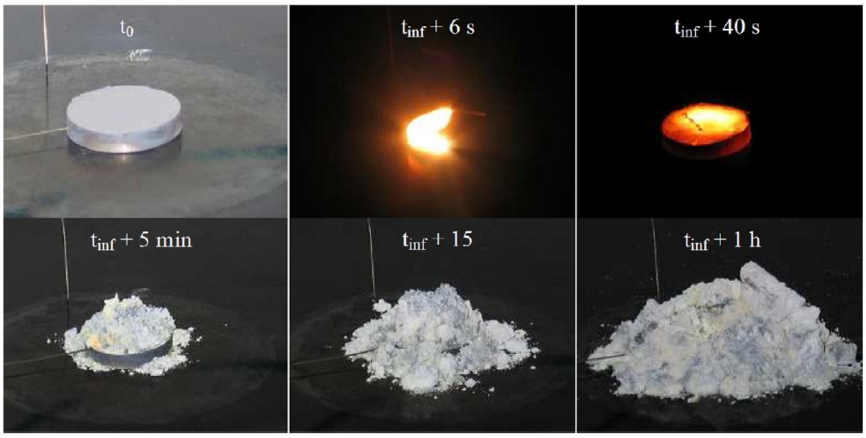


Figure 5: Ignition of a fine niobium layer during the determination of its minimum ignition temperature

On the other hand, according to Rendeberg E. and Eckhoff R.K. in their journal on measurement of minimum ignition energies of dust cloud in the 1 mJ region, applying the new spark generator to the explosive dust cloud showed that a number of dusts do in fact have minimum ignition energies that are one or two orders of magnitude lower than 1 mJ. The new spark generator may offer a basis for developing a standard test apparatus in the low energy region. An integrated system for measurement of spark voltage and current as function of time offers the opportunity to determine the sparks energy. Sparks are generated by using a high voltage pulse to charge a discharge capacitor, which is subsequently discharged when the breakdown voltage of the electrode gap is reached.

The spark voltage is measured using a high voltage probe (Tektronic P6015), and the current is measured differentially using two conventional scope probes across the current measurement resistor. The spark energy is taken as the product of spark current and voltage, integrated over the duration of the spark, typically about 0.1 µs, minus energy losses to the current measurement resistor. Using the present spark generator, spark with energies between about 0.03 and 10 mJ can be generated.

The schematic layout of the discharge circuit is shown in Figure 6. The electrodes are made of 2 mm diameter tungsten rods, sharpen to an angle of approximately 60^0C. the electrode gap was one of the parameters that could be varied between tests.

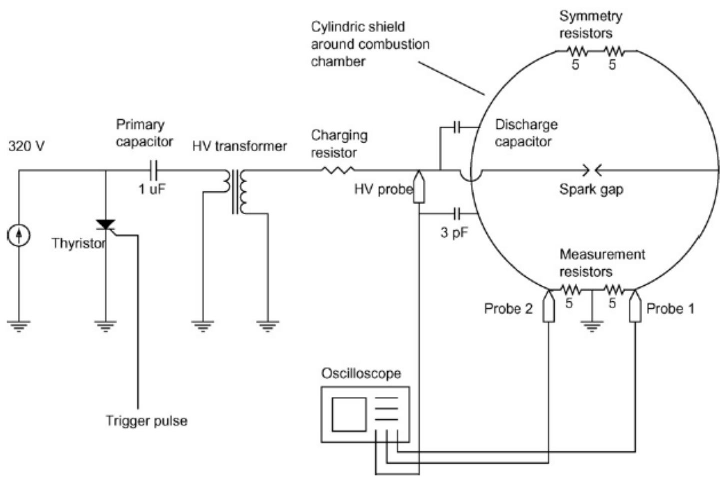


Figure 6 : Schematic layout of the new spark discharge circuit and integrated spark energy measurement system.

Figure 7: The spark generator, the spark energy measurement system and dust explosion chamber.

According to Hong C. W. in his journal in research of minimum ignition energy for nano titanium powder and nano iron powder, also had use almost similar method as above which is using spark generator. In this experiment the apparatus used is the modified version of 1.2 L Hartmann apparatus which requires visual inspection of the ignition to confirm whether or not a dust cloud explosion has been induced. The sizes of titanium powder have been used during the experiment is 3 µm, 8 µm, 20 µm and 45 µm for microscale and 35 nm, 15 nm, 75 nm and 100 nm for nano scale. The spark ignition energies also varies from 1 to 1000 mJ.

Therefore, the entire experimental procedure in this research was carried out in accordance with the Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air in ASTM E 2019 published by American Society for Testing and Materials (2001). The minimum ignition energy is significantly affected by the turbulence that is observed in the apparatus. Then, prior to this experiment 1200 mg each of 15 nm Iron and 35 nm titanium powders were subjected to turbulence experiments and tested at 60 ms, 90 ms, 120 ms, 150 ms and 180ms. All the values are smaller than 1 mJ and the time delay for the experiment was 120 ms. Results from the experiment is as follows.

Table 2 : Minimum ignition energy of nanoscale and micrometer scale metal powder

Nanoscale		**Micrometer scale**	
Diameter	**Minimum ignition energy**	**Diameter**	**Minimum ignition energy**
Titanium		**Titanium**	
35 nm	<1 mJ	3 µm	<1 mJ
75 nm	<1 mJ	8 µm	21.91 mJ
100 nm	<1 mJ	20 µm	18.73 mJ
		45 µm	21.91 mJ
Iron		**Iron**	
15 nm	<1 mJ	150 µm	---
35 nm	<1 mJ		
65 nm	<1 mJ		

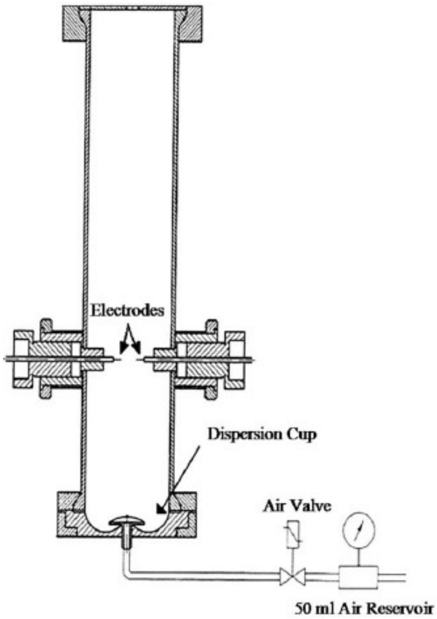
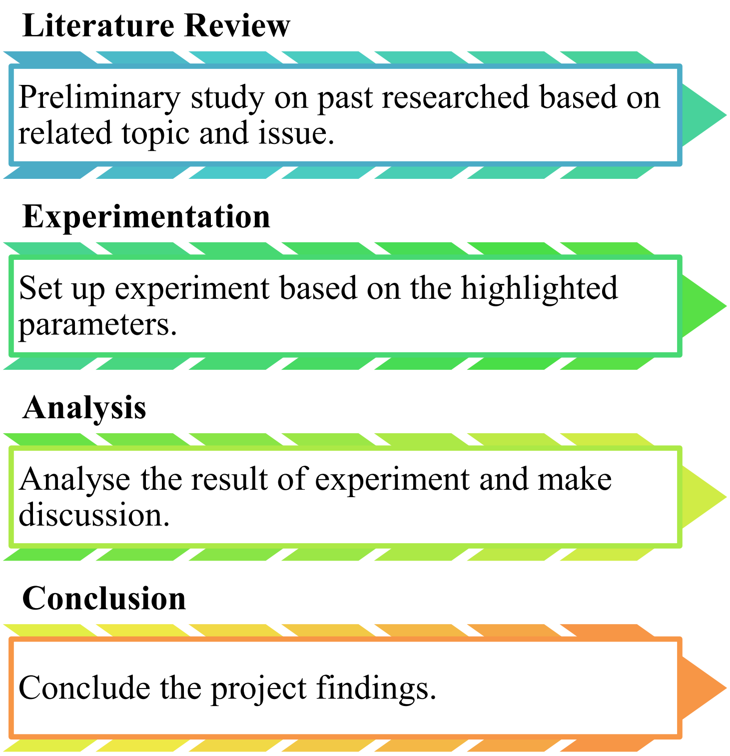


Figure 8: Schematic diagram of the Hartmann apparatus

Chapter 3: Methodology

3.1 Project flowchart



3.2 Gantt Chart and Key Milestone

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Selection of project topic.	■	■												
2.	Preliminary of research work.		■	■	■	■									
3.	Submission of extended proposal.						●								
4.	Proposal defense								■	■					
5.	Project work continues										■	■	■		
6.	Submission of Interim Draft Report													●	
7.	Submission of Interim Report														●

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Project work continues	■	■	■	■	■	■	■							
2.	Submission of Progress Report							●							
3.	Project work continues.								■	■	■	■	■		
4.	Pre-SEDEX										●				
5.	Submission of Draft Final Report											●			
6.	Submission of Dissertation (soft bound)												●		
7.	Submission of Technical Paper												●		
8.	Viva													●	
9.	Submission of Project Dissertation (hard bound)														●

■ Process   ● Milestone

3.3 Experiment Methodology

Hot-Plate Test for Minimum Ignition Temperature Determination

Based on previous experiment conducted by researchers, the simplest technique to conduct the experiment to identify the minimum ignition temperature is by using hot plate. In order to set up the apparatus the experiment will need a modified electric hot plate, a temperature control unit, three thermocouples and a two channel recorder.

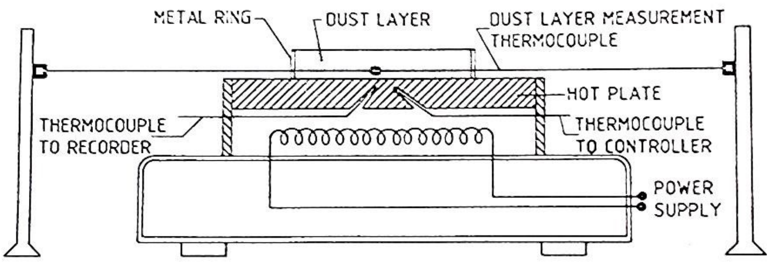


Figure 9: Apparatus set-up for Hot-Plate test

The possible procedures are:

- The hot plate is kept at given temperature, which is read by one of the thermocouples and displayed on one of the recorder channel.
- On the surface of the hot plate is laid a metal ring, with a diameter of 100mm and a height of either 5mm.
- The dust sample to be tested is placed in the metal ring and carefully leveled off to the height of the ring.
- Thermocouple is placed in the sample through holes in the metal ring. The temperature is displayed on the second recorder channel.
- The third thermocouple is used to regulate the plate temperature.
- Repeat the experiment until the minimum ignition temperature recorded.

It is important to know that the minimum hot plate ignition decrease systematically with decrease of dust layer thickness. The minimum ignition temperature will be recorded in the table 3.

From the data collected, the minimum ignition energy will be calculated using the following formula:

$$Q = mC_p\Delta T$$

Where,

$m =$ *mass of the dust*

$C_p =$ *specific heat capacity*

$\Delta T =$ *change in temperature of the dust (minimum ignition temperature – initial temperature)*

After that, the experiment will be conduct repeatedly to test the effect of minimum ignition temperature on the different sizes of the dust and different types of the dust.

Table 3 : Sample of data collection table for ignition temperature

Type of Sample	Mass of Sample (g)	Ignition Temperature (^{O}C)		
		T_1	T_2	T_3
Sago Starch				
Potato Starch				
Tapioca Starch				
Corn Starch				
Custard Powder				
Wheat Flour				
Brown Sugar				
Caster Sugar				

For the sample sizing, all samples had gone through particle size analyzer (Mastersizer 2000). From this analysis, the size of the samples had been determined according to the size range. The result of the analysis can be seen in the Appendix A. The range of particles size according to its highest percentage has been recorded in table 4 below.

Table 4 : Sample of data collection table for sample size.

Type of Sample	Size of Sample (µm)
Sago Starch	
Potato Starch	
Tapioca Starch	
Corn Starch	
Custard Powder	
Wheat Flour	
Brown Sugar	
Caster Sugar	

After the value of the ignition temperature is collected in the table 3, the value will be used to calculate the minimum ignition energy using the formula as per stated above. The value of the minimum ignition energy will be tabulated in the following table 5.

Table 5 : Sample of data collection table for determining ignition energy

Type of Sample	Ignition Energy (kJ)		
	Q_1	Q_2	Q_3
Sago Starch			
Potato Starch			
Tapioca Starch			
Corn Starch			
Custard Powder			
Wheat Flour			
Brown Sugar			
Caster Sugar			

Chapter 4: Result

Experiment set-up

Figure 10 : Experiment apparatus set-up

Please refer Appendix A for individual particle size analysis for each sample.

Table 6: Data for minimum ignition temperature

Type of Sample	Mass of Sample (g)	Ignition Temperature (^{O}C)			
		T_1	T_2	T_3	T_{avg}
Sago Starch	26.14	226.2	238.1	210.4	224.9
Potato Starch	31.72	186.0	189.2	177.7	184.3
Tapioca Starch	22.83	223.5	215.9	200.8	213.4
Corn Starch	22.43	251.8	236.2	221.2	236.4
Custard Powder	25.83	208.9	220.9	212.4	214.1
Wheat Flour	27.22	197.5	166.6	152.9	172.3
Brown Sugar	29.02	122.6	129.6	127.9	126.7
Caster Sugar	29.47	114.7	115.0	109.5	113.1

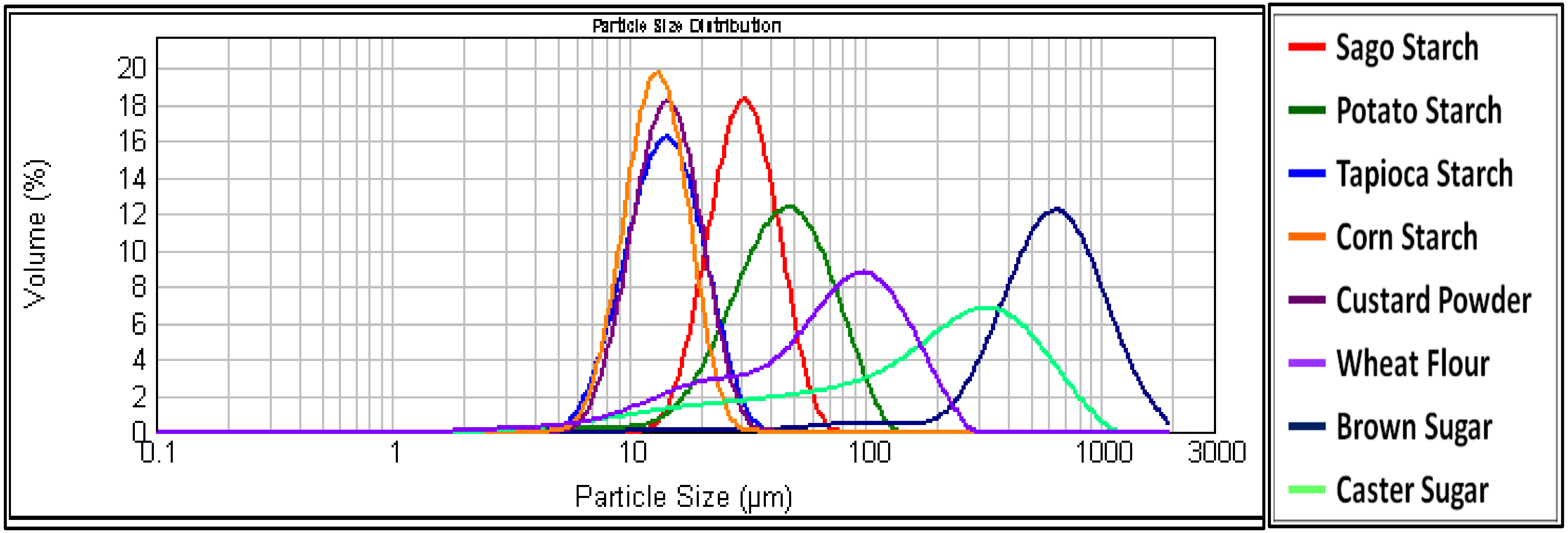


Figure 11 : Particle size distribution graph.

Table 7: Data for size of samples

Type of Sample	Size of Sample
Sago Starch	30.20 – 34.67
Potato Starch	45.71 – 52.48
Tapioca Starch	13.18 – 15.14
Corn Starch	13.18 – 15.14
Custard Powder	13.18 – 15.14
Wheat Flour	91.20 – 104.71
Brown Sugar	630.96 – 724.44
Caster Sugar	316.23 – 363.08

Table 8 : Data for Minimum ignition energy of samples

Type of Sample	Ignition Energy (kJ)
	Q_1
Sago Starch	9.2039
Potato Starch	8.9371
Tapioca Starch	7.9306
Corn Starch	8.9025
Custard Powder	8.3127
Wheat Flour	8.2170
Brown Sugar	4.9566
Caster Sugar	4.6261

Sample calculation:

$Q = mC_p\Delta T$

$m = \; 26.14g$

$C_p = \; 1.75 kJ/kg.K$

$\Delta T = (499.2 - 298) = 255K$

$Q = (0.02614)(1.75)(201.2)$

$Q = 9.2039kJ$

Discussion

From the experiment conducted on the sugar dust the dust start to melt and become brownish in colour as the temperature was increased. At the temperature the dust start to become brown the temperature was recorded and consider as the minimum temperature for the particle to burns in figure 10 below. Comparing between brown sugar and caster sugar, the brown sugar took a longer time to burn compare to caster sugar. This is because brown sugar has bigger particle size compare to caster sugar.

Figure 12: Comparison of caster sugar dust before (left) and after (right) the experiment.

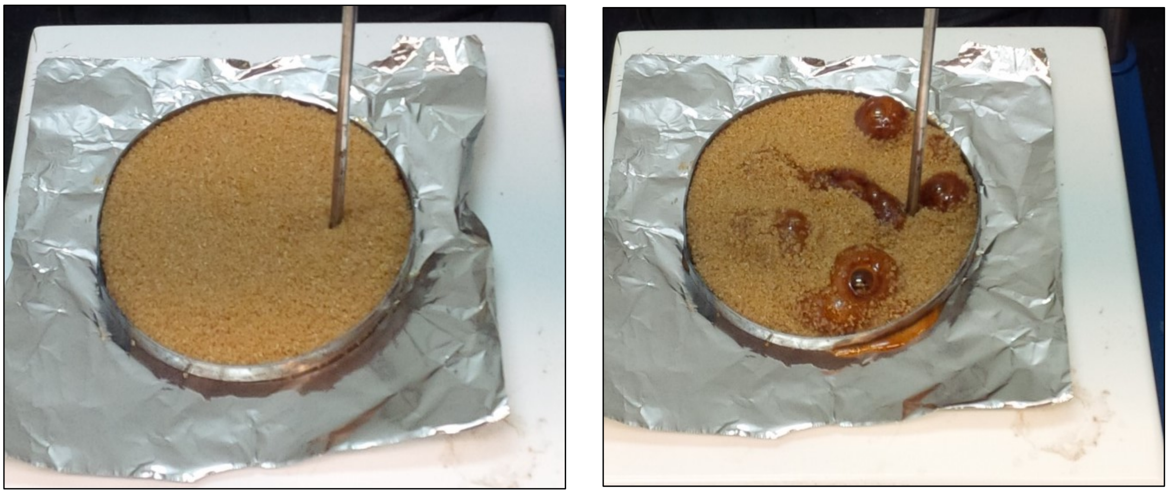


Figure 13: Comparison of brown sugar dust before (left) and after (right) the experiment

For the experiment conducted on the wheat flour dust the dust start to become brown as the temperature was increased. When the dust start to browning and produce smokes, the temperature was recorded and consider as the minimum temperature for the dust start to burns as shown in figure 14 below. Comparing between all the flour dust samples, corn starch should have the lowest ignition energy as it have the smallest size of all the samples.

Figure 14: Comparison of wheat flour dust before (left) and after (right) the experiment.

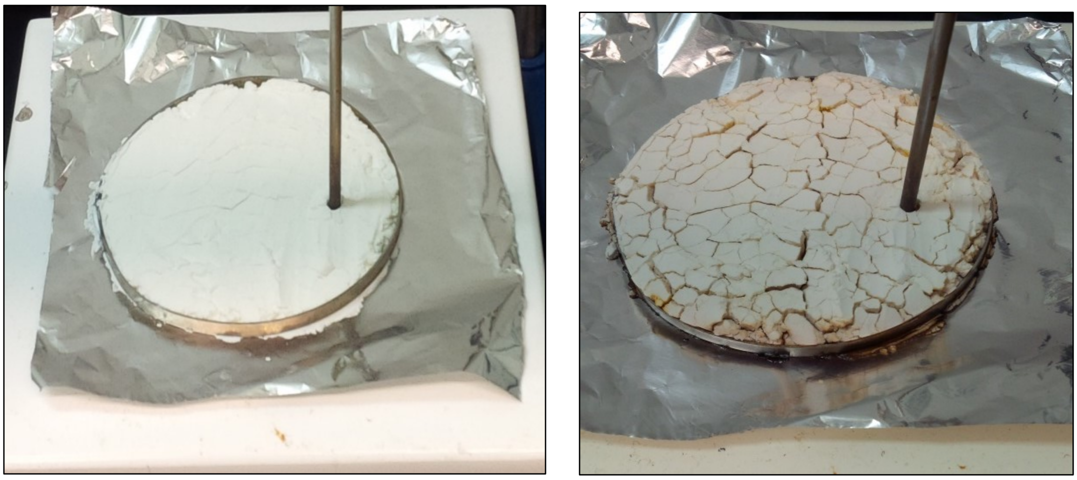


Figure 15: Comparison of corn starch dust before (left) and after (right) the experiment

Figure 16: Comparison of custard powder dust before (left) and after (right) the experiment

Figure 17: Comparison of potato starch dust before (left) and after (right) the experiment

Figure 18: Comparison of sago starch dust before (left) and after (right) the experiment

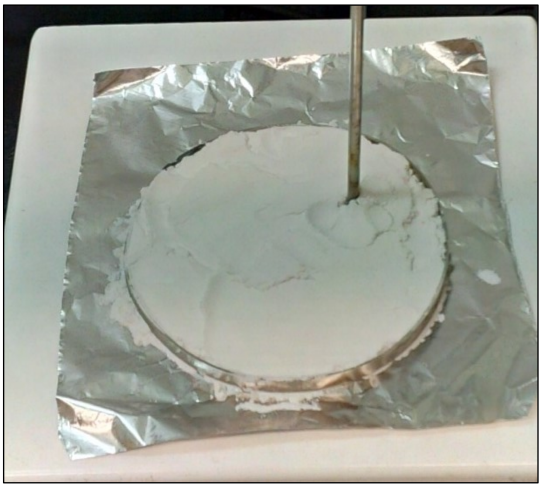
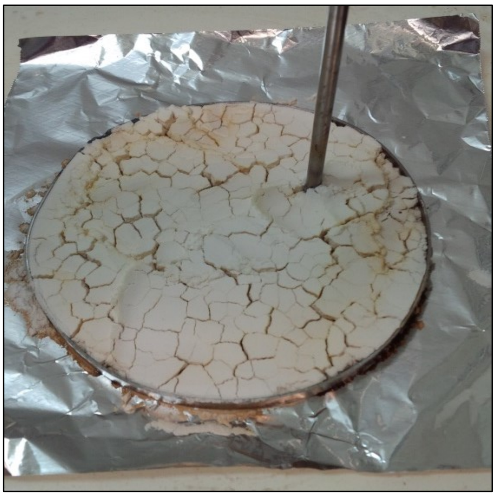
 

Figure 19: Comparison of tapioca starch dust before (left) and after (right) the experiment

Comparing between starches and sugar, sugar has lower ignition temperature and ignition energy. This occurred might be due to the chemical properties of the starch and sugar. As sugar is the simplest molecule of starch which is glucose known as monosaccharide. While starch is the complex form of glucose, it was made up of multiple chains of disaccharides. Where disaccharides is refer to the two molecule glucose.

Chapter 5: Conclusion

In conclusion, hopefully this project will benefit human beings in a long term and will give human more awareness towards the hazards of dust fire and explosion in the workplace. Thus, study in the minimum ignition energy for dust fire and explosion will be the best option for industries to know the hazards around their factories and be more cautious towards the consequences, especially to the food processing industries. On the same time the will be ready with the method to prevent or reduce the risk of dust fire and explosion.

In future, I would like to recommend running this experiment by using other techniques such as Thermogravimetric Analysis (TGA) or Differential Thermal Analysis (DTA). In addition, this project is feasible by taking into account the time constraint and the capability of final year student with the assist from the supervisor and coordinator. It is a big hope for the accomplishment of this study. Later in the final report there will be improvement on the outcomes of the experiment as well as on the method of the experiment.

References

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Appendix

Particle Size Analysis Report

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Tapioca Starch

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Tapioca Starch

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 9:57:10 AM

Analysed:
Friday, October 31, 2014 9:57:12 AM

Particle Name:
Tapioca Starch

Particle RI:
1.330

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.480 %

Sensitivity:
Enhanced

Obscuration:
3.52 %

Result Emulation:
Off

Concentration:
0.0015 %Vol

Specific Surface Area:
0.453 m²/g

Span :
0.960

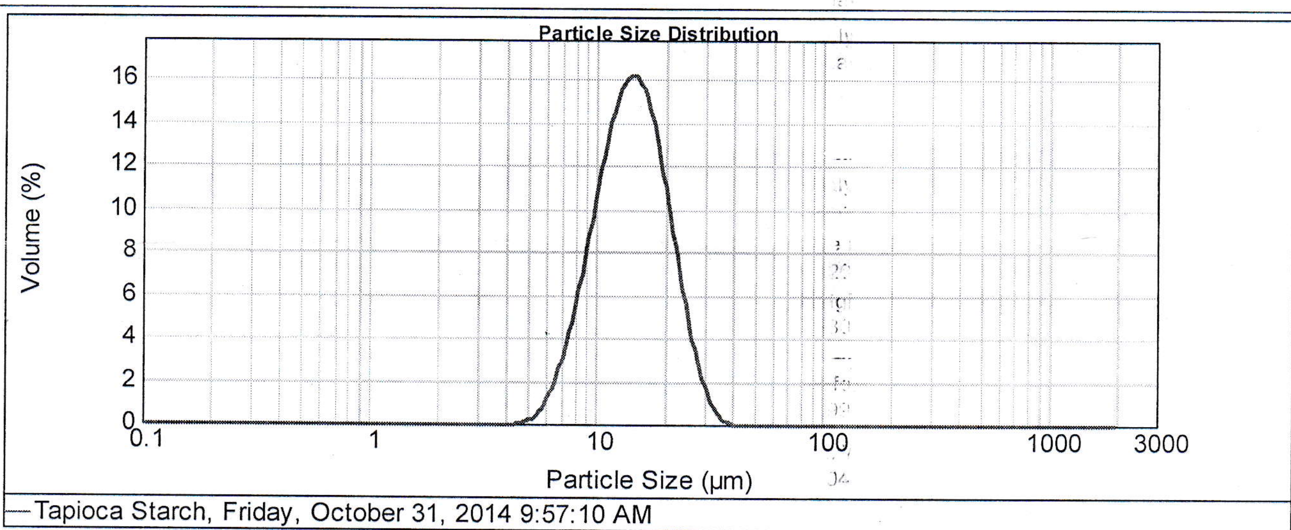
Surface Weighted Mean D[3,2]:
13.237 um

Uniformity:
0.299

Vol. Weighted Mean D[4,3]:
15.049 um

Result units:
Volume

d(0.1): **8.799** um   d(0.5): **14.216** um   d(0.9): **22.448** um



Size (μm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	

Size (μm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.00
0.316	0.00
0.363	0.00
0.417	0.00
0.479	0.00
0.550	0.00
0.631	0.00
0.724	0.00
0.832	0.00
0.955	0.00
1.096	

Size (μm)	Volume In %
1.096	0.00
1.259	0.00
1.445	0.00
1.660	0.00
1.905	0.00
2.188	0.00
2.512	0.00
2.884	0.00
3.311	0.00
3.802	0.00
4.365	0.06
5.012	0.32
5.754	1.25
6.607	2.77
7.586	5.13
8.710	8.02
10.000	11.06
11.482	

Size (μm)	Volume In %
11.482	13.46
13.183	14.58
15.136	13.99
17.378	11.79
19.953	8.62
22.909	5.29
26.303	2.61
30.200	0.91
34.674	0.14
39.811	0.00
45.709	0.00
52.481	0.00
60.256	0.00
69.183	0.00
79.433	0.00
91.201	0.00
104.713	0.00
120.226	

Size (μm)	Volume In %
120.226	0.00
138.038	0.00
158.489	0.00
181.970	0.00
208.930	0.00
239.883	0.00
275.423	0.00
316.228	0.00
363.078	0.00
416.869	0.00
478.630	0.00
549.541	0.00
630.957	0.00
724.436	0.00
831.764	0.00
954.993	0.00
1096.478	0.00
1258.925	

Size (μm)	Volume In %
1258.925	0.00
1445.440	0.00
1659.587	0.00
1905.461	0.00
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Tepung sagu

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Tepung sagu

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 9:42:30 AM

Analysed:
Friday, October 31, 2014 9:42:32 AM

Particle Name:
Tepung sagu

Particle RI:
1.331

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.655 %

Sensitivity:
Enhanced

Obscuration:
2.19 %

Result Emulation:
Off

Concentration:
0.0021 %Vol

Specific Surface Area:
0.207 m²/g

Span :
0.846

Surface Weighted Mean D[3,2]:
29.010 um

Uniformity:
0.262

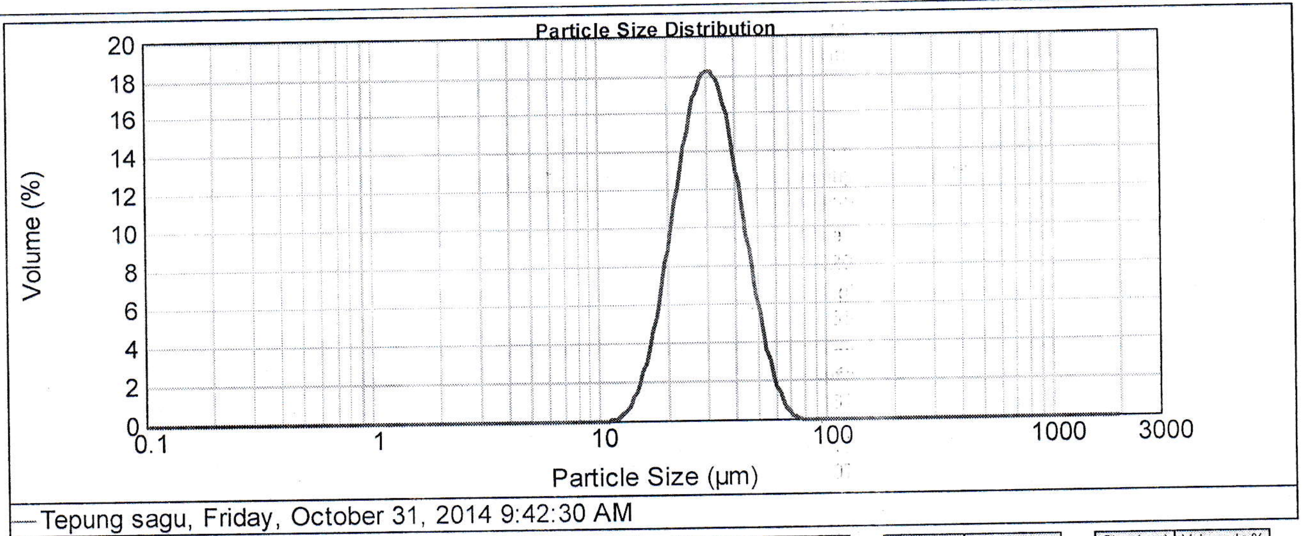
Vol. Weighted Mean D[4,3]:
32.072 um

Result units:
Volume

10%
d(0.1): 20.115 um

50%
d(0.5): 30.631 um

90%
d(0.9): 46.034 um



Size (μm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	

Size (μm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.00
0.316	0.00
0.363	0.00
0.417	0.00
0.479	0.00
0.550	0.00
0.631	0.00
0.724	0.00
0.832	0.00
0.955	0.00
1.096	

Size (μm)	Volume In %
1.096	0.00
1.259	0.00
1.445	0.00
1.660	0.00
1.905	0.00
2.188	0.00
2.512	0.00
2.884	0.00
3.311	0.00
3.802	0.00
4.365	0.00
5.012	0.00
5.754	0.00
6.607	0.00
7.586	0.00
8.710	0.00
10.000	0.00
11.482	

Size (μm)	Volume In %
11.482	0.15
13.183	0.95
15.136	2.74
17.378	5.71
19.953	9.51
22.909	13.32
26.303	15.91
30.200	16.33
34.674	14.33
39.811	10.61
45.709	6.44
52.481	3.01
60.256	0.92
69.183	0.06
79.433	0.00
91.201	0.00
104.713	0.00
120.226	

Size (μm)	Volume In %
120.226	0.00
138.038	0.00
158.489	0.00
181.970	0.00
208.930	0.00
239.883	0.00
275.423	0.00
316.228	0.00
363.078	0.00
416.869	0.00
478.630	0.00
549.541	0.00
630.957	0.00
724.436	0.00
831.764	0.00
954.993	0.00
1096.478	0.00
1258.925	

Size (μm)	Volume In %
1258.925	0.00
1445.440	0.00
1659.587	0.00
1905.461	0.00
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Potato Starch

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Potato starch

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 9:50:32 AM

Analysed:
Friday, October 31, 2014 9:50:34 AM

Particle Name:
Potato starch

Particle RI:
1.331

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.634 %

Sensitivity:
Enhanced

Obscuration:
1.18 %

Result Emulation:
Off

Concentration:
0.0014 %Vol

Specific Surface Area:
0.164 m²/g

Span :
1.271

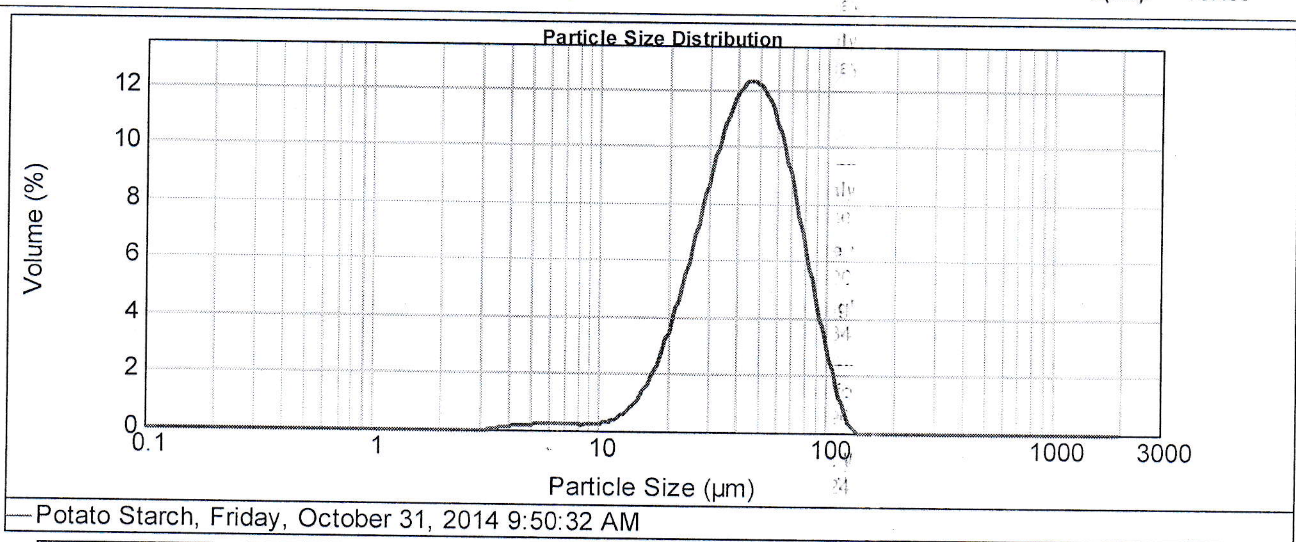
Surface Weighted Mean D[3,2]:
36.595 um

Uniformity:
0.396

Vol. Weighted Mean D[4,3]:
48.241 um

Result units:
Volume

d(0.1): 22.682 um **d(0.5):** 44.701 um **d(0.9):** 79.488 um



Size (μm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	

Size (μm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.00
0.316	0.00
0.363	0.00
0.417	0.00
0.479	0.00
0.550	0.00
0.631	0.00
0.724	0.00
0.832	0.00
0.955	0.00
1.096	

Size (μm)	Volume In %
1.096	0.00
1.259	0.00
1.445	0.00
1.660	0.00
1.905	0.00
2.188	0.00
2.512	0.00
2.884	0.00
3.311	0.06
3.802	0.12
4.365	0.17
5.012	0.19
5.754	0.20
6.607	0.19
7.586	0.18
8.710	0.19
10.000	0.26
11.482	

Size (μm)	Volume In %
11.482	0.45
13.183	0.82
15.136	1.45
17.378	2.39
19.953	3.64
22.909	5.18
26.303	6.88
30.200	8.56
34.674	9.98
39.811	10.89
45.709	11.10
52.481	10.53
60.256	9.20
69.183	7.34
79.433	5.22
91.201	3.16
104.713	1.42
120.226	

Size (μm)	Volume In %
120.226	0.23
138.038	0.00
158.489	0.00
181.970	0.00
208.930	0.00
239.883	0.00
275.423	0.00
316.228	0.00
363.078	0.00
416.869	0.00
478.630	0.00
549.541	0.00
630.957	0.00
724.436	0.00
831.764	0.00
954.993	0.00
1096.478	0.00
1258.925	

Size (μm)	Volume In %
1258.925	0.00
1445.440	0.00
1659.587	0.00
1905.461	0.00
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Brown Sugar

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Brown Sugar

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 10:02:53 AM

Analysed:
Friday, October 31, 2014 10:02:55 AM

Particle Name:
Brown Sugar

Particle RI:
1.359

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.797 %

Sensitivity:
Enhanced

Obscuration:
0.08 %

Result Emulation:
Off

Concentration:
0.0011 %Vol

Specific Surface Area:
0.0145 m²/g

Span :
1.342

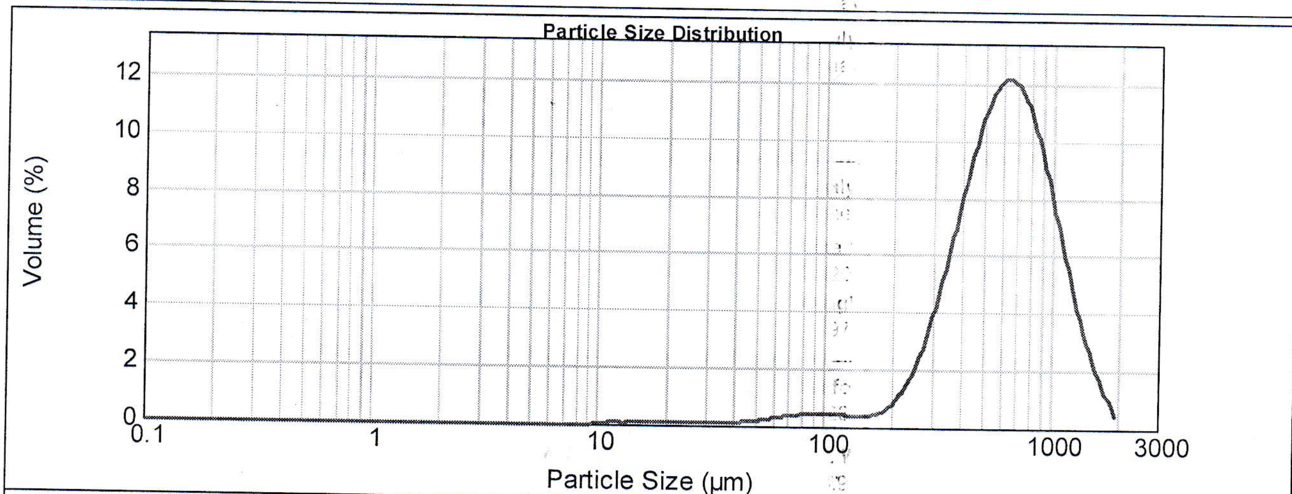
Surface Weighted Mean D[3,2]:
412.768 um

Uniformity:
0.423

Vol. Weighted Mean D[4,3]:
673.963 um

Result units:
Volume

d(0.1): 305.302 um **d(0.5):** 617.821 um **d(0.9):** 1134.648 um



Brown Sugar, Friday, October 31, 2014 10:02:53 AM

Size (μm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	

Size (μm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.00
0.316	0.00
0.363	0.00
0.417	0.00
0.479	0.00
0.550	0.00
0.631	0.00
0.724	0.00
0.832	0.00
0.955	0.00
1.096	

Size (μm)	Volume In %
1.096	0.00
1.259	0.00
1.445	0.00
1.660	0.00
1.905	0.00
2.188	0.00
2.512	0.00
2.884	0.00
3.311	0.00
3.802	0.00
4.365	0.00
5.012	0.00
5.754	0.00
6.607	0.00
7.586	0.00
8.710	0.00
10.000	0.05
11.482	

Size (μm)	Volume In %
11.482	0.06
13.183	0.06
15.136	0.07
17.378	0.07
19.953	0.07
22.909	0.06
26.303	0.06
30.200	0.06
34.674	0.08
39.811	0.11
45.709	0.16
52.481	0.22
60.256	0.28
69.183	0.34
79.433	0.39
91.201	0.40
104.713	0.39
120.226	

Size (μm)	Volume In %
120.226	0.36
138.038	0.34
158.489	0.39
181.970	0.62
208.930	1.11
239.883	1.97
275.423	3.22
316.228	4.84
363.078	6.65
416.869	8.46
478.630	9.94
549.541	10.83
630.957	10.94
724.436	10.22
831.764	8.80
954.993	6.96
1096.478	5.02
1258.925	

Size (μm)	Volume In %
1258.925	3.30
1445.440	1.96
1659.587	0.93
1905.461	0.20
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

Malvern Instruments Ltd.
Malvern, UK
Tel := +[44] (0) 1684-892456 Fax +[44] (0) 1684-892789

Mastersizer 2000 Ver. 5.54
Serial Number : MAL18486

File name: Hazwan
Record Number: 4
31 Oct 2014 10:03:10 AM

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Custard Powder

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Custard Powder

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 10:06:36 AM

Analysed:
Friday, October 31, 2014 10:06:37 AM

Particle Name:
Custard Powder

Particle RI:
1.331

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.339 %

Sensitivity:
Enhanced

Obscuration:
3.23 %

Result Emulation:
Off

Concentration:
0.0014 %Vol

Specific Surface Area:
0.439 m²/g

Span :
0.855

Surface Weighted Mean D[3,2]:
13.677 um

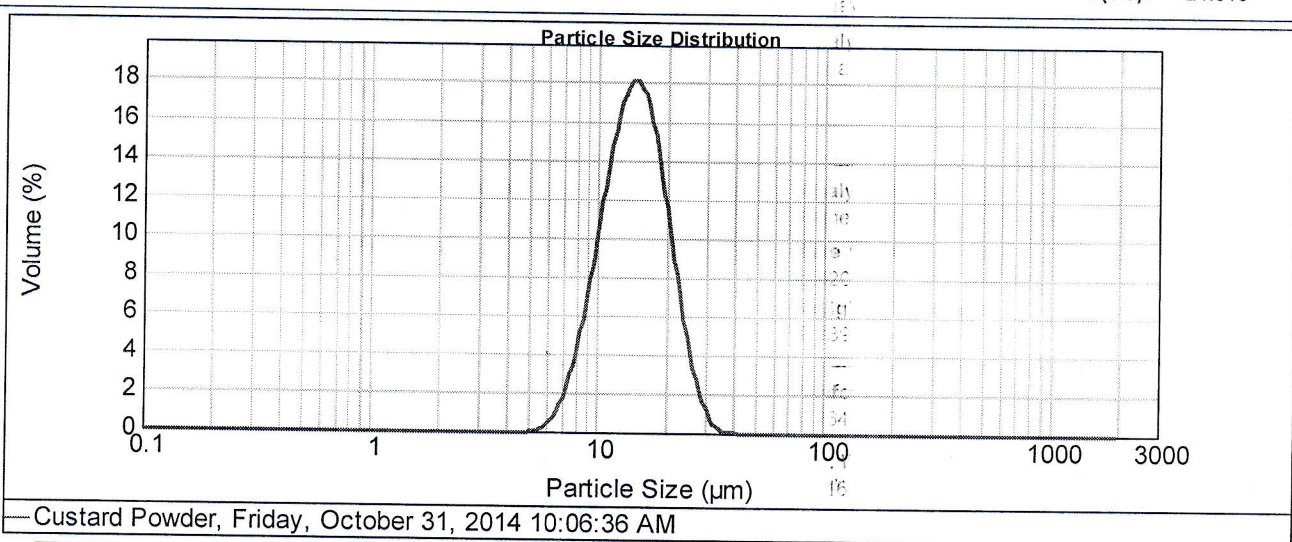
Uniformity:
0.264

Vol. Weighted Mean D[4,3]:
15.164 um

Result units:
Volume

---

d(0.1): 9.454 um **d(0.5):** 14.463 um **d(0.9):** 21.816 um



Size (μm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	

Size (μm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.00
0.316	0.00
0.363	0.00
0.417	0.00
0.479	0.00
0.550	0.00
0.631	0.00
0.724	0.00
0.832	0.00
0.955	0.00
1.096	

Size (μm)	Volume In %
1.096	0.00
1.259	0.00
1.445	0.00
1.660	0.00
1.905	0.00
2.188	0.00
2.512	0.00
2.884	0.00
3.311	0.00
3.802	0.00
4.365	0.00
5.012	0.05
5.754	0.49
6.607	1.67
7.586	3.95
8.710	7.25
10.000	11.17
11.482	

Size (μm)	Volume In %
11.482	14.55
13.183	16.30
15.136	15.66
17.378	12.78
19.953	8.75
22.909	4.81
26.303	2.02
30.200	0.50
34.674	0.06
39.811	0.00
45.709	0.00
52.481	0.00
60.256	0.00
69.183	0.00
79.433	0.00
91.201	0.00
104.713	0.00
120.226	

Size (μm)	Volume In %
120.226	0.00
138.038	0.00
158.489	0.00
181.970	0.00
208.930	0.00
239.883	0.00
275.423	0.00
316.228	0.00
363.078	0.00
416.869	0.00
478.630	0.00
549.541	0.00
630.957	0.00
724.436	0.00
831.764	0.00
954.993	0.00
1096.478	0.00
1258.925	

Size (μm)	Volume In %
1258.925	0.00
1445.440	0.00
1659.587	0.00
1905.461	0.00
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Corn Starch

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Corn Starch

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 10:10:15 AM

Analysed:
Friday, October 31, 2014 10:10:17 AM

Particle Name:
Corn Starch

Particle RI:
1.330

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.228 %

Sensitivity:
Enhanced

Obscuration:
3.12 %

Result Emulation:
Off

Concentration:
0.0012 %Vol

Specific Surface Area:
0.481 m²/g

Span :
0.784

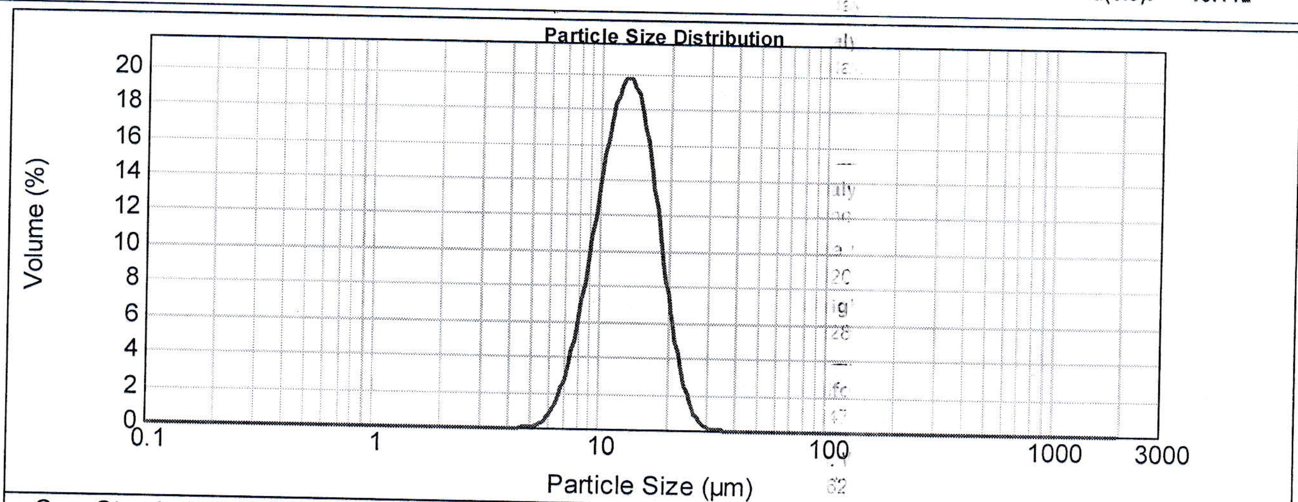
Surface Weighted Mean D[3,2]:
12.472 um

Uniformity:
0.247

Vol. Weighted Mean D[4,3]:
13.626 um

Result units:
Volume

d(0.1): 8.846 um **d(0.5):** 13.092 um **d(0.9):** 19.112 um



Size (μm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	

Size (μm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.00
0.316	0.00
0.363	0.00
0.417	0.00
0.479	0.00
0.550	0.00
0.631	0.00
0.724	0.00
0.832	0.00
0.955	0.00
1.096	

Size (μm)	Volume In %
1.096	0.00
1.259	0.00
1.445	0.00
1.660	0.00
1.905	0.00
2.188	0.00
2.512	0.00
2.884	0.00
3.311	0.00
3.802	0.00
4.365	0.01
5.012	0.13
5.754	0.83
6.607	2.50
7.586	5.64
8.710	9.93
10.000	14.45
11.482	

Size (μm)	Volume In %
11.482	17.39
13.183	17.44
15.136	14.46
17.378	9.69
19.953	5.10
22.909	1.95
26.303	0.42
30.200	0.05
34.674	0.00
39.811	0.00
45.709	0.00
52.481	0.00
60.256	0.00
69.183	0.00
79.433	0.00
91.201	0.00
104.713	0.00
120.226	

Size (μm)	Volume In %
120.226	0.00
138.038	0.00
158.489	0.00
181.970	0.00
208.930	0.00
239.883	0.00
275.423	0.00
316.228	0.00
363.078	0.00
416.869	0.00
478.630	0.00
549.541	0.00
630.957	0.00
724.436	0.00
831.764	0.00
954.993	0.00
1096.478	0.00
1258.925	

Size (μm)	Volume In %
1258.925	0.00
1445.440	0.00
1659.587	0.00
1905.461	0.00
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Caster Sugar

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Caster Sugar

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 10:13:49 AM

Analysed:
Friday, October 31, 2014 10:13:51 AM

Particle Name:
Castor Sugar

Particle RI:
1.366

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.421 %

Sensitivity:
Enhanced

Obscuration:
1.17 %

Result Emulation:
Off

Concentration:
0.0022 %Vol

Specific Surface Area:
0.103 m²/g

Span :
2.569

Surface Weighted Mean D[3,2]:
58.406 um

Uniformity:
0.805

Vol. Weighted Mean D[4,3]:
253.249 um

Result units:
Volume

d(0.1): 22.225 um **d(0.5):** 208.040 um **d(0.9):** 556.646 um

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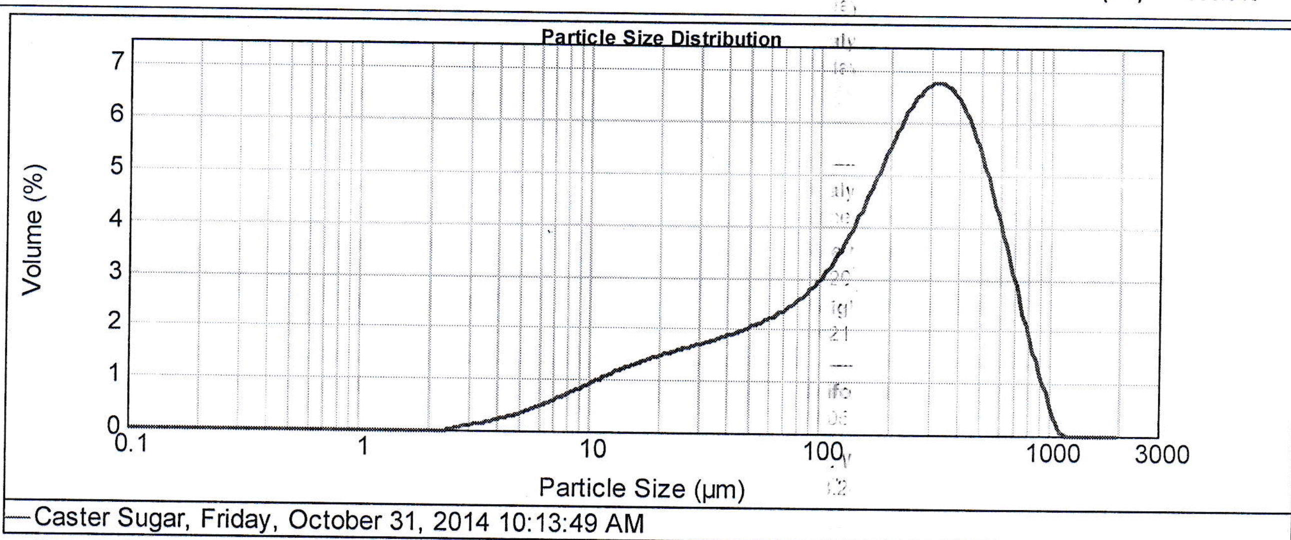


Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.00	11.482	0.99	120.226	3.29	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.00	13.183	1.10	138.038	3.76	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.00	15.136	1.19	158.489	4.28	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.00	17.378	1.28	181.970	4.83	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.00	19.953	1.35	208.930	5.36	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.00	22.909	1.42	239.883	5.79	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.05	26.303	1.49	275.423	6.06	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.10	30.200	1.56	316.228	6.12	3311.311	0.00
0.030	0.00	0.316	0.00	3.311	0.14	34.674	1.64	363.078	5.91	3801.894	0.00
0.035	0.00	0.363	0.00	3.802	0.20	39.811	1.72	416.869	5.45	4365.158	0.00
0.040	0.00	0.417	0.00	4.365	0.27	45.709	1.82	478.630	4.76	5011.872	0.00
0.046	0.00	0.479	0.00	5.012	0.35	52.481	1.92	549.541	3.89	5754.399	0.00
0.052	0.00	0.550	0.00	5.754	0.44	60.256	2.04	630.957	2.95	6606.934	0.00
0.060	0.00	0.631	0.00	6.607	0.54	69.183	2.19	724.436	2.00	7585.776	0.00
0.069	0.00	0.724	0.00	7.586	0.65	79.433	2.37	831.764	1.14	8709.636	0.00
0.079	0.00	0.832	0.00	8.710	0.77	91.201	2.60	954.993	0.42	10000.000	
0.091	0.00	0.955	0.00	10.000	0.88	104.713	2.91	1096.478	0.00		
0.105		1.096		11.482		120.226		1258.925			

Operator notes:

Malvern Instruments Ltd.
Malvern, UK
Tel := +[44] (0) 1684-892456 Fax +[44] (0) 1684-892789

Mastersizer 2000 Ver. 5.54
Serial Number : MAL18486

File name: Hazwan
Record Number: 7
31 Oct 2014 10:14:04 AM

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
Wheat Flour

Sample Source & type:
Hazwan

Sample bulk lot ref:

SOP Name:
Wheat Flour

Measured by:
Administrator

Result Source:
Measurement

Measured:
Friday, October 31, 2014 10:17:07 AM

Analysed:
Friday, October 31, 2014 10:17:09 AM

Particle Name:
Wheat Flour

Particle RI:
1.333

Dispersant Name:

Accessory Name:
Scirocco 2000

Absorption:
0

Dispersant RI:
1.000

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.373 %

Sensitivity:
Enhanced

Obscuration:
1.08 %

Result Emulation:
Off

Concentration:
0.0013 %Vol

Specific Surface Area:
0.163 m²/g

Span :
1.936

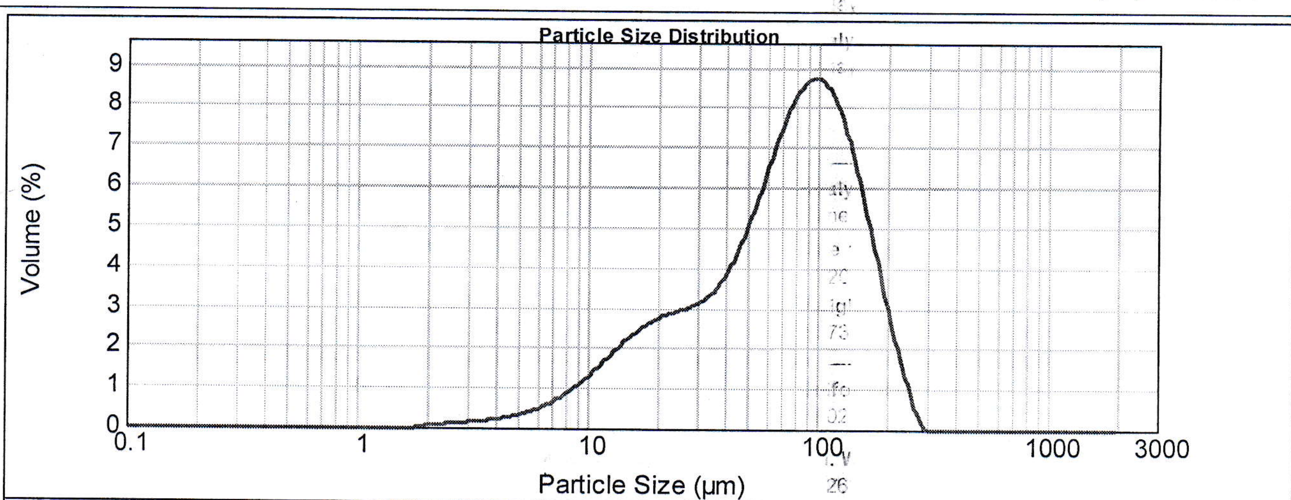
Surface Weighted Mean D[3,2]:
36.736 um

Uniformity:
0.602

Vol. Weighted Mean D[4,3]:
81.263 um

Result units:
Volume

d(0.1): **16.150** um　　**d(0.5):** **73.428** um　　**d(0.9):** **158.291** um



—Wheat Flour, Friday, October 31, 2014 10:17:07 AM

Size (μm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	

Size (μm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.00
0.316	0.00
0.363	0.00
0.417	0.00
0.479	0.00
0.550	0.00
0.631	0.00
0.724	0.00
0.832	0.00
0.955	0.00
1.096	

Size (μm)	Volume In %
1.096	0.00
1.259	0.00
1.445	0.00
1.660	0.00
1.905	0.07
2.188	0.08
2.512	0.11
2.884	0.13
3.311	0.17
3.802	0.21
4.365	0.26
5.012	0.34
5.754	0.45
6.607	0.60
7.586	0.79
8.710	1.02
10.000	1.30
11.482	

Size (μm)	Volume In %
11.482	1.59
13.183	1.89
15.136	2.16
17.378	2.37
19.953	2.52
22.909	2.62
26.303	2.73
30.200	2.89
34.674	3.20
39.811	3.69
45.709	4.40
52.481	5.26
60.256	6.20
69.183	7.04
79.433	7.66
91.201	7.89
104.713	7.65
120.226	

Size (μm)	Volume In %
120.226	6.94
138.038	5.82
158.489	4.46
181.970	3.03
208.930	1.74
239.883	0.71
275.423	0.02
316.228	0.00
363.078	0.00
416.869	0.00
478.630	0.00
549.541	0.00
630.957	0.00
724.436	0.00
831.764	0.00
954.993	0.00
1096.478	0.00
1258.925	

Size (μm)	Volume In %
1258.925	0.00
1445.440	0.00
1659.587	0.00
1905.461	0.00
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

Malvern Instruments Ltd.
Malvern, UK
Tel := +[44] (0) 1684-892456 Fax +[44] (0) 1684-892789

Mastersizer 2000 Ver. 5.54
Serial Number : MAL18486

File name: Hazwan
Record Number: 8
31 Oct 2014 10:17:20 AM