DRYING WET GRANULES: STUDY THE EFFECT OF OVER WETTING PROBLEM

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CERTIFICATION OF APPROVAL

Drying Wet Granules: Study the Effect of Over Wetting Problem

by

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Approved by,

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(Prof Dr Duvvuri Subbarao)

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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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Zulfadli Hariz Bin Ahmad

ABSTRACT

Granulation is a process that combining finer particles together in order to produce coarser particles. The purpose of granulation is to improve the flow properties of the particles, to modify the bulk densities and the dissolution rates of the particles. The objective of this project is to do an experimental study on the drying of wet granules and the effect of over wetting in particles. Wet granules composed of flour were dried in under various volumes of liquid solution. The effects of the conditions on the properties of granules such as diameter, drying rate and density of the granules are investigated. The relationships between the operating conditions and the drying rates were also examined. This project will reflect the important of over wetting study in granulation process. The writer will explained on related theories regarding granulation and relate it on drying granules with the effect of over wetting process. As the project continues, the objective of the project is clearly arising and this project will reply to the problem statement perfectly.

ACKNOWLEDGEMENT

The writer wish to thank everybody that assisting him throughout the course, without the guidance, cooperation, advice and ideas from all of them, the writer may not complete this project and may not meet the objectives of final year project. Therefore, the writer would like to express his special thanks to the following individuals and members for their respective professionalism and contribution to the course. Special thanks to Prof Dr Duvvuri Subarao for their effective preparation for accepting the writer and willing to supervise the project done and for his support and care during the period works and for fruitful introduction into the working lifestyle and understanding. Thanks and appreciation for friends and colleague, Mohd Fikri Hj Jamak and Mohd Khairul Syazwan Abu Samah their full cooperation and constant exchange of information was very satisfactory throughout the time and proved to be key to optimizing output with regard to the work goals.

For their mutual understanding, motivation and co-operative action the writer want to thank all the staff from the Chemical Department of Universiti Teknologi Petronas, who accepted the writer like a friend and who gave the writer a place to do experimental works. This basis of trust and willingness to progress made it possible to archive what the writer did and ensure future success. Especially I want to thank the technician, Miss Hazimah, and Mr Faisal for his powerful support and leadership. The writer enjoyed the effective and professional work very much and he is very happy to have learned so many valuable things under this course.

To the writer's parents, Ahmad Asral Mohamed and Haslina Md Tahir that always there by the writer's side to guide him and gave him the courage that the writer can do the best in life and taught him the difference between good and evil, for this to be the writer guide in his life.

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CHAPTER 1
INTRODUCTION

In this part, a brief description about Drying Wet Granules is being documented as well as the related problem statement with respect towards the project and followed by the objectives and scope of study.

1.1 BACKGROUND OF STUDY

Granulation is a common unit operation in manufacturing of oral dosage forms and also in food industries. Granules are often prepared by wet process which has been extensively studied. Remarkably, the subsequent drying step has received relatively little attention. In batch production, drying is often the bottleneck either for time or product quality reasons (*Hemati, 2003*). Plate drying is a slow process. In the fast fluid-bed drying process attrition, a size reduction phenomenon which leads to the formation of fines is considered a product quality diminishing side effect. Moreover granule characterization during fluid bed drying enables better process understanding which leads to better process control.

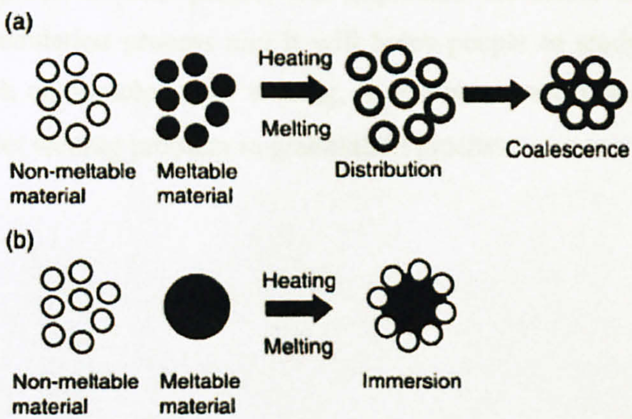

Figure 1: Granulation Process

The method of drying medicinal granules in a fluidized bed has received wide dissemination in the preparation of tablets. Dryers with a fluidized bed are simple in construction, compact, and are very economical as compared with other drying installations (*Hemati, 2003*). The effectiveness of the drying process in such apparatus depends in large measure on the temperature and supply rate of the drying agent, the specific charge of granules onto the grid, and also on the character of bonding of the moisture to be evaporated with the material. The effect of temperature, rate of drying agent supply, and specific load of granules on the drying process has been studied in a specially developed unit. In determining the mean particle diameter of a mixture of granules of various sizes, as the decisive property adopted the specific surface of the particles, which is the main factor in the process of drying granules and pressing them into tablets.

1.2 PROBLEM STATEMENT

Nowadays, granulation is often required to improve the flow of powder mixtures and mechanical properties of tablets. Granules are usually obtained by adding liquids (binder or solvent solutions). When it comes to liquids, the granule will be wet and need to be dried. Conventional ways shows that the over wetting process is slightly neglected. It is important but there is no option to avoid the over wetting problem. This project will explained the effect of over wetting problem in granulation process and it will helps people to study and to make deeper research on avoiding over wetting. It will be a project that will help the research on over wetting problem in granulation process.

1.3 OBJECTIVE AND SCOPE OF STUDY

The objectives of this study are to investigate the behavior of the granules and to study the over wetting problem in granulation. In order to achieve this objective, a few tasks and research need to be carried out by collecting all technical details regarding the granulation, the drying process, ideal size and the correct way to calculate the rate of granule drying.

1.4 FEASIBILITY OF PROJECT

Granulation is widely use in our life as it helps us in pharmaceutical industries, food chemical industries and also in making fertilizer. Everything that involves small particles substance can always be enlarging by granulation process. Granulation of particle and substance will improve the flow ability of the material, have the desirable particle size and distribution and also it change the appearance of the material.

This project is important to help our industries that used granulation as their main assets. This project targeted in increasing productivity of granulation in industrial scale production, understanding the drying conditions, to meet the product quality with minimum energy cost and minimum quantity loss.

In term of feasibility of this project, granulation is possible to be done as it only required liquid, small particle and then tested the drying process.

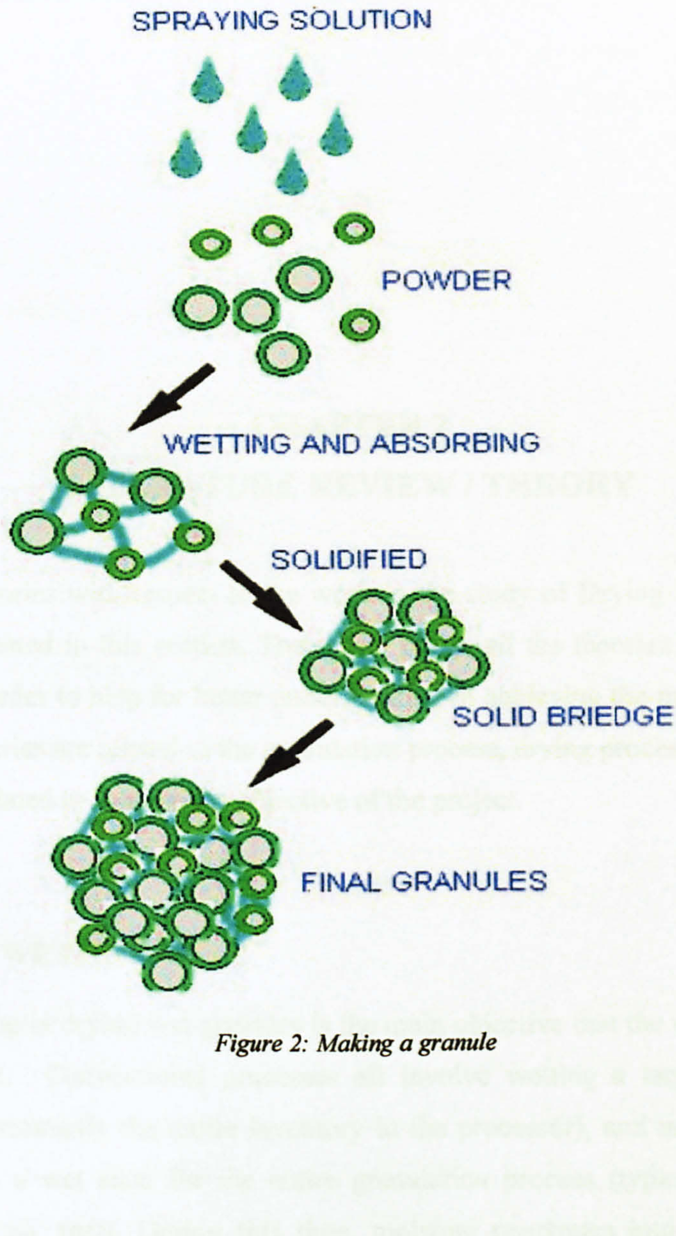

Figure 2: Making a granule

CHAPTER 2

LITERATURE REVIEW / THEORY

Related theories with respect to the work in the study of Drying Wet Granules are documented in this section. The writer put in all the theories related to the project in order to help for better understanding in achieving the project's result. All the theories are related to the granulation process, drying process and some of them are related to achieve the objective of the project.

2.1 OVER WETTING

Over wetting in drying wet granules is the main objective that the writer looks in this project. Conventional processes all involve wetting a large amount of material (essentially the entire inventory in the processor), and maintaining the material in a wet state for the entire granulation process (typically 15 to 30 minutes) (*Gao, 2002*). During this time, moisture penetrates into the particles. Soluble materials can dissolve. Hygroscopic materials can become quite sticky and no longer fluidizable. The process requires a fine balance between under wetting (where the agglomeration rate is too slow) and over wetting, where the process can become impossible to operate. Over wetting invites problem as when the particles are dissolve in the liquid solution, granulation are impossible to happen. This is because when the particles are dissolving in the liquid solution, the drying rate will be very small. When the drying rate is small, it will take a longer time to dry which will cause the process to be much more expensive. The more liquid solution sprayed to the particle, the bigger granule can be produced until it reach the over wetting point where the particle will dissolve in the solution and producing lesser granule and un-wanted soluble materials, the dissolved particles.

Figure 3: 1mm of liquid granule

Figure 4: 5mm of liquid granule

2.2 TEMPERATURE OF AIR

The influence of drying temperature on granulation is critical in this project. Logically, temperature will affect the rate of drying. Higher temperature will result in higher energy given to the wet particle to release the water content in their body. The existence of high temperature in air flow will take the evaporation process of the moisture and water content much easier as water will evaporate easily in high temperature. In this project, the writer has put the temperature in constant, which is 120°C. The writers choose 120°C as the temperature because of the liquid solution used, which is distilled water will evaporate at 100°C and choosing 120°C as temperature can be considered ideal as the liquid will evaporate and as it is higher that 100°C it is expected to be evaporated faster. The temperature need to be constant due to the objective of this project that needed to be tested on over wetting problem. In order to determine the over wetting point, all sample should be put on same temperature as temperature is an essential factor in drying. Difference in temperature may cause the drying rate to be varies among the samples.

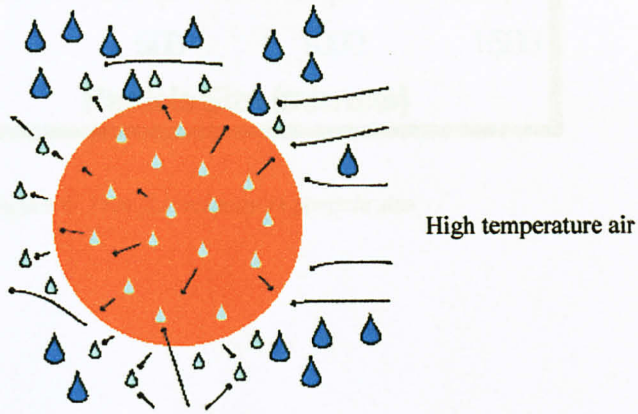

Figure 5: High temperature evaporating water moisture inside granules

2.3 FLUIDIZING VELOCITY

Fine particles can be difficult to granulate in the conventional fluid bed process. With very small particle size the viscosity effect of the fluidizing gas (usually air) can be quite pronounced. The gas velocity needed to fluidize a bed is typically in the range of 20 to 50% of the particle free fall velocity. For instance, 40-micron particles have a free fall velocity of .05 meter/second while 400-micron particles have a free fall velocity of 1.75 meter/second (*P. Roy, 2009*). This broad range of required fluidizing velocities makes it difficult to fluidize a bed containing a wide distribution of particle sizes, and difficult to control fluidization in a bed where particle sizes are growing (due to agglomeration). Realizing this problem, it is also possible to process a feed which consists of large base particles, plus fine particles of another material that is to be coated on the base particles, or distributed through the agglomerates.

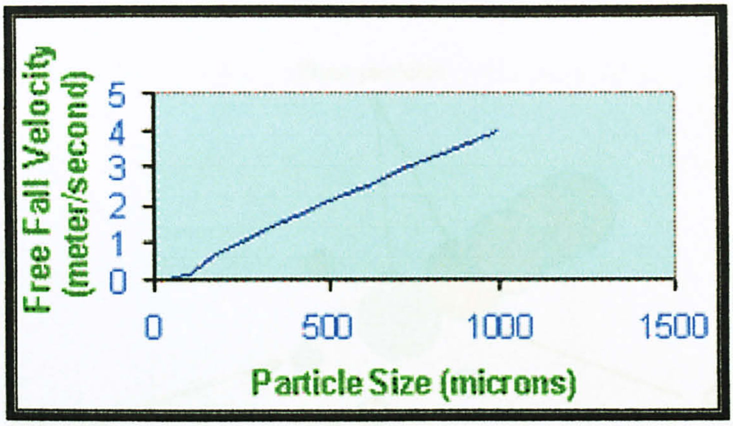

Figure 6: Free fall velocity vs particle size

2.4 ATTRITION

All conventional fluid beds the granulation process needs to continue for a relatively long time (typically 15 to 30 minutes). As the process continues, the fluidization and collision process breaks some agglomerates (*Mort, 2001*). The process then becomes a race between agglomeration and attrition. Faster agglomeration rates are needed to overcome the affects of attrition, but faster agglomeration rates can lead to over wetting and a collapse of the fluid bed. Attrition can lead to fines in the product, causing higher than desired bulk density, dusty product, and poor dispersibility. Attrition can be especially severe if lengthy post drying is required to meet final moisture specifications. Attrition can be defined as weakness to the process as it produced poor quality of granules achieved. Effect of attrition are severe in industry as the process of granulation need to be pull much more longer to clean up the granules to achieved the suitable quality.

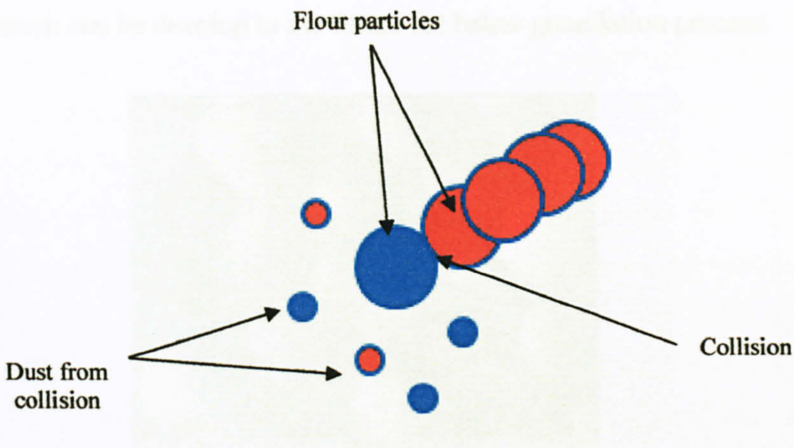

Figure 7: Attrition

2.5 BULK DENSITY CONTROL

The danger of over wetting has limited conventional fluid bed agglomeration processes to producing low bulk density, high surface area agglomerates. These are desirable for some applications (particularly where re-dispersion is a goal), but are undesirable for others (for instance, where the agglomerated material will subsequently be pressed into a solid shape - such as a tablet pharmaceutical or detergent, a powder metal part, or a timed release fertilizer) (*Gao, 2002*). By making the process rapidly, surface moisture has little chance to penetrate the particles. This allows many soluble and hygroscopic materials to be granulated. The writer will try to study the over wetting problem thus it is less of a concern, so it is possible to operate with very high humidity in the granulation tube. This makes it possible to produce high bulk density agglomerates. The process is also capable of producing the low bulk density; high surface area agglomerates of interest where re-dispersibility is an issue. But in this project, as the writer a focusing on over wetting, high density granulation will be pull aside. Although it is preferable for high density but it need extra work and patient to do so. This area of research can be develop in the future for better granulation process.

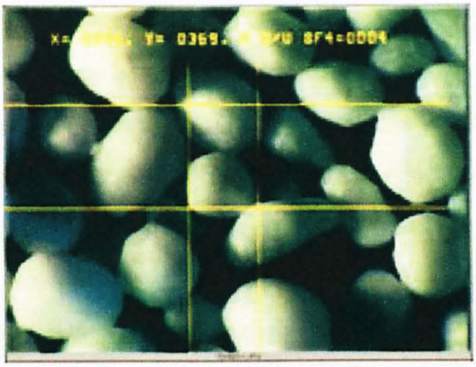

Figure 8: Preferable High Bulk Density Granulation

2.6 SOLUBLE AND HYDROPHILIC MATERIALS

Hydrophilic or the term hydro means "water" and philic or philia means "friendship" explain to us about the characteristic of this material. This material refers to a physical property of a molecule that can transiently bond with water (H_2O) through hydrogen bonding. This is thermodynamically favorable, and makes these molecules soluble not only in water, but also in other polar solvents. There are hydrophilic and hydrophobic parts of the cell membrane (*http://en.wikipedia.org/wiki/Hydrophilic*). With conventional granulation, the wetting agent can become physically or chemically bound to the particles, causing unwanted chemical changes and making post drying difficult. If the particles are soluble, the feed charge can actually liquefy. This has made it impractical to agglomerate many water-soluble materials. Soluble and hydrophilic materials is such a headache to the drying wet granules industries but later, people has discovered a way to do soluble and hydrophilic materials granulation. The problem arise when the particles a soluble in the liquid solution, making it a no-particle and more liquid which is impossible to dry.

2.7 CONTROLLING GRANULATION PROBLEM

In granulation process, the particle collision process is somewhat random, with some particles agglomerating faster than others. This makes the process difficult to control because the charge becomes non-uniform (a large variation of particle size and particle moisture content). As the process continues, and the feed particles become larger and wetter, the optimum airflow and spray rate change (*Aulton, 1981*). This means a sophisticated control scheme or a highly trained operator is needed to get optimum results. When there is difference in agglomerating process, it will lead to different size of granule. Some of the finished granule will be bigger than the other and some of them will be smaller. Controlling granulation size is important to ensure the granulation is uniformly granulated and it reflects perfection in the process.

2.8 METHOD OF DRYING

The first method of drying is the application of heated air (convective or direct drying). Air heating reduces air relative humidity, which is the driving force for drying. Besides, higher temperatures speed up diffusion of water inside the solids, so drying is faster. However, product quality considerations limit the applicable rise to air temperature. Another method of drying is the indirect or contact drying (heating through a hot wall), as drum drying, vacuum drying. Another ways of drying is dielectric drying (radiofrequency or microwaves being absorbed inside the material). It may be used to assist air drying or vacuum drying. Some researchers have found that microwave finish drying speeds up the otherwise very low drying rate at the end of convective drying. Next method in drying is freeze drying. Freeze drying increasingly applied to dry foods, beyond its already classical pharmaceutical or medical applications. It keeps biological properties of proteins, and retains vitamins and bioactive compounds. Pressure may be reduced by a vacuum pump. If using a vacuum pump, the vapor produced by sublimation is removed from the system by converting it into ice in a condenser, operating at very low temperatures, outside the freeze drying chamber (*http://en.wikipedia.org/wiki/Freeze_drying*). Supercritical drying or superheated steam drying involves steam drying of products containing water. This is possible because the water in the product is boiled off, and joined with the drying medium, increasing its flow. It is usually employed in closed circuit and allows a proportion of latent heat to be recovered by recompression, a feature which is not possible with conventional air drying, for instance (*http://en.wikipedia.org/wiki/Supercritical_drying*). Natural air drying takes place when materials are dried with unheated forced air, taking advantage of its natural drying potential. The process is slow and weather-dependent, so a wise strategy "fan off-fan on" must be devised considering the following conditions: Air temperature, relative humidity and moisture content and temperature of the material being dried. Grains are increasingly dried with this technique, and the total time may last from one week to various months, if a winter rest can be tolerated in cold areas.

2.9 RESEARCH ON DRYING WET GRANULES

In drying the granulation process, it involves various type of drying process for granulation. The writer needs to look carefully in order to make sure that he can improve the granulation drying process. In order to improve the drying process, the writer needs to understand the basic thing about drying.

2.9.1 MEANING OF DRYING

Drying is a mass transfer process resulting in the removal of water moisture or moisture from another solvent, by evaporation from a solid, semi-solid or liquid (hereafter product) to end in a solid state. To achieve this, there must be a source of heat, and a sink of the vapor thus produced. In the most common case, a gas stream, for example, air, applies the heat by convection and carries away the vapor as humidity.

Other possibilities are vacuum drying, where heat is supplied by contact conduction or radiation (or microwaves) while the produced vapor is removed by the vacuum system. Another indirect technique is drum drying, where a heated surface is used to provide the energy and aspirators draw the vapor outside the room.

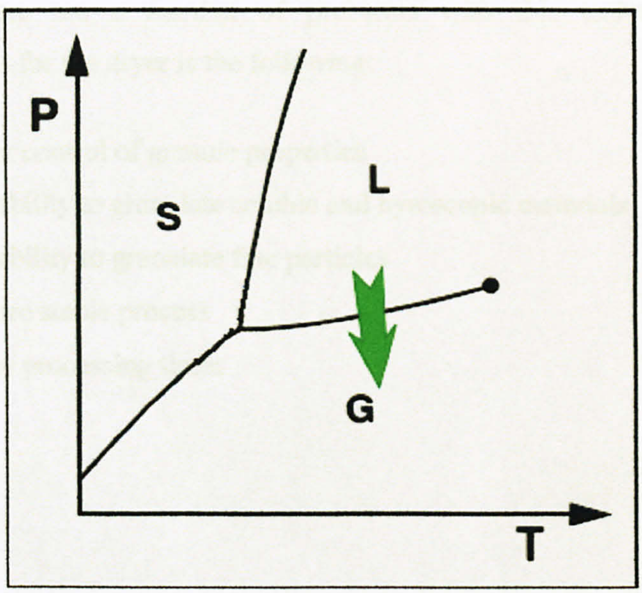

Figure 9: Drying take place when liquid change into gas

2.9.2 HOW THE GRANULATION DRYERS WORKS?

A high velocity air stream, which is also rotating, is established in the central tube. Particles are picked up at the base of the tube and accelerated by the air stream. While in the stream, the particles are contacted with liquid droplets produced by the spray nozzle at the base of the tube. Within the central tube the relative velocities of air, liquid droplets and particles are high so wetting is efficient and drying begins almost immediately. The agglomerates are dry by the time they leave the top of the tube.

2.9.3 WHY NEED TO IMPROVE DRYING PROCESS?

While conventional top spray fluid bed granulation is a well-established process; there are a number of problems with this technology. The improvement for the dryer is the following:

- Better control of granule properties
- The ability to granulate soluble and hyroscopic materials
- The ability to granulate fine particles
- A more stable process
- Faster processing times

2.9.4 WETTING AND NUCLEATION

Wetting and nucleation is the process of bringing liquid binder into contact with dry powder and attempting to distribute this liquid evenly throughout the powder. It is regarded as an important stage in granulation processes but is rarely identified and separated from other effects such as coalescence and attrition. Many studies have focused on granule growth but have given no details of the binder addition method or the extent of binder distribution. In this section on wet granulation nucleation and binder dispersion processes, the writer will focus on the nucleation zone in this part. The writer defines this as the area where the liquid binder and powder surface first come into contact and form the initial nuclei (*Iveson, 2001*). The size distribution of these initial nuclei depends critically on the processes happening in the nucleation zone, although other processes in the rest of the granulator, such as mechanical mixing, may subsequently alter this distribution. Two processes are important in the nucleation zone. Firstly, there is nuclei formation, which is a function of wetting thermodynamics and kinetics. Secondly, there is binder dispersion, or effective mixing of the powder and binder, which is a function of process variables.

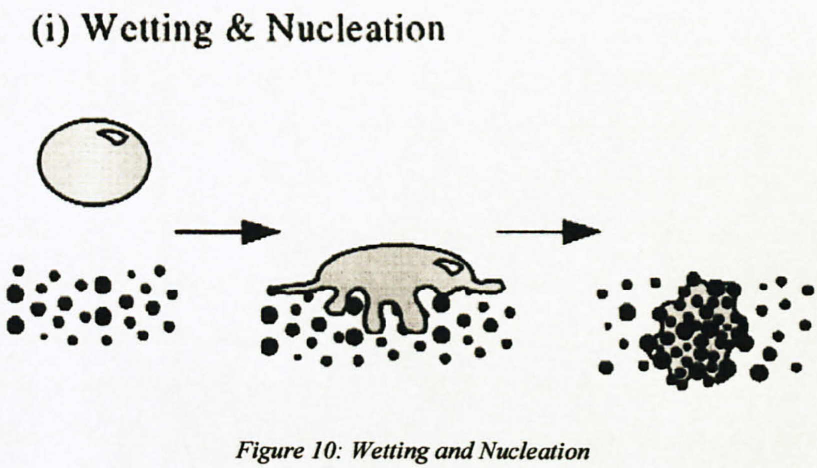

Figure 10: Wetting and Nucleation

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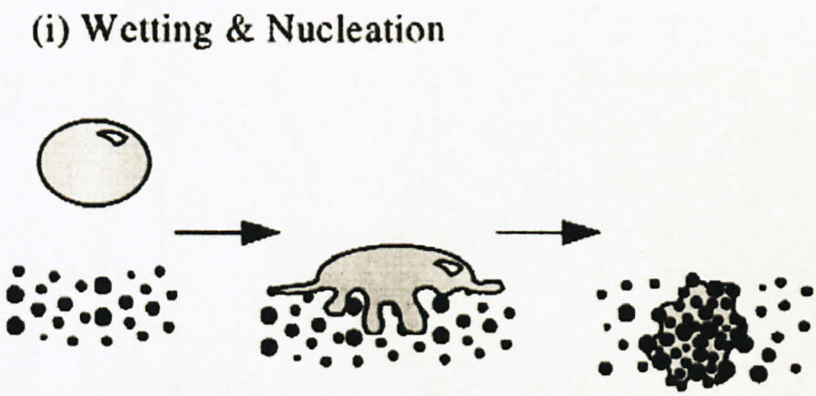


Figure 10: Wetting and Nucleation

2.9.5 LIQUID ABSORPTION CAPACITY

The granules formed during the agglomeration process can be viewed as the arrangement of particles in a structured packing. The main aspect of the agglomeration and binding among the particle is the liquid absorption capacity which determines whether it is coalescence or immersion (*Lankes, 2003*). This capacity hold the particles together and when it come to the drying process, the final granules is form

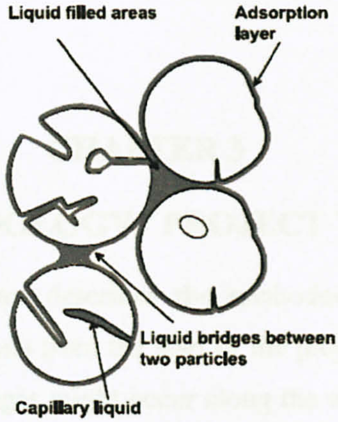


Figure 11: Binding Mechanism

CHAPTER 3

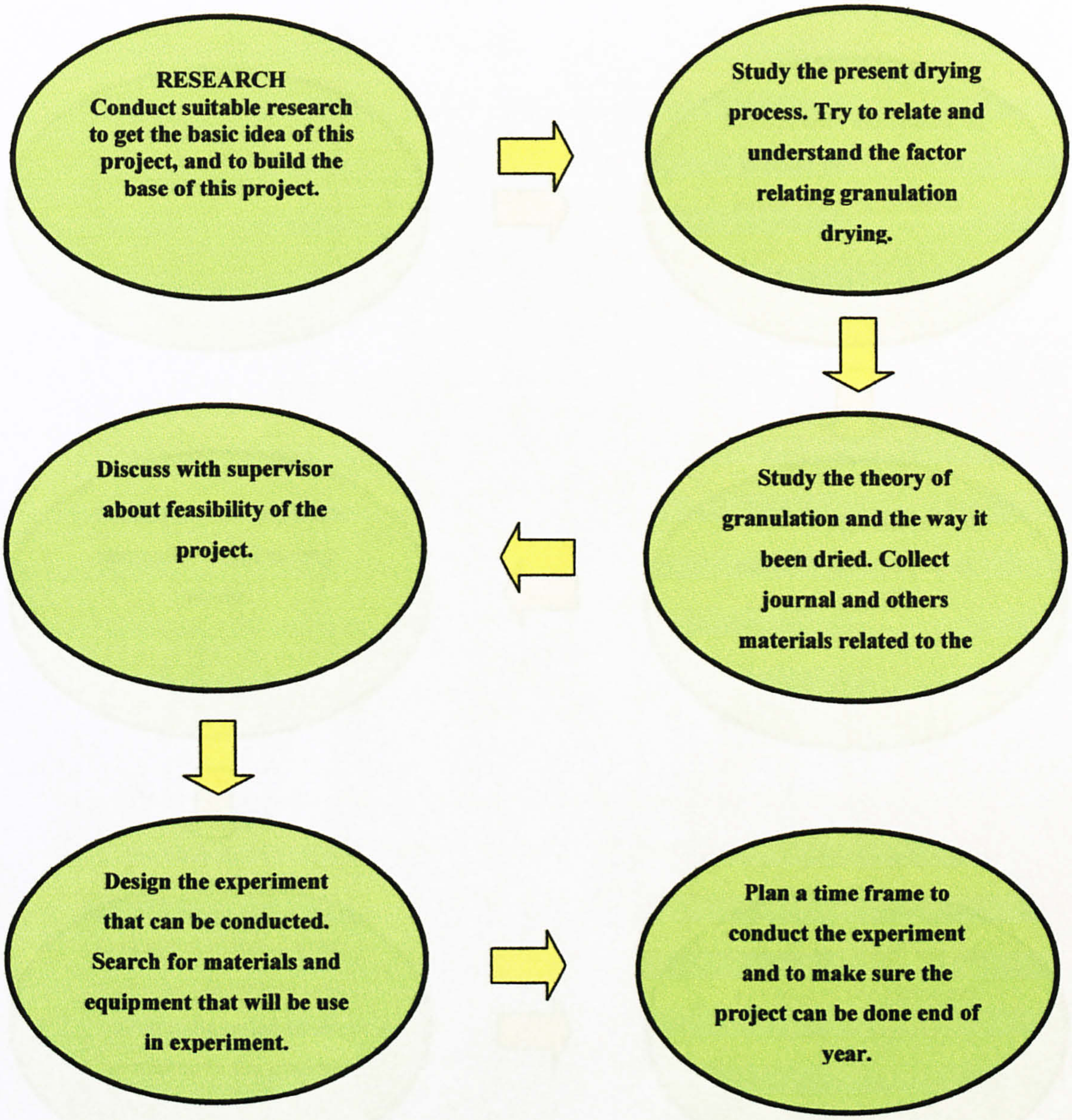
METHODOLOGY / PROJECT WORK

For this section, the writer describes the methodology of the project work process. Related applications from the start of the project towards the end are to be described. Certain changes might occur along the way, but will not change or disrupt the whole objective of the study of the Drying Wet Granules Project.

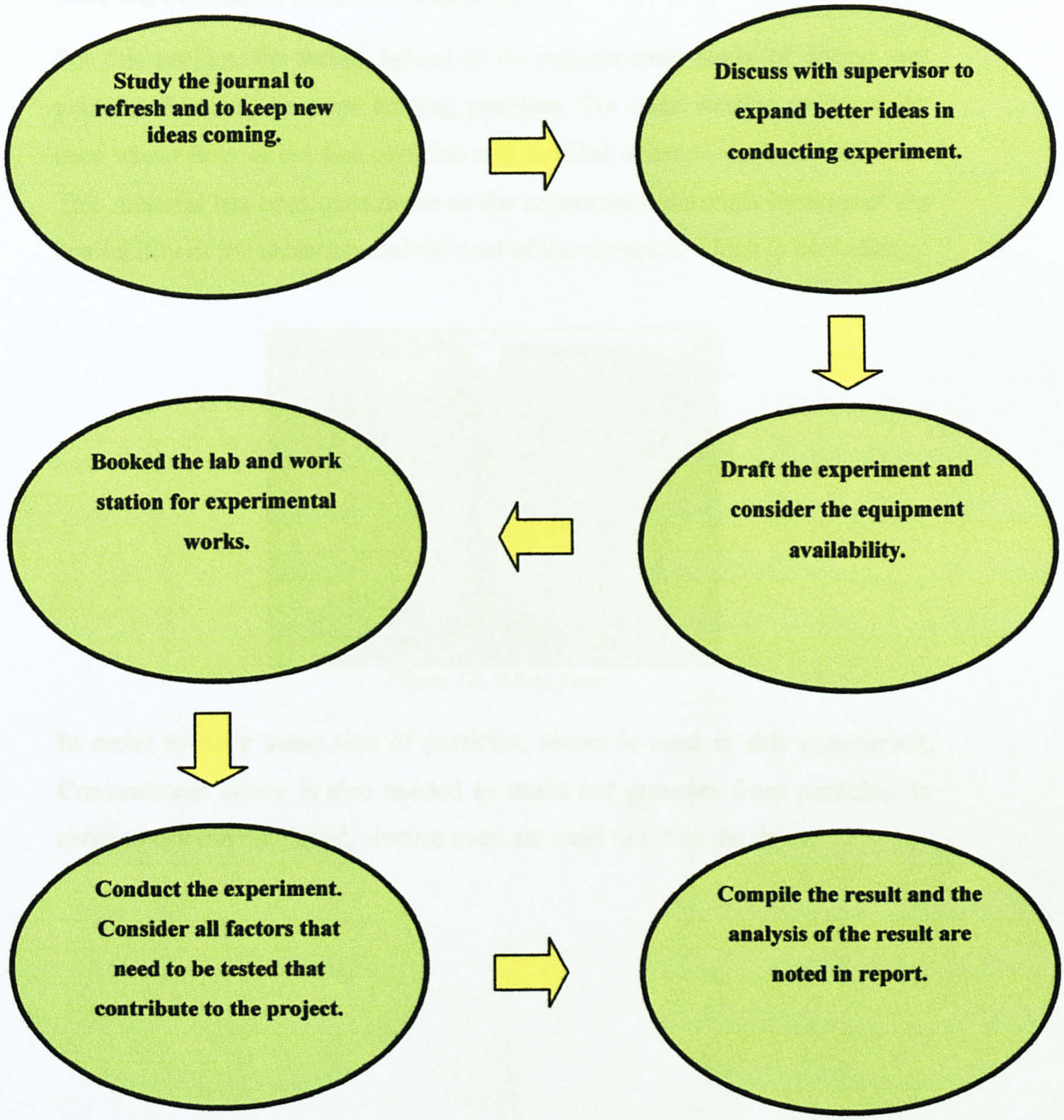
3.1 WORK FLOW

During develop the wet granules drying process, some work should be followed and been planning in order to make sure that this project success and can be finish within the time frame. The course takes one year by separating FYP 1 and FYP 2 on each semester. The writer have to organize and arrange the time neatly in order to make sure the work flow throughout the course will not be complicated and to make sure no error and redundancy while working on this project. Thus, flow chart and Gantt-chart are used to monitor the work done in time, and to act like guidance in completing this course. The work flow is essential because it frame the writer's organization on work and to minimize any mistake that can be done.

3.2 FINAL YEAR PROJECT 1 FLOW CHART



3.3 FINAL YEAR PROJECT 2 FLOW CHART



3.4 EXPERIMENT METHODOLOGY

3.4.1 EQUIPMENT AND MATERIAL

For this project, the writer agreed to do experimental study of drying wet granules focusing on over wetting problem. For over wetting problem, he used wheat flour as the fine particles and distilled water as the liquid solution. This material has been considered as the experiment materials because of the availability of the materials and the cost of the materials which is very cheap.

Figure 12: Wheat flour

In order to have same size of particles, siever is used in this experiment. Conventional siever is also needed to strain out granules from particles. In order to dry out the liquid, electric oven are used to act as the dryer.

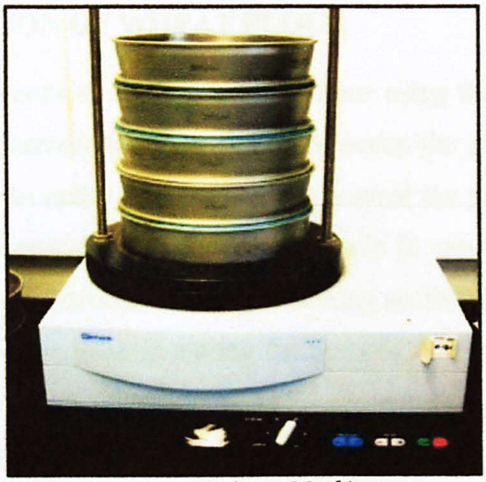


Figure 13: Sieve Machine

Figure 14: Electric Oven

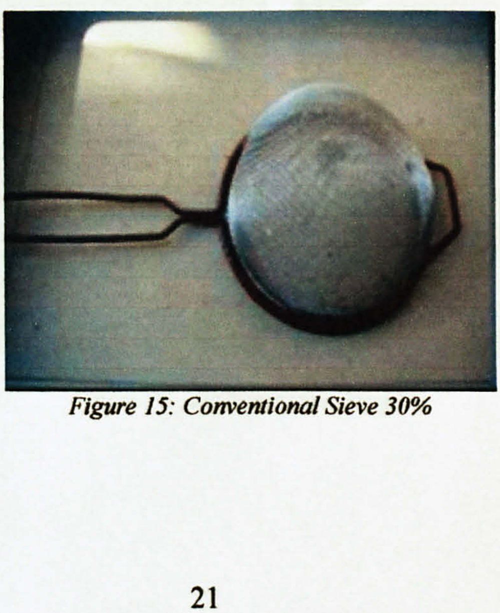


Figure 15: Conventional Sieve 30%

3.4.2 PREPARATION OF WHEAT FLOUR

Firstly, the writer needs to strain the wheat flour using the sieve machine in order to have 63 microns of wheat flour. He needs the particle to be in the same size in order to make sure that he can control the granulation process. As the size of the particles is same, the particle is assumed to have same weight. Therefore, the particle will be granulating uniformly and there will be no faster agglomeration process among the particle. This process will ensure that the size of granule produce will be likely the same and there is not a huge different in size after the granulation process.

3.4.3 GRANULATION

After the wheat flour been strained, the flour is weighted. 18g of flour needed in the granulation process. Weighted flour then put on the metal plate and distilled water is sprayed on the flour. When the distilled water made contact with the flour, the water will act like bridge to each particle. Now the agglomeration process takes place.

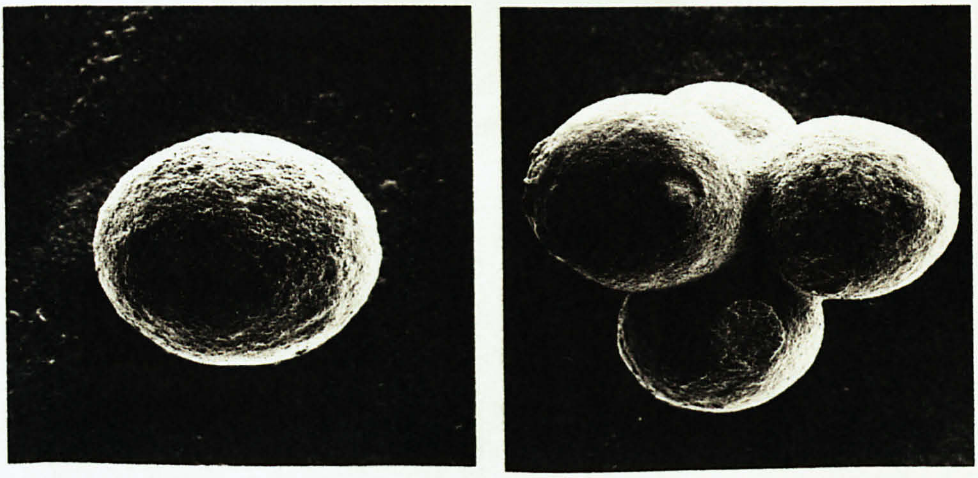


Figure 16: Agglomeration happens

3.4.4 DRYING PROCESS

The wet particles of flour were then put into the electric oven to undergo drying process. The liquid solution or distilled water need to be dry out in order to finish up the granulation process. The temperature was set on 120°C as water will evaporated on 100°C and 120°C will act perfectly in this project. Drying takes place 20 minutes in every process. After 20 minutes, the flour will then be strained again to remove finished granule (granule will be bigger than 63 microns of particle). Granules will be weighted and put into graphical data. All necessary calculation showed in next part of this report.

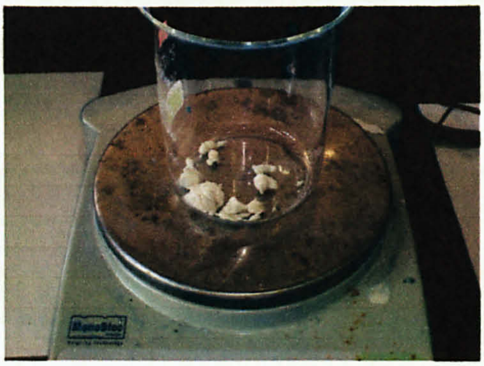


Figure 17: Finish granules

CHAPTER 4

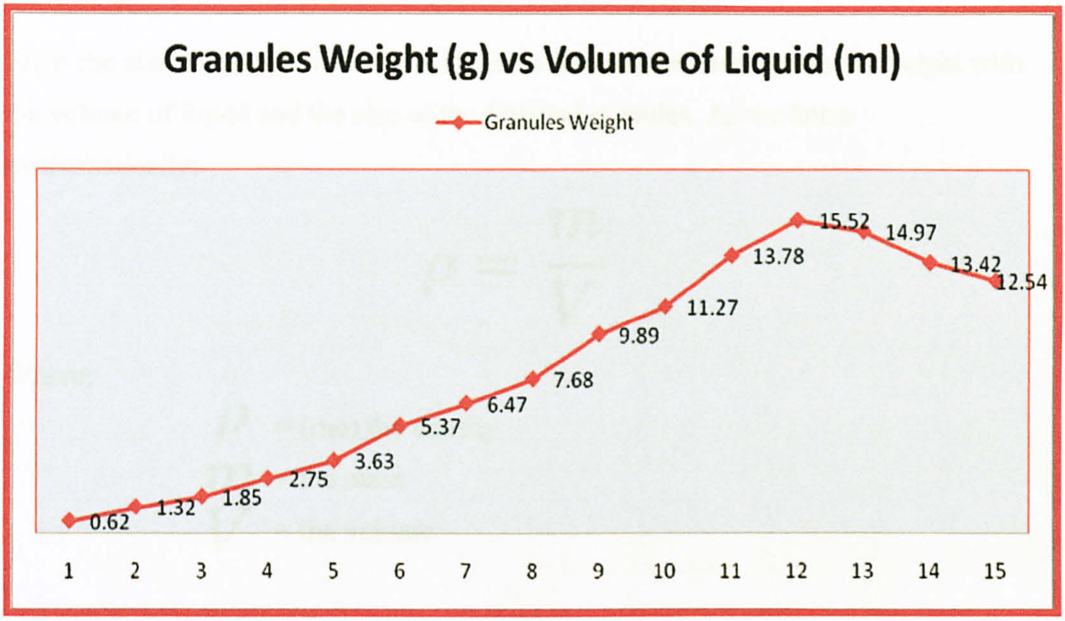
RESULTS AND DISCUSSION

This chapter will show the result obtained from the experiment. This includes the calculation involves in the process and all necessary data will be taken out.

4.1 WEIGHT OF GRANULES OBTAINED AND SIZE OF GRANULES

Table 1: Weight and Diameter of Granules Obtained

Liquid Solution Volume (ml)	Weight of Granules Obtained (g)	Diameter of Granules (cm)
1	**0.62**	**0.3**
2	**1.32**	**0.4**
3	**1.85**	**0.6**
4	**2.75**	**0.7**
5	**3.63**	**1.1**
6	**5.37**	**1.2**
7	**6.47**	**1.3**
8	**7.68**	**1.5**
9	**9.89**	**1.7**
10	**11.27**	**1.8**
11	**13.78**	**2.1**
12	**15.52**	**2.3**
13	**14.97**	Over Wetting
14	**13.42**	Over Wetting
15	**12.54**	Over Wetting



Graph 1: Granules Weight (g) vs Volume of Liquid (ml)

From the graph the writer can summarize that when 12ml of distilled water were sprayed for granulation process, it form the heaviest and the biggest size of granules. At the point of 13ml and above, the weight of granules dropped. This is due to the some particles are dissolve in the distilled water resulting the weight of granules will be lesser. At this point, the size cannot be determine as the granules are not perfectly dried and it still in wet condition. At the 12ml point, it is the maximum point for the distilled water to made contact with the 18g of flour. From 13ml point and above, it start over wetting and losing the granule characteristic and dissolve with the distilled water.

4.2 DENSITY OF GRANULES

From the above data, the writer already have the correlation on granules weight with the volume of liquid and the size of the finished granules. As we know mathematically:

$$\rho = \frac{m}{V}$$

Where;

ρ = (rho) the density

m = the mass

V = the volume

Assuming the granules is in spherical form, so the volume of the granules:

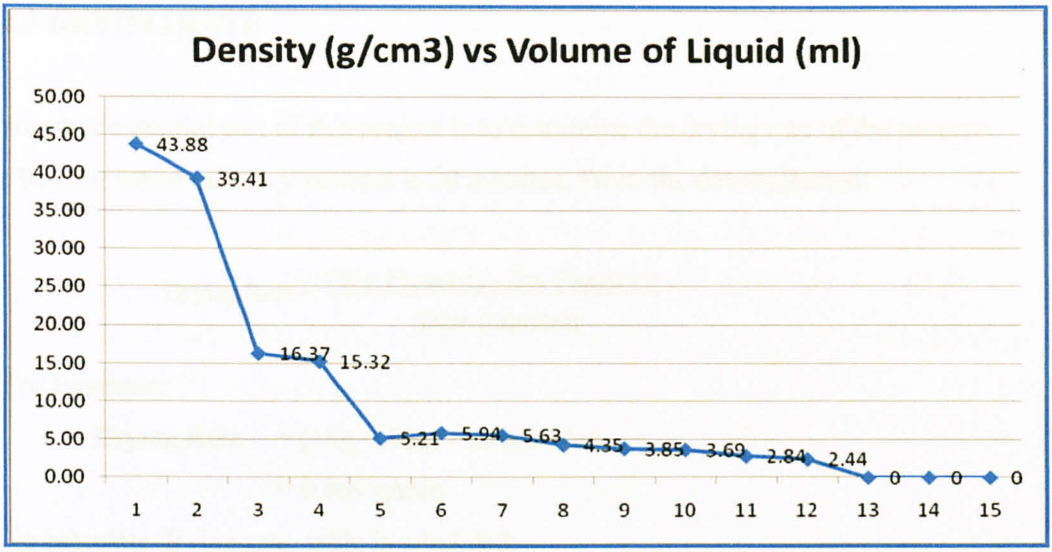
$$\frac{4}{3}\pi r^3$$

Take the volume of sphere.

Table including volume and density is formed:

Table 2: Volume and Density of Granules Obtained

Liquid Solution Volume (ml)	Volume of Granules (cm^3)	Density of Granules (g/cm^3)
1	0.0141	43.88
2	0.0335	39.41
3	0.1130	16.37
4	0.1795	15.32
5	0.6966	5.21
6	0.9043	5.94
7	1.1498	5.63
8	1.7663	4.35
9	2.5711	3.85
10	3.0521	3.69
11	4.8466	2.84
12	6.3674	2.44
13	Over Wetting	Over Wetting
14	Over Wetting	Over Wetting
15	Over Wetting	Over Wetting



Graph 2: Granules Density (g/cm^3) vs Volume of Liquid (ml)

For this part, the density of the granules is high on the first point of the graph and it getting lower and lower. This is due to the bridging supply by the distilled water. When the liquid solution or distilled water at 1ml, the particle are near to each other in agglomeration process resulting the granule form with packed of particles. Reversely, when the volume of distilled water increases, the form of particle inside the granule is slowly getting far away. This will result low density of granule is form. Until the 13ml point, the over wetting occur. Granule's size cannot be determined or granulation is not happen. Thus, from the 13ml point after words, density cannot be calculated.

4.3 DRYING RATE

Another essential part of this project is to determine the drying rate of the process. The time taken on every process is 20 minutes. From the data collected:

$$\text{Drying Rate} = \frac{(\text{Wet Flour (g)} - \text{Dry Flour (g)})}{\text{Time (minutes)}}$$

For Example:

Drying Rate = (18g-0.62g) / 20 minutes

= 0.869 g/min

To calculate drying rate, table is tabulated:

Table 3: Drying Rate Table

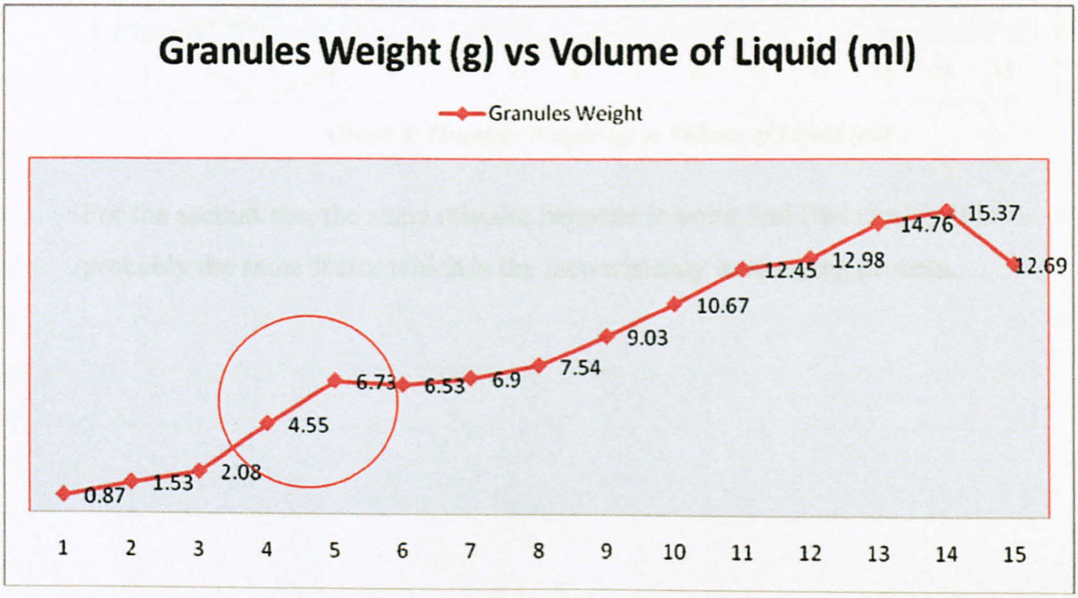
Liquid Solution Volume (ml)	Wet flour-Dry Flour(g)	Time (minutes)	Drying Rate (g/min)
1	17.38	20	0.869
2	16.68	20	0.834
3	16.15	20	0.808
4	15.25	20	0.763
5	14.37	20	0.719
6	12.63	20	0.632
7	11.53	20	0.577
8	10.32	20	0.516
9	8.11	20	0.406
10	6.73	20	0.337
11	4.22	20	0.211
12	2.48	20	0.124
13	Over Wetting	Over Wetting	Over Wetting
14	Over Wetting	Over Wetting	Over Wetting
15	Over Wetting	Over Wetting	Over Wetting

From the table, the writer can extract some of the important point. When the granulation process involve with the small amount of liquid, e.g 1ml, the drying rate is high, 0.869 g/min. This data shows us that the process will dry faster when there is small amount of liquid. This is supported logically as lower the existence of water, the faster the drying rate. The drying rate keeps on falling when the volume of liquid is increasing until the over wetting point where the drying rate will be much more slower as the particle is already dissolve in water. It means that the amount of liquid is much bigger than the other process.

4.4 DISCUSSION ON MISTAKES IN EXPERIMENT

Before the writer got the data of the result and discussion, the writer face a slight problem in making this experiment. For first and second run of the project, the data is fluctuating and behaving not according to the theory.

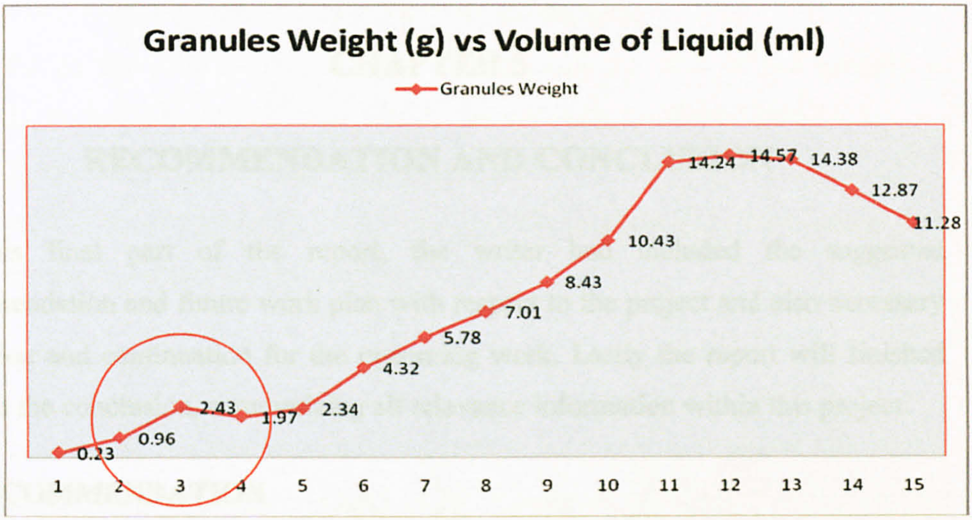
4.4.1 FIRST RUN



Graph 3: Granules Weight (g) vs Volume of Liquid (ml)

From this graph, on point 4ml to 5ml the weight of the granule is bigger than 6ml's granules (in red circle). This shows that there is a mistake on spraying particles which result more than 4ml or 5ml liquid are spray during the process. The error done will give wrong data on the graph and leading to the wrong conclusion.

4.4.2 SECOND RUN



Graph 4: Granules Weight (g) vs Volume of Liquid (ml)

For the second run, the same mistake happens in point 3ml (red circle). It is probably the same factor which is the inconsistency in spraying process.

CHAPTER 5

RECOMMENDATION AND CONCLUSION

For this final part of the report, the writer had included the suggested recommendation and future work plan with respect to the project and also necessary expansion and continuation for the upcoming work. Lastly the report will finished off with the conclusion, summarizing all relevance information within this project.

5.1 RECOMMENDATION

After observing and experiencing this project, the course have given the writer a lot of benefits in terms of experience, key management in handling work and also the skill to communicate with certain people to ensure that the progress of this report goes as smooth as possible. Nevertheless, there are always going to be ups and downs for any project to be done. That is why there are certain recommendations and also the future work plan that the author might believe could help to improve the outcome of this project.

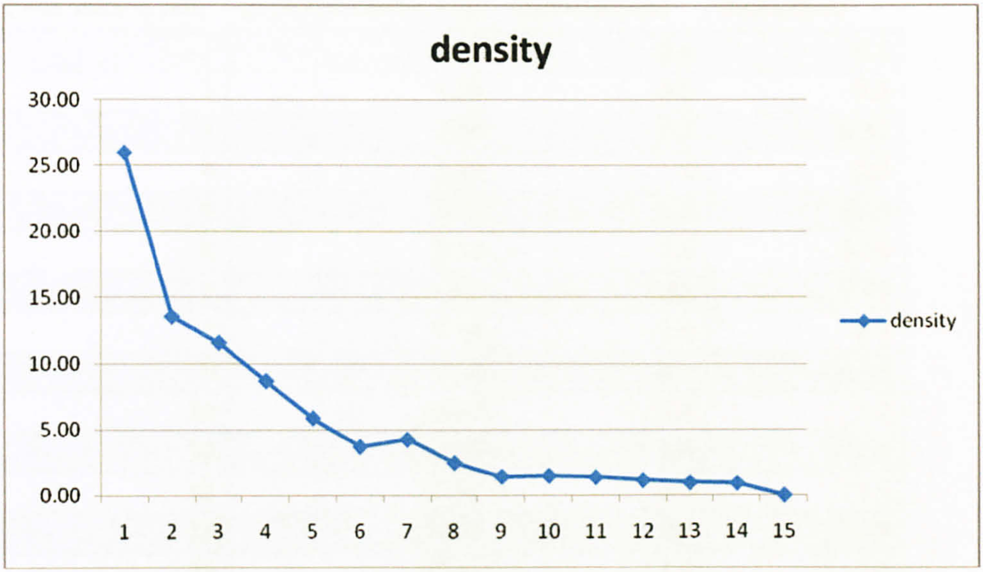
Recommendations towards the project include:

- To have a much simpler way to gather information at the Information Resource Centre in terms of duplicating the information from the book, in which the writer is referring to the photocopy section. This is due some of the reading materials can't be loan outside the IRC and the photocopy will be only available if a student obtains the photocopy cards.
- A better connection towards the internet availability. This would help the writer to gather easier information while off campus.
- To go for size articles analysis which when the size of the particle is increasing, what will be the total surface are contact with air behavior.
- Relate the drying rate with the particle size.
- Rate of spray should be using more specific machine in order to make sure the data obtained is more accurate.

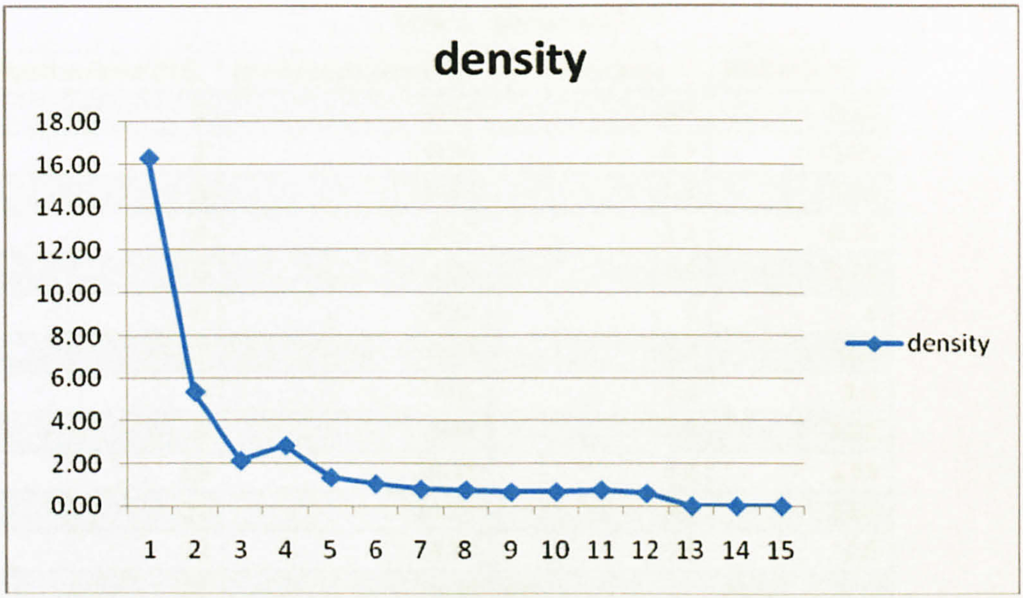
5.2 CONCLUSION

As for conclusion, the importance of granulation was well appreciated, but it was also indicated that little understanding of the process of granulation existed at that time and there was a strong need for further study on this. Now, numerous researchers from all over the world have studied the granulation process. However, there are still a number of problems with the well established granulation drying process. For this project, the writer has emphasis on over wetting problem on the granulation process. When it comes to the over wetting point, some particles are dissolve in the distilled water resulting the weight of granules will be lesser. At this point, the size cannot be determine as the granules are not perfectly dried and it still in wet condition. When it starts over wetting, it will lose the granule characteristic and dissolve with the distilled water. Another point that can be summarized is when the particle is near to each other in agglomeration process it will result the granule to form packed particles resulting the density to be higher. Vice versa, when the volume of distilled water increases, the form of particle inside the granule is slowly getting far away. This will result low density of granule is form. For the last conclusion, drying rate is related to the amount of liquid inside the granule. When the amount of liquid is high, it will take bigger drying rate.

APPENDICES



Graph 1: Density of granules in run 1



Graph 2: Density of granules in run 2

Table 1: Data on Run 1

liquid volume (ml)	granules obtained (g)	diameter (cm)	Radius(cm)
1	0.87	0.4	0.2
2	1.53	0.6	0.3
3	2.08	0.7	0.35
4	4.55	1	0.5
5	6.73	1.3	0.65
6	6.53	1.5	0.75
7	6.9	1.46	0.73
8	7.54	1.8	0.9
9	9.03	2.3	1.15
10	10.67	2.4	1.2
11	12.45	2.6	1.3
12	12.98	2.8	1.4
13	14.76	3.1	1.55
14	15.37	3.2	1.6
15	12.69	nil	

Table 2: Data on run 2

liquid volume (ml)	granules obtained (g)	diameter (cm)	Radius (cm)
1	0.23	0.3	0.15
2	0.96	0.7	0.35
3	2.43	1.3	0.65
4	1.97	1.1	0.55
5	2.34	1.5	0.75
6	4.32	2	1
7	5.78	2.4	1.2
8	7.01	2.6	1.3
9	8.43	2.9	1.45
10	10.43	3.1	1.55
11	14.24	3.3	1.65
12	14.57	3.6	1.8
13	14.38	nil	nil
14	12.87	nil	nil
15	11.28	nil	nil

Table 3: Run 1 Density Table

liquid volume (ml)	volume (cm3)	density(g/cm3)
1	0.033493	25.98
2	0.113040	13.54
3	0.179503	11.59
4	0.523333	8.69
5	1.149763	5.85
6	1.766250	3.70
7	1.628685	4.24
8	3.052080	2.47
9	6.367397	1.42
10	7.234560	1.47
11	9.198107	1.35
12	11.488213	1.13
13	15.590623	0.95
14	17.148587	0.90
15	over wet	over wet

Table 4: Run 2 Density Table

liquid volume (ml)	volume(cm3)	density(g/cm3)
1	0.014130	16.28
2	0.179503	5.35
3	1.149763	2.11
4	0.696557	2.83
5	1.766250	1.32
6	4.186667	1.03
7	7.234560	0.80
8	9.198107	0.76
9	12.763577	0.66
10	15.590623	0.67
11	18.807030	0.76
12	24.416640	0.60
13	over wet	over wet
14	over wet	over wet
15	over wet	over wet

Table 5: Run 1 Drying Rate

liquid volume (ml)	granules obtained (g)	time(min)	wet-dry flour(g)	granules %	rate (g/min)
1	0.87	20	17.13	0.05	0.857
2	1.53	20	16.47	0.09	0.824
3	2.08	20	15.92	0.12	0.796
4	4.55	20	13.45	0.25	0.673
5	6.73	20	11.27	0.37	0.564
6	6.53	20	11.47	0.36	0.574
7	6.9	20	11.1	0.38	0.555
8	7.54	20	10.46	0.42	0.523
9	9.03	20	8.97	0.50	0.449
10	10.67	20	7.33	0.59	0.367
11	12.45	20	5.55	0.69	0.278
12	12.98	20	5.02	0.72	0.251
13	14.76	20	3.24	0.82	0.162
14	15.37	20	2.63	0.85	0.132
15	12.69	20	5.31	0.71	0.266

Table 6: Run 2 Drying Rate

liquid volume (ml)	granules obtained (g)	time(min)	wet-dry flour(g)	granules %	rate (g/min)
1	0.23	20	17.77	0.01	0.889
2	0.96	20	17.04	0.05	0.852
3	2.43	20	15.57	0.14	0.779
4	1.97	20	16.03	0.11	0.802
5	2.34	20	15.66	0.13	0.783
6	4.32	20	13.68	0.24	0.684
7	5.78	20	12.22	0.32	0.611
8	7.01	20	10.99	0.39	0.550
9	8.43	20	9.57	0.47	0.479
10	10.43	20	7.57	0.58	0.379
11	14.24	20	3.76	0.79	0.188
12	14.57	20	3.43	0.81	0.172
13	14.38	20	3.62	0.80	0.181
14	12.87	20	5.13	0.72	0.257
15	11.28	20	6.72	0.63	0.336

Project Gantt-Chart

NO	Activities	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
2	Preliminary Research Work														
3	Submission of Preliminary Report														
4	Seminar 1 (optional)														
5	Project Work														
6	Submission of Progress Report														
7	Seminar 2 (compulsory)														
8	Project work continues														
9	Submission of Interim Report Final Draft														
10	Oral Presentation														

Indication:

FYP 1 Milestone

Mid Sem Break

Work Progress

....

Supervisor Signature

Name:...

Designation:...............................

Date:...

....

Chemical Engineering Student Signature

Name: Zulfadli Hariz Bin Ahmad

Student ID: 7764

Final Year Project

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