TEXTURE ANALYSIS OF SAWDUST

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DECLARATION

I hereby that the work embodied in this report is the result of original research and has not been submitted for a higher degree to any universities or institutions.

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I certify that the report of the final year project with the title of "Texture analysis of Sawdust for Animal Feed" by Mohammad Hasif Hafizi Bin Mohd Shukri with the matric number of F18A0065 has been examined and all the correction recommended by the examiners have been done for the degree of Applied Science (Food Security), Faculty of Agro- Based Industry, University Malaysia Kelantan.

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LIST OF TABLE AND FIGURES

PAGES

TABLE OF CONTENTS.

PAGES

LIST OF SYMBOLS

No.	Symbols	Meaning
1	cm	Centimeter
2	℃	Degree Celsius
3	µ	micrometer
4	f	Force
5	mL	milliliter
6	ATP	Adenosine triphosphate
7	g	Gram
8	SD	Standard deviation

TEXTURE ANALYSIS OF SAWDUST FOR ANIMAL FEED

ABSTRACT

Sawdust is one of the highly potential agricultural wastes that can be used as the animal feed for cattle. This research mainly focuses on the texture of the sawdust that can be affected by the different on container size, the moisture inside the container, the temperature that the sample was stored and the presence of oxygen during fermentation process. The hardness of sawdust can be measured by using the Texture analyzer after the sawdust undergoing fermentation by using yeast as main component for fermentation of sawdust. The duration of fermentation of sawdust are 14 days, During the fermentation process, the hardness of every sample was recorded and stored based on their conditions(different on container size, temperature, moisture and presence of oxygen) was selected during the fermentation process.

Keywords: Cattle, Fermentation, Yeast, Texture analyzer, sawdust

ABSTRAK

Habuk kayu adalah salah satu sisa pertanian yang berpotensi tinggi yang boleh digunakan sebagai makanan haiwan untuk lembu. Penyelidikan ini tertumpu terutamanya kepada tekstur habuk kayu yang boleh dipengaruhi oleh perbezaan saiz bekas, kelembapan dalam bekas, suhu tempat sampel disimpan dan kehadiran oksigen semasa proses penapaian. Kekerasan habuk kayu boleh diukur dengan menggunakan penganalisis Tekstur selepas habuk kayu mengalami penapaian dengan menggunakan ragi sebagai komponen utama untuk penapaian habuk kayu. Tempoh pernapaianj habuk kayu adalah 14 hari. Semasa proses penapaian, kekerasan setiap sampel direkodkan dan disimpan berdasarkan situasi (berbeze pada saiz bekas, suhu, kelembapan dan kehadiran oksigen)

Kata kunci: Lembu, Penapaian, Yis, Penganalisis tekstur, Habuk kayu, Yis

CHAPTER 1 INTRODUCTION

1.1 Research Background

Sawdust is a byproduct or waste of woodworking operations especially during sawing, sanding, milling, and planning that composed of small chip of wood. Sawdust is made largely of cellulose, a carbohydrate, but bound together with a compound named lignin which hard to digest. The lignin cannot completely be digested by the ruminant bacteria and can increase intestinal diseases because the digestion of lignin required oxygen. The excess of fiber reduces the ration of energy supply. The sawdust can be used as an alternate feed for cattle because the presence of cellulose inside the wood chip. The sawdust was one of the versatile products that can be used to create new products such as bedding for animal, firestarter etc. The sawdust also can be used as alternate feed towards farm animals especially cattle. The sawdust mostly be used as the bedding for the farm animals. Based on the existing research, there are several ways in which a treatment that can be given to a substratum of sawdust to modify its composition. Texture analysis of sawdust refer to the characterization of the sawdust based on the hardness of the sawdust after fermentation process.

The fermentation of sawdust was used to reduce the hardness of the sawdust and increase the rate of digestion inside the cattle. The fermentation of sawdust can be easily be executed by using white fungus (yeast). The fermentation is defined as metabolic process that produces chemical changes in organic substrates through the action of the enzymes. For examples, yeast performs fermentation to gain energy by converting sugar into alcohol meanwhile bacteria convert carbohydrates into lactic acid. White fungus (yeast) was used to convert the starch inside the sawdust into carbon dioxide and alcohol. To measure the texture/ hardness of the sawdust, we need to perform fermentation process. The fermentation of the sawdust would take 14 days or more to complete the process. During the process, the growth of the white fungus was observed and recorded. The growth of white fungus can be influenced by times, temperature, ~~the lack of~~ sunlight intensity, moisture etc.

1.2 Problem Statement

Sawdust is one of the most versatile agriculture wastes. The sawdust can be used to make fake snow, fire starters, animal bedding etc. The sawdust also a great potential for dietary meal towards ruminants due to cellulose that was essential towards ruminants diet`s. The disposal of sawdust has becoming one of the greatest challenges in Malaysia. The main focus on the final year project is towards the texture analysis of sawdust especially on the effect of different variables (container size, temperature, moisture and presence of oxygen) towards the texture of sawdust during fermentation process. Moreover, there is a lack of proper research on the fermentation process of sawdust towards the effect of storage size, temperature, moisture, and presence of oxygen towards the texture of sawdust. During the fermentation process, Yeast or *Saccharomyces cerevisiae* are used as the medium for fermentation process for sawdust during the experiment was executed.

1.3 Objective of Study

The aims for the project were:

I) to investigate the relationship between the different variable (Different of container size, temperature, moisture, and presence of oxygen) during the fermentation process with hardness of the sawdust.

II) to investigate the sawdust hardness during the fermentation process.

III) to investigate the growth of sawdust during the fermentation process on different external variable (Different of container size, temperature, moisture and presence of oxygen).

1.4 Hypothesis

The variables (container size, temperature, moisture content and presence of ~~excess~~ oxygen) can contribute to~~wards~~ the different value on the hardness of the sawdust after the fermentation process was completed. The highest gap on the different value of the hardness of sawdust are towards the moisture inside the container during the fermentation process. The lowest gap of different value on the hardness of sawdust was the container size.

1.5 Scope of Study

The present study was focusing on the effect of the container size, temperature, moisture, and presence of oxygen towards the texture of fermented sawdust for 14 days. The fermentation process of the sawdust can be used to inspect the hardness of the sawdust. The duration for the fermentation process during the project is 14 days. The fermentation process will decrease the hardness of the sawdust because ragi/ white fungi break down the cellulose inside the cell wall of the sawdust into other organic products. The fermentation process occurs during the metabolic activity and anaerobic respiration of the white fungi. ~~The fermentation process occurs during the anaerobic respiration of white fungi cell.~~ The results of the study can give a better understanding towards the fermentation process of sawdust that can be affected by the variable that was stated inside the study.

1.6 Significance of Study

Many study on the sawdust mainly focused on the nutritional value of the sawdust towards their cattle. They mainly focus on the benefits of sawdust towards the health of their cattle and the side effect of feeding sawdust towards their cattle. The nutritional of sawdust can be vary based on the species of tree that was used as the sample. Some trees have a higher Crude fiber compared to other species. The texture of the sawdust during fermentation are decreasing due yeast break down the cellulose into alcohol, CO_2, and lactic acid. But rate of reduction of hardness can be influenced by the external factors such as the different of temperature, the container sizes, the presence of oxygen and the moisture that was use before the fermentation process started. The external factor can affect the rate of reduce hardness of sawdust.

CHAPTER 2 THE LITERATURE REVIEW

2.1 SAWDUST

Wood industry plays important role in the economic development of the country. The rise production of wood indicates the rise of waste in the country. Sawdust was a byproduct of the wood processing industry. Generally, sawdust composed of fine particles of wood. Sawdust has a lot of practical uses such as in animal bedding, agricultural mulch, and manufacturing of white board. The sawdust is a small piece of wood that was fall as powder during the wood making process. The sawdust is generally be considered as the wood-making industry waste that can pollutes the environment. The sawdust may collect in piles and add harmful leachates into the local water systems and can cause an environmental hazard. The sawdust can inflict damage towards. The water borne bacteria inside the local water can digest the organic materials. During the digestion process of materials, they used a lot of oxygen that would suffocate fish and other organisms inside the local water system creating environmental hazard.

Airborne sawdust can present several health and safety hazards. People can be exposed to the sawdust in the workplace by breathing in, skin contact or eye contact. The Occupational Safety and Health Administration (OSHA) put a legal limit (permissible exposure limit) for sawdust exposure in the workplace are 15mg/m^3 total exposure and 5mg/m3 respirator exposure limit towards 8-hour workday or more. The National Institute for Occupational Safety and Health (NIOSH) have set a recommended exposure limit (REL) of 1mg/m3 for

8 hour of workday or more. Next, Sawdust can be flammable and airborne sawdust can be ignited by sparks resulting an explosion.

According to Gan and Ho (1995), The removal of wood waste in wood industry in Malaysia is an important activity and certain extent affects the productivity and profitability of the mill operation. However, the removal of waste can cause pollution towards long term effect on environment. The abundance amount of sawdust waste can be a good supporting factor considering the usage as potential substrate for bioprocess.

Plant biomass such as sawdust is being researched as one of the desirable alternative raw materials because of their low cost and easy availability (Musatto and Teixera, 2010). There are a lot of advantages of the employment of agro-industrial waste as substrate for bioconversion process. The use of agro-industrial as substrate contribute to the reduction of cost on enzyme production at the same time increase the awareness of the energy recycling and conservation.

2.2 THE NUTRIENT VALUE OF ANIMAL FEED IN SAWDUST.

Sawdust can be the best source of fiber for cattle. Using the conventional ingredients for the sawdust contain Metabolize Energy (ME), Crude Protein (CP), Crude Fibre (CF) and Total Ash content (TA) to the considerable amounts. (Keith, 1976: Oke and Oke, 2007). In 1994, Radwan conducted a study on the nutritional value inside the sawdust and based on the report, Radwan discover that sawdust composes of 2,53 % of crude protein, 0.76 of ether extract, 60.26 % of crude fibre, 24.53 % of nitrogen free extract and 0.8% of crude ash. Another experiment that was reported by Oke and Oke , they has discover that another sample of sawdust contain 0.88% crude protein, 1.47% ether extract, 67.61% crude fibre and 0.64% crude ash. These observations are in close agreement with present study. the need of fibre for normal physical functions of cattle, are established perfectly. Fibre materials aren't merely a root of dietary fibre, but rather, in true sense, they contain effective extra nutrients essential for standard gut to function. Davis and Briggs (1947) used a pure source of cellulose and added to the entire diet. The addition of cellulose increases the expansion rate up to 15. Although, the precise reason for the increasing growth obtained by consuming cellulose wasn't clear. It had been assumed that hydrolysis of cellulose within the alimentary canal may have contributed to a marginal extent as a growth stimulant aside from simply source of glucose derived from breakdown of cellulose (Davis and Briggs, 1947). Enzymes and other metabolites of microbiological source may become the cause of the increasing growth. In fact, a good range of good microorganisms with the ability to metabolize the cellulose inside the gut and therefore the decaying of the products derived from cellulose breakdown may act as growth stimulant towards the cattle growth.

In different study, rations containing screened sawdust didn't physically injure the gastrointestinal lining nor exhibit any toxic effects. one-fourth sawdust was found to be the foremost desirable level for roughage substitution; higher levels occasionally induced impaction of digestion. Voluntary regulation of feed intake at A level comparable Morrison's recommendation for feeding beef calves was accomplished with feeds containing 35% sawdust. Addition of sawdust up to fifteen to the rabbit diets had no detrimental effect on growth (Radwan, 1994). Similarly, incorporation of sawdust up to fifteen didn't affect feed intake. However, because the level exceeded, intake decreased gradually thanks to poor palatability of the diet. Similar results were obtained by other investigators. In another study, addition of sawdust up to eight g/100 didn't exhibit any lethal effect. Despite many advantages, Sibbald et al. (1960) reported a big decrease in apparent digestible nitrogen thanks to incorporation of increased dietary fibre. The abrasive nature of fibre and greater volume of digesta could have caused a rise in metabolic nitrogen excretion (Hegde et al., 1978). The change in protein utilisation due to dietary fibre treatments may have caused changes in carcass composition. a rise in abdominal fat pad thickness related to high fibre diets of equal energy content was found in laboratory trial.

Birds usually plan to satisfy energy demand from voluntary intake. Therefore, increased feed consumption is typically related to increased dietary fibre

Dietary fibre adversely affects rate of growth and food conversion of birds (Abdelsamie, 1983). Similarly, high dietary fibre derived from sawdust resulted increased relative length and weight of intestine and length of caeca (Abdelsamie, 1983; Savory and delicate, 1976). However, this is often not very clear, whether fibre naturally available in foodstuffs would exert similar effects while they're in sawdust. In another study, equal concentrations of cellulose and sawdust had markedly different effects on the gut (Savory and delicate, 1976)

2.3 THE POTENTIAL OF SAWDUST

Sawdust is a useful material in energy, manufacturing, and agriculture industries. Sawdust does possess the characteristics like wood but in particles form with some structural properties had been altered. It can be utilized as source of energy due to the heating value compared to other fuels. Sawdust has very low thermal conductivity and can be used as an insulate to reduce the heat loss through conductor. The materials can produce briquettes (compress block of coal) with density above 100kgm-3 and the bulk density of sawdust could be between 150 – 200kgm-3. The increasing costs, crisis, and depletion of energy from conventional sources over the past few years before the development of alternative sources of energy. The world's energy requirements were gasses, running water and nuclear energy. The specific energy content of the sawdust and charcoal are 16795.96kj/kg, charcoal 18711.70kj/kg respectively. It can be converted into bitumen or heavy oil due to the presence of cellulose during the processing with water, sodium carbonate and gas enriched with carbon oxide (CO) with the temperature of 250°C - 400°C. The sawdust can be used as an insulating material inside the refrigerating system and cold conservation.

The sawdust also can be used in the manufacturing industry with the application of modern technology that specialist in pulp and paper making, particle boards with several benefits such as availability of high-quality product. Several structural materials and employment opportunities for the populace to mention. Sawdust can be marketed foe the use in molded or laminated composite wood products (e.g., toilet seats, countertops) in automotive materials and oil water isolation for environmental control industry. Currently, a primary usage of baled dry shavings is for equine and livestock bedding or small pet bedding applications. This mainly takes a form of aromatic material from eastern red cedar, soft ponderosa pine and chlorophyll pine that was prepared based on the specific pets such as dogs, cats gerbils and hamsters.

Next, the sawdust can be used as an important factor for the agricultural industry in making fertilizer called sawdust compost and food for chicken brooders. The burned sawdust can be used as a mulch, growers for small fruits. It also an increasing usage of sawdust as litter for barns and feed lots and soil conditioner in general agriculture. The usage of sawdust has been largely be on a trial-and-error basis that usually with good results but under certain conditions, sawdust can cause a deficiency of available of nitrogen inside the soils and retard the grow of plant. Certain woods contain tannins and other extractives that have toxic influences on plants and soil microorganisms. It is well known that mulches be low cost, readily available

2.4 FERMENTATION PROCESS

Fermentation is a metabolic process that produces occur by converting carbohydrates into energy during the absence of oxygen through the action of enzymes. Fermentation is the primary means of producing adenosine triphosphate (ATP) for microorganisms by degradation of organic nutrients during anaerobic activity. Yeast is a form of fungus that can occurs in almost any environment and capable of supporting microbes from the skins of the fruits and was used to convert (break down) sugar rich molecules into ethanol and carbon dioxide. Yeast plays an essential role in the production of methane in habitats that ranging from the rumens of cattle to the sewage digesters and freshwater sediments. They produce carbon dioxide, formate and acetate and carboxylic acids.

Fermentation process starts with the reaction of NADH with an organic electron acceptor. Pyruvate are formed from sugar that was been through glycolysis process. The reaction produces NAD+ and organic products that usually being ethanol, lactic acid and hydrogen gas and carbon dioxide gas. However, more exotic materials can be produced during fermentation such as butyric acid and acetone and all fermentation products are considered as waster products because they cannot be metabolized further without the use of oxygen. Fermentation normally occurs in anaerobic environments. With the presence of oxygen, NADH and pyruvate are used to generate ATP during respiration. This process is called oxidative phosphorylation.

This process generates more ATP than glycolysis process. This process releases the chemical energy of O2. Fermentation process rarely used O2 but some strains of yeast such as Saccharomyces cerevisiae prefer fermentation during the aerobic respiration as long as there was abundant supply of glucose. This phenomenon was known as the Crabtree effect. Some fermentation processes involve obligate anaerobes which means that they cannot tolerate the presences of oxygen. The Yeast was used to carry out the fermentation during the production of ethanol in beers, wines, and other alcoholic drinks.

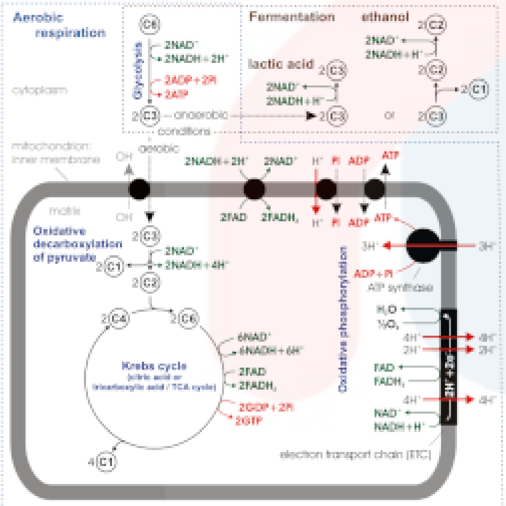


Figure 1.0 The cellular respiration during the fermentation process

2.5 WHITE FUNGI

White Fungi/ Yeast are a eukaryotic, singled cell microorganism that are classified as the member of the fungus kingdom that mainly in water, soil, air and plant and fruits surfaces. They directly intervene in the decomposition of ripe fruit and participate in the fermentation process. Yeasts carried out metabolism and fermentation activity because they need necessary nutrients and substrate to survive in the natural environment. Yeast are the unicellular organisms that evolved from multicellular ancestors with some of species that having the ability to develop multicellular characteristics by forming strings of connected budding cells that known as pseudohyphae or false hyphae. The diameter of the yeast is vary depending on the species and environment that the yeast was exposed. They usually between 3 – 4 µm in diameter and some can grow into 40µm in size. Most Yeast reproduce asexually by mitosis and asymmetric division to become budding. The yeast species such as Saccharomyces cerevisiae converts carbohydrate into CO2 and alcohols through fermentation process. Yeast also was used for baking and the production of penicillin. Yeast also was used during the baking of flour to create baking goods such as bread, cake, muffin etc. The yeast can be contrasted with molds which grow hyphae. The Fungal species that can take both forms depending on the temperature and other conditions are called dimorphic fungi. Yeasts do not have a single taxonomic or phylogenetic grouping. The term yeast usually used as a synonym towards Saccharomyces cerevisiae. Saccharomyces cerevisiae usually used during the winemaking, baking, and brewing since the ancient times. It is the microorganisms that commonly used for fermentation process.

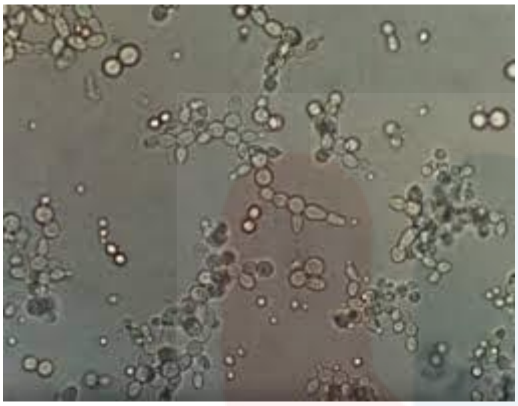


Figure 1.1 show the cell of white fungi under the microscope

CHAPTER 3 MATERIALS AND METHOD

3.1 MATERIALS AND EQUIPMENT

The equipment that was used during the experiment are the texture analyzer. Other items that were used are a dozen of 1000cm^3 containers, a dozen of 750cm^3 containers, 3 kg raw sawdust, 500g white fungus (yeast) and 1L measuring cup. The sawdust was collected locally from the wood cutting company at Pasir Mas, Kelantan.

3.2 THE PROCEDURE FOR TEXTURE ANALYSIS OF SAWDUST.

The sawdust was used for the fermentation of sawdust by using yeast and 150 ml of water inside a container with the volume of 1000mm3. The plastic container is marked based on the variable that were applied towards the fermentation process of sawdust. The variables that are include inside the experiment based on moisture of the sawdust, the size of the container, the presence of oxygen and the different temperature impacting the fermentation process of sawdust. The container is marked as S1, S2, T1, T2, M1, M2, O1 and O2. The texture analysis was executed with different variable based on moisture, volume, the presence of oxygen and temperature. The sawdust was weighted, and the yeast was scatter inside the container evenly. The water was measured inside the plastic measuring jug. The volume of water that normally be used are 150ml because. The fermentation take place for 2 weeks and the texture analysis for all containers need to measure every day for 14 days.

The results of the hardness of fermented sawdust were recorded based on their variable measure. The initial hardness for the sawdust was measured on Day 0. The hardness of every container was recorded into the table below. Based on the table below, we can construct graph hardness x time taken for fermentation process. After that, we can analyze the graph on the different variables on sawdust hardness.

Before the 1st day of the experiment, the sawdust without any addition of yeast or original sawdust was prepared to become the origin hardness of sawdust without the influence of yeast. After the origin sawdust was prepared, the sample was analyzed by using the texture analyzer and the data was recorded as the origin hardness of sawdust without the presence of yeast.

3.3 MEASUREMENT OF DATA

The hardness of the sawdust was measured by using the texture analyzer. The texture analyzer is the measurement system that moves in either up or down direction to compress or stretch a sample. The texture analyzer can be used to measure the hardness, the distance and the which indicated the texture of the samples. After the sawdust was exposed with water, it hardens, and we can analyze the hardness of the sawdust. But we need to use the correct probes to analyzer the hardness of the sawdust. The probes that were choose are. The probes are used to measure the hardness and firmness of the sample. The sample was place on the stage of the texture analyzer. After placing the sample, ~~we analyzer~~ the hardness of the sample was analyzed by using the computer that connected to the texture analyzer.

The hardness of the sawdust was recorded. The traveling arm that was fitted with load was recorded as the force response of the pressure at the load cell. After the probe contact the sawdust, the probe will return to the origin point and repeat the descent the second time. The probe will return towards the origin position. After that, the data about the texture of the sawdust was displayed on the computer.

3.4 OBSERVATION OF YEAST GROWTH

Yeast can only growth under favorable environmental conditions and the spores in the white fungus germinate inside the container and form hyphae. The white fungus was used to convert the starch inside the sawdust into carbon dioxide and alcohol. During the fermentation process, the white fungus was spotted, and the growth of the fungus was calculated. The growth of the white fungus can be calculated by using the marked close lip for the container. The lip was marked by using marker and the gap of the square are 1cm x 1cm.Next, the growth of the white fungus was inspected by using the marked cover for the containers. The growth of the fungus was used to benchmark the hardness of the sawdust and the effect of different size, temperature, moisture, and the presence of oxygen towards the hardness of the sawdust.

3.5 STATISTICAL ANALYSIS.

The data of the study were expressed in mean ± standard deviation (SD). The results were obtained to differentiate the container size, temperature, moisture content and presence of oxygen towards the hardness of sawdust. The Standard deviation are rounded up to 3 decimal point. The significant difference between two means was compared using percentage difference of the hardness of sawdust based on the external variable (container size, temperature, moisture content and presence of oxygen) and the data was rounded into 2 decimal places. The formula for the calculation of mean and standard deviation are:

$$\bar{x} = \frac{\Sigma x}{N}$$

Figure 3.0 the formula for the Mean of the data

$$\sigma = \sqrt{\frac{(\sum x - \bar{x})^2}{N}}$$

Figure 3.1 The formula for Standard Deviation of the data.

$${}^{0}/_{0} = \frac{\bar{x}}{881} \times 100\%$$

Figure 3.2 The formula for the percentage on the reduction of hardness sawdust

CHAPTER 4 RESULTS AND DISCUSSION

4.1 THE RESULTS

The Table below show the hardness of sawdust based on the external variable (container size, temperature, moisture content and presence of oxygen) that was used during the experiment. The data was taken 3 times and the mean and standard deviation was calculated based on the formula on chapter 3.5.

DAYS	Hardness of sawdust in Container size 1, S1 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of hardness (%)
	1	2	3			
0	881.0	881.0	881.0	881	1017.291	100
1	800	798.5	801.5	800	923.760	90.81
2	780	782.3	781.1	781.13	901.975	88.66
3	683	684.2	682.8	683.33	789.045	77.56
4	552	554.3	551.7	552.67	638.165	62.73

5	478	482	476	478.67	552.717	54.33
6	289	285	283	285.67	329.860	32.43
7	184	182	185	183.67	212.080	20.85
8	179	176	182	179	206.691	20.32
9	176.8	176.4	176.8	176.67	203.997	20.05
10	175.6	175.8	175.2	175.53	202.688	19.92
11	174.8	174	174	174.27	201.226	19.78
12	172.8	172	172	172.27	198.916	19.55
13	168	170	170	169.33	195.529	19.22
14	168	168	168	168	193.990	19.07

Figure 4.0 The results on the hardness of sawdust on Container size 1(S1)

DAYS	Hardness of sawdust in Container size 1, S2 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of sawdust hardness (%)
	1	2	3			
0	881.0	881.0	881.0	881	1017.291	100
1	804	802	805.6	803.87	928.225	91.24
2	771	773	768	770.67	889.889	87.48
3	662	665	659	662	764.412	75.14
4	541	545	542	542.67	626.618	61.60
5	467	468	467	467.33	539.630	53.05
6	231	234	233	232.67	268.660	26.41
7	187	185	182	184.67	213.235	20.96
8	183	183	183	183	211.310	20.77
9	180.6	180	179.4	180	207.846	20.43
10	178.2	178	178	178.07	205.614	20.21
11	176.1	176	176	176.03	203.266	19.98
12	174.9	174	174	174.30	201.264	19.78
13	172.1	172	172	172.03	198.647	19.53
14	172.1	172	171.6	171.90	198.493	19.51

Figure 4.1 The results on the hardness of sawdust on Container size 2(S2)

DAYS	Hardness of sawdust in Temperature container 1, T1 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of sawdust hardness (%)
	1	2	3			
0	881.0	881.0	881.0	881	1017.291	100
1	791.2	791.4	792.2	791.6	914.061	89.85
2	707.2	706.9	707.3	707.13	816.527	80.26
3	664.1	664	665.1	664.4	767.183	75.41
4	572.5	572	571.9	572.13	660.643	64.94
5	456	456	454	455.33	525.774	51.68
6	381	380.4	382	381.13	440.095	43.26
7	254	255	253	254	293.294	28.83
8	178.4	178.1	176.9	177.8	205.306	20.18
9	121	121	121.8	121.27	140.027	13.76
10	121	121	121.6	121.2	139.950	13.75
11	121	121	121.4	121.13	139.873	13.74

12	121	121	120.8	120.93	139.6412	13.73
13	121	121	120.4	120.8	139.488	13.71
14	121	120.8	120.2	120.67	139.334	13.70

Figure 4.2 The results on the hardness of sawdust on Temperature 1(T1)

DAYS	Hardness of sawdust in Temperature of container 2, T2 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of sawdust hardness (%)
	1	2	3			
0	881.0	881.0	881.0	881	1017.291	100
1	800	799	803	800.67	924.530	90.88
2	778	776	778	777.33	897.587	88.23
3	700	703	701	701.33	809.83	79.61
4	640	643	645	642.67	742.088	72.95
5	581	583	582	582	672.036	66.06
6	514	514	516	514.67	594.286	58.42

7	445	446	443	444.67	513.457	50.47
8	306	307	307	306.67	354.108	34.81
9	275	278	278	277	319.852	31.44
10	209	208	205	207.33	239.408	23.53
11	184	186	186	185.33	214.005	21.04
12	176	178	176	176.67	203.997	20.05
13	143	143	146	144	166.277	16.35
14	143	143	143	143	165.122	16.23

Figure 4.3 The results on the hardness of sawdust on Temperature 2 (T2)

DAYS	Hardness of sawdust on moisture content, M1 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of sawdust hardness (%)
	1	2	3			
0	881.0	881.0	881.0	881	1017.291	100
1	768	770	766	768	886.810	87.17
2	664	668	660	664	766.721	75.37

3	592	590	594	592	683.582	67.20
4	504	500	506	503.33	581.199	57.13
5	406	402	400	402.67	464.959	45.71
6	302	304	307	304.33	351.414	34.54
7	235	232	231	232.67	268.660	26.41
8	175	175	178	176	203.227	19.98
9	155	159	158	157.33	181.673	17.89
10	126	127	124	125.67	145.107	14.26
11	118	116	112	115.33	133.176	13.09
12	106	108	104	106	122.398	12.03
13	102	104	102	102.67	118.549	11.65
14	102	102	102	102	117.760	11.58

Figure 4.4 The results on the hardness of sawdust on Moisture content 1 (M1)

DAYS	Hardness of sawdust on moisture content 2, M2 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of sawdust hardness (%)
	1	2	3			
0	881.0	881.0	881.0	881	1017.291	100
1	668	668	664	666.67	769.800	75.67
2	540	544	538	540.67	624.308	61.37
3	467	459	464	463.33	535.011	52.59
4	389	385	386	386.67	446.484	43.89
5	345	345	340	343.33	396.447	38.97
6	267	270	272	269.67	311.384	30.61
7	138	140	136	138	159.349	15.66
8	132	136	132	133.33	153.960	15.13
9	128	128	124	126.6	146.262	14.38
10	115	117	118	116.67	134.715	13.24
11	109	111	114	111.33	128.557	12.64
12	98	96	102	98.67	113.931	11.20
13	97.5	97.5	98.6	97.87	113.006	11.11

14	97.5	97	97.3	97.27	112.314	11.04

Figure 4.5The results on the hardness of sawdust on Moisture content 2 (M2)

DAYS		Hardness of sawdust on presence of Oxygen 1, O1 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of sawdust hardness (%)
		1	2	3			
0		881.0	881.0	881.0	881	1017.291	100
1		805	803	802	803.33	927.6094	91.18
2		771	776	775	774	893.7382	87.85
3		668	662	664	664.67	767.491	75.44
4		572.5	572.5	572	572.33	660.874	64.96
5		479	480	477	478.67	552.717	54.33
6		401	405	400	402	464.190	45.63
7		342	346	340	342.67	395.677	38.90
8		265	267	264	265.33	306.381	30.12
9		168	167	165	166.67	192.450	18.92
10		132	134	132	132.67	153.190	15.06

11		105	105	102	104	120.089	11.80
12		98	99.7	98.3	98.67	113.931	11.20
13		87	90	87	88	101.614	9.99
14		87	87	87	87	100.458	9.88

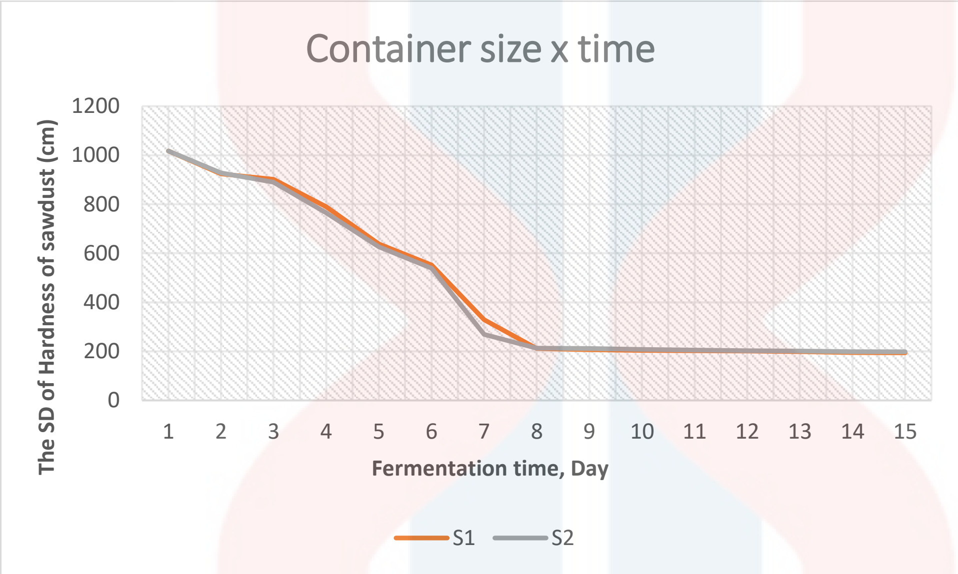
Figure 4.6 The results on the hardness of sawdust on Presence of Oxygen 1 (O1)

DAYS	Hardness of sawdust on presence of Oxygen 2, O2 (cm)			Mean, (cm)	Standard deviation SD, (cm)	The reduction of sawdust hardness (%)
	1	2	3			
0	881.0	881.0	881.0	881	1017.291	100
1	800	798	804	666.67	924.530	90.88
2	665	667	664	540.67	768.261	75.52
3	504	506	502	463.33	581.969	57.21
4	443	442	445	386.6	511.917	50.32
5	378	380	382	343.33	438.786	43.13
6	332	334	336	269.67	385.67	37.91
7	278	278	274	138	319.467	31.40

8	201	200	203	133.33	232.480	22.85
9	182	184	186	126.67	212.465	20.89
10	138	136	132	116.67	156.270	15.36
11	132	134	130	111.33	152.421	14.98
12	124	122	126	98.67	143.183	14.07
13	109	110	111	97.87	127.017	12.49
14	109	108	109	97.27	125.478	12.33

Figure 4.7 The results on the hardness of sawdust on Presence of Oxygen 2 (O2)

4.2 THE EFFECT OF DIFFERENT SIZE ON THE FERMENTATION OF SAWDUST



S1= The SD on hardness of sawdust on Container Size 1

S2= The SD on hardness of sawdust on Container Size 2

Figure 4.8 show the hardness of sawdust on different Container size.

Based on the figure above, the initial hardness of the sawdust was 881.0 cm. The fermentation of the sawdust was incubated for 14 days with the different variable on size of the container, moisture, temperature, and the presence of oxygen. As different of container size was tested, the graph shows they were a significant different towards the hardness of the sawdust based on the different size of container. The S1 container is a plastic container with the volume of 1000cm^3 meanwhile the S2 container is a plastic container with the volume of 750cm^3. During the first week of the project, the average hardness of the sawdust on S1 are 800cm on the first day and ended with 183.67cm on the seventh day meanwhile, the average hardness of sawdust is 803.87 cm on the first day and ended with 184.67 cm on the seventh day. During the first week, there were a significant reduction of hardness on the sawdust towards the sample but the reduction on the S2 sample is lower than S1 sample. During the first day of the experiment, the hardness of sawdust on the S1 sample are reduce by 9.2 % meanwhile the hardness of sawdust on S2 sample are reduce by 8.76%. After that, the hardness of sawdust on S1 sample was reduced by 11.34 % on the 2nd day compared to the original hardness. The hardness of sawdust was rapidly decrease during the 3rd and 4th day for 22.44 % and 37.27% respectively compared to the original hardness of sawdust before the influence of yeast. After a week, the rate of reduction of sawdust started to slow down on the 7th day for 79.15% compared the original hardness of sawdust. After the 7th day, the rate of reduction is less than 1% per day compared to the big reduction on the first week.

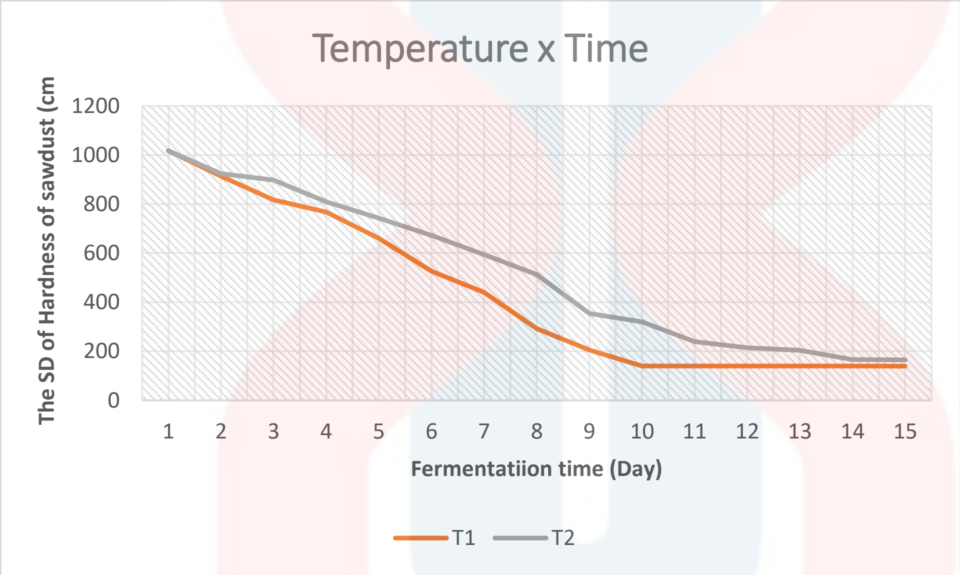
The hardness of sawdust on the S2 sample on the 2nd day are reduce by 12.52 % compared to the original hardness of sawdust. The hardness of sawdust was rapidly decrease during the 3rd and 4th day for 24.86 % and 38.4 % compared to the original hardness before the influence of yeast. After a week, the rate of reduction on the hardness of sawdust started to slow down on the 7th day for 79.04% compared to original hardness of sawdust. After the 7th day, the rate of reduction is less than 1% per day compared to the big leap on the reduction of hardness on sawdust on the first week. On the 1st day of the fermentation process of the sawdust, the hardness of S1 and S2 are the same due to the fermentation process does not start yet. After 2nd day, the hardness of sawdust on the S1 are lower than the sawdust in S2 due to the volume of oxygen that was left inside the container.

Fermentation processes occur due to the anerobic respiration of yeast to produce ATP, CO_2, and alcohol. The cellulase inside the sawdust was breakdown into glucose by hydrolysis process. Next, glucose was breakdown into pyruvate during the glycolysis process. During the Fermentation process, The NADH was used to convert the glucose into pyruvate and ATP energy for metabolic activity. Next, pyruvate inside the sawdust was oxidized into lactic acid, alcohol, and CO_2.

Glucose + 2 NAD+ + 2ADP + 2Pi ------> 2 Pyruvate + 2 NADH + 2 H+ +2ATP +$2H_20$

Figure 4.9 show the glycolysis process of glucose during fermentation

4.3 THE EFFECT OF DIFFERENT TEMPERATURE TOWARDS THE FERMENTATION OF SAWDUST.



T1= The SD on hardness of sawdust on Temperature 1 (±27℃)

T2= The SD on hardness of sawdust on Temperature 2 (±5℃)

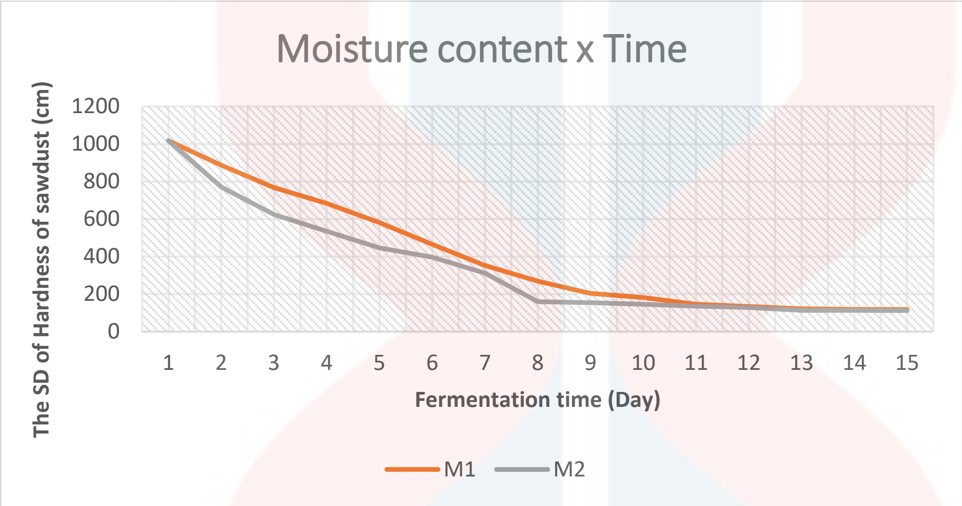
Figure 4.10 show the SD on hardness of sawdust on different temperature

Based on the graph above, the initial hardness of the sawdust was 881.0 cm. The fermentation of the sawdust was incubated for 14 days with the different variable on size of the container, moisture, temperature, and the presence of oxygen. The different on the temperature during the fermentation of sawdust was tested, The T1 container was stored on cabinet in the room temperature meanwhile T2 sample was store inside the chiller that was set at 5°C. During the 1st day of the experiment, the average hardness of the sawdust on T1 are 791.6cm and ended with 254cm on the 7th day meanwhile the average hardness of sawdust on T2 sample are 800.67cm on the 1st day and ended with 444.67cm on the 7th day. During the first week, there were a significant reduction of hardness on the sawdust towards the sample but the reduction on the T1 sample is lower than T2 sample. During the 1st day of the experiment, the hardness of the sawdust on the S1 sample are reduced by 10.15 % compared to the original hardness of sawdust before fermentation process After that, the hardness of sawdust on T1 sample was reduced by 19.74% compared to the original hardness of sawdust. The hardness of sawdust was reduced rapidly during the 3rd and 4th day for 24.59 % and 35.06% respectively. After the 9th day the rate of reduction started to slow down for 86.24 % compared to the original hardness of sawdust. After the 9th day, the rate of reduction of the hardness on sawdust is less than 1% per day compared to other big reduction during the first week.

The hardness of sawdust on the T2 sample on the 1st day are reduced by 9.12% compared to the original hardness of sawdust. After that, the hardness of sawdust on T2 was further reduced by 11.77% compared to the original hardness. The hardness of sawdust was reduced rapidly during the 6th and 8th day for 41.58 % and 65.19% respectively. After the 8th day, the reduction of the hardness on sawdust started to slow down and the rate of reduction is less than 1% per day compared to the big reduction on the 6th and 8th day. Based on the graph, the T1 container have a lower hardness compared to the T2 container. This result can be contributing due to the different temperature towards the growth of the yeast in the sawdust. Yeast needs an optimum temperature to maturely growth within the sawdust compound. Low temperature can stunt the growth of the white fungus on the wet sawdust.

The optimum temperature for the growth of yeast during fermentation process are between 32℃- 35℃. The T2 container was placed inside the chiller with the average temperature of 5℃. The low temperature also reduces the metabolic activity of the yeast. It also decreases the production of ATP on the anaerobic respiration process. Low temperature can kill the yeast cells if they were exposed for longer duration. The low temperature reduce the cycle time and decrease the metabolic production inside the container.

4.4 THE EFFECT OF DIFFERENT MOISTURE TOWARDS THE FERMENTATION OF SAWDUST



M1= The SD hardness of sawdust on Moisture content 1(150ml water)

M2 = The SD hardness of sawdust on Moisture content 2(250ml water)

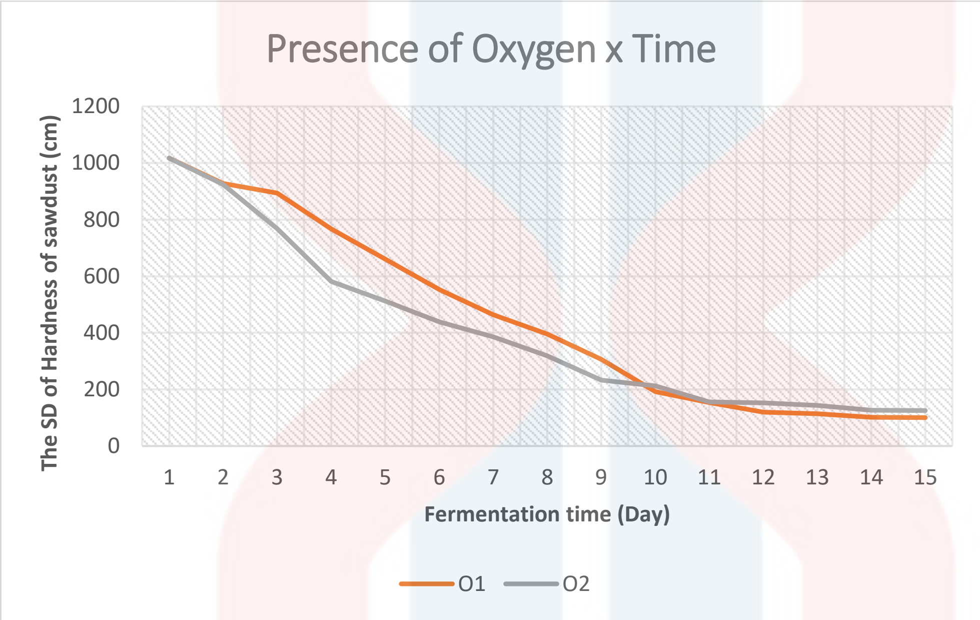
Figure 4.11 show the SD on hardness of sawdust on different moisture content.

Based on the figure above, the initial hardness of the sawdust was 881.0 cm. The fermentation of the sawdust was incubated for 14 days with the different variable on size of the container, moisture, temperature, and the presence of oxygen. The volume of water that was poured into the M1 container are 150ml of water meanwhile the volume of water in the M2 container are 250ml. During the 1^{st} day of the experiment, the average hardness of the sawdust on M1 are 768cm and ended with 231cm on the 7^{th} day meanwhile the average hardness of sawdust on M2 sample are 666.67cm on the 1st day and ended with 138cm on the 7th day. During the first week, there were a significant reduction of hardness on the sawdust towards the sample but the reduction on the M2 sample is lower than M1 sample. During the 1st day of the experiment, the hardness of the sawdust on the M1 sample are reduced by 12.83 % compared to the original hardness of sawdust before fermentation process After that, the hardness of sawdust on M1 sample on the 2nd day was reduced by 24.63 % compared to the original hardness of sawdust. The hardness of sawdust was reduced rapidly during the 4th for 42.87% compared to the original hardness. After the 8th day the rate of reduction started to slow down for 80.02 % compared to the original hardness of sawdust. After the 8th day, the rate of reduction of the hardness on sawdust is less than 3 % per day compared to other big reduction during the first week.

The hardness of sawdust on the M2 sample on the 1st day are reduced by 24.33% compared to the original hardness of sawdust. After that, the hardness of sawdust on M2 was further reduced by 39.63 % compared to the original hardness. The hardness of sawdust was reduced rapidly during the 6th for 84.34 % compared to the original hardness. After the 6th day, the reduction of the hardness on sawdust started to slow down and the rate of reduction is less than 1% per day compared to the big reduction on the 6th day. Based on the graph on the moisture of the sawdust before the fermentation process with the time taken during the fermentation process, there were a big gap on the decrease of hardness of sawdust on the M2 container compared to M1 container. It can be contributed towards the amounts of moisture that was exposed during the fermentation process of sawdust. During fermentation process, the moisture was used as a medium to convert the cellulose inside the sawdust into

CO_2, alcohol, and lactic acid. The increase of moisture can increase the growth of yeast. The moisture inside the fermented sawdust was used to convert water into the CO_2 and alcohol. In the M2 container, the production of alcohol and CO_2 gas was higher than M1 container due to the higher amount of moisture was used during fermentation of sawdust.

4.5 THE EFFECT OF THE PRESENCE OF OXYGEN ON THE FERMENTATION OF SAWDUST



O1= The SD hardness of sawdust on Presence of Oxygen 1 (close container)

O2= The SD hardness of sawdust on Presence of Oxygen 2 (open container)

Figure 4.12 show the SD on hardness of sawdust on presence of oxygen.

Based on the graph above, the initial hardness of the sawdust was 881.0 cm. The fermentation of the sawdust was incubated for 14 days with the different variable on size of the container, moisture, temperature, and the presence of oxygen. As different on the presence of oxygen was tested, the O1 container cover does not have small holes to maintain the volume of oxygen that was trap inside the container for the sample. The O2 container cover have a lot of small holes to increase the volume of oxygen that was trapped inside the container. During the 1st day of the experiment, the average hardness of the sawdust on O1 are 803.33cm and ended with 342.67cm on the 7th day meanwhile the average hardness of sawdust on O2 sample are 800.67cm on the 1st day and ended with 276.67cm on the 7th day. During the first week, there were a significant reduction of hardness on the sawdust towards the sample but the reduction on the O2 sample is lower than O1 sample. During the 1st day of the experiment, the hardness of the sawdust on the O1 sample are reduced by 8.82 % compared to the original hardness of sawdust before fermentation process After that, the hardness of sawdust on O1 sample was reduced by 12.15% compared to the original hardness of sawdust. The hardness of sawdust was reduced rapidly during the 9th day for 81.88% compared to the original hardness of sawdust. After the 10th day the rate of reduction started to slow down for 84.94 % compared to the original hardness of sawdust. After the 10th day, the rate of reduction of the hardness on sawdust is less than 3% per day compared to other big reduction during the first week.

The hardness of sawdust on the O2 sample on the 1st day are reduced by 9.12% compared to the original hardness of sawdust. After that, the hardness of sawdust on T2 was further reduced by 24.48% compared to the original hardness. The hardness of sawdust was reduced rapidly during the 3rd for 42.79%. After the 11th day, the reduction of the hardness on sawdust started to slow down and the rate of reduction is less than 1% per day compared to the big reduction on the 1st week. Based on the graph on the presence of oxygen inside the container with the duration of fermentation process of sawdust, the O1 container have lower value of force on the hardness of the sample during the 1st week of fermentation process compared to the O2 container. That can be contributed ~~towards~~ by the anaerobic reaction inside the container during the fermentation process of sawdust. The presence of excess oxygen can reduce the fermentation process rate. After 9^{th} day, the hardness of fermented sawdust on the O2 container was lower compared to the O1 container. This was happened due to the consumption of oxygen by the yeast cells had a positive influence on the fermentation kinetics and increase the cell biomass formation. The Oxygen consumption rates, and the total capacity of oxygen consumption based on the corresponding to the yeast lees that was decrease when oxygen was added during the fermentation. This marked decrease in yeast lees reactivity towards the oxygen was concomitantly related to the increase in ergosterol synthesis and oxygen dependent sterol degradation. Such degradation occurred due to the excess amount of oxygen was supplied during the fermentation process.

The excess amount of oxygen

CHAPTER 5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The hardness of the sawdust texture can be influenced by the presence of oxygen gas, the temperature of the container was stored, the amount of moisture that was used before the fermentation process of sawdust and the volume of the container that was used to hold the sample without exposing the sample towards other external change. The excess amount of moisture during the fermentation process contribute to the highest growth spurt of the yeast due to water was used as the medium to convert the carbohydrates into alcohol, CO_2 gas and lactic acid. The different size of container has the least gap value of the hardness of sawdust.

5.2 RECOMMENDATION

As the recommendation for future research, the study should be continued with sawdust of different species of tree. Different sawdust from different species of trees has a different value on the hardness during the fermentation process of sawdust. ~~The~~ Moreover, further research should be conducted towards the other factors that effecting the texture of the sawdust. Next, future research can use the project as the baseline on the fermentation process of sawdust. Lastly, more research and chemical trials are needed towards the usage and the effect of sawdust as animal feed towards future generations of farmers.

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APPENDIX

Appendix A: The equipment and materials were used for Fermentation of sawdust

Please label your appendix as Figure xx for each picture

Figure 7.0: The measuring cup that was used to measure the water before fermentation of sawdust

Figure 7.1: The Ragi/ yeast that was used for fermentation of sawdust

Figure 7.2 :The containers that were used to store the sawdust of different condition

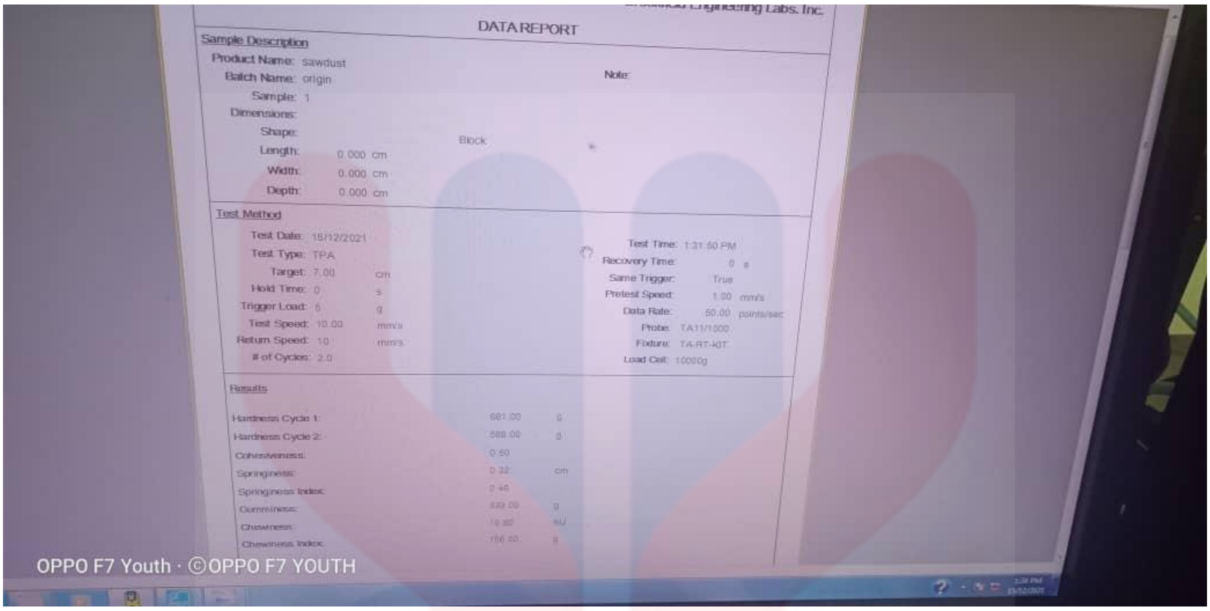
Figure 7.3: The sawdust that was used during the project

Figure 7.4: Brookfield CT3 Texture Analyzer for physical properties analysis.

Appendix B: The texture analysis value from Texture analyzer.

The growth of ragi/ white fungi on S1 Container

The growth of white Fungi/ Ragi in S2 container



The texture analysis of sawdust without Ragi/white fungi after the 2nd day.