



Bio-Conversion of Sweet Potato Peel Waste to Bio-Ethanol Using *Saccharomyces Cerevisiae*

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ABSTRACT

The bio-production of ethanol from sweet potato peel using microorganism was examined. Proximate analysis was carried out on the peel and the results from the analysis demonstrated that sweet potato peel contained sufficient amounts of starch and total carbohydrates to guarantee use for bio-ethanol production. To obtain maximum conversion of starch into fermentable sugars, sweet potato peel was hydrolysed by hydrochloric acid at different temperature and concentration. The effect of inoculum size, pH, temperature and time to obtain maximum ethanol from sweet potato peel waste were studied in batch fermentation. The maximum ethanol yield obtained was 6.39g/L at pH 5.0, temperature of 32.5°C and inoculums size of 6% (v/v) after 48 hours of fermentation. The results obtained showed that sweet potato peel which is a waste, can be a feedstock for bio-ethanol production.

Key Words: *Sweet Potato, Bio-Ethanol, Proximate Analysis, Hydrolysis, Fermentable Sugar.*

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INTRODUCTION

Over the years, there has been an increase in the demand for chemical energy as a result of the increase in the world's population. Nowadays, the demand of energy for transportation, heating, and industrial processing increases spontaneously, therefore environmental issues are a point of concern [1]. Also, the strict government regulations on exhaust emissions, increase in the prices of petroleum based fuels and future depletion of worldwide petroleum reserves encourages studies searching for alternative fuels [2-4]. Ethanol and methanol have been seen and considered as alternative fuels for diesel engines [5, 6]. However, over 30 billion barrels of oil are consumed annually, and this poses negative impacts on the environment. To sustain a healthy environment, likewise meeting the high strong need for energy and renewable energy sources have been employed as alternative sources.

Ethanol fermented from renewable sources for fuel or fuel additives are known as bio-ethanol [7]. Bio-ethanol is one

of the many renewable energy sources produced through a microbiological process called fermentation. During this process, simple sugars are converted by microorganisms to ethanol and carbon (IV) oxide [8], although ethanol can also be produced chemically by reacting ethylene with steam [9]. Ethanol is a principal fuel that can be used as petrol substitute for vehicles also as an additive that can oxygenate fuel mixture [10].

In many European countries, the use of bio-ethanol serves as an alternative to fuel or gasoline is up to 15% [11].

When blending ethanol with gasoline, the fuel mixture is oxygenated so that it burns more completely thereby reducing emission of unburned gas that causes environmental pollution. Brazil and USA are the major producers of bio-ethanol; they have produced 16.12 billion liters of ethanol since 2005 [12]. These countries either use bio-ethanol fuel directly or ethanol-blended fuel. Bio-ethanol also has other advantages such as: lower carbon (IV) oxide emission, lower dust emission, biodegradable. It is also the only liquid made from biomass that can be

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used as transportation fuels and does not cause greenhouse gas effect [9].

Saccharomyces cerevisiae are microorganisms that cannot be seen with the naked eye, they convert carbon sources (Sugar) to bio-ethanol during fermentation process, thereby meeting energy demand [13]. In the breweries, *Saccharomyces cerevisiae* is used in alcohol production and this occurs by converting sugar to energy. *Saccharomyces cerevisiae* is also used in the bakeries for raising dough. Other enzyme uses dextrin to make glucose especially during saccharification [14]. *Zymomonas mobilis* can also ferment but it is limited to glucose, fructose and sucrose [15]. Additionally, *Klebsiella oxytoca* and *Escherichia coli* are modified as ethanol producers [1].

Crops with starchy materials such as corn, rice, wheat, potato, cassava, yam, plantain and sorghum are the main carbon source for ethanol fermentation. The sugar which are fermented to obtain ethanol are obtained from these starchy crops. Potato requires very simple pretreatments compared to other starchy crops because it is rich in simple starch, complex carbohydrate, and sugar; therefore, it can be considered as a high value crop for ethanol fermentation. Waste vegetable oil and waste animal fats are mostly used because they are not food value added products [16-18].

Feed-stocks are typically grouped under the heading "biomass" and include municipal solid waste, wood, agricultural residues and energy crops [19, 20]. It is essential that feedstock accounts for about 20-50% of total production costs [10, 21].

The Potato processing industry generates lots of waste, one quarter of potato that goes into potato processing plant as input comes out as waste. These waste can be used as a carbon source for yeast during alcohol fermentation to produce bio-ethanol. In Minnesota, 400,000 tonnes of waste potato is produced per year and these wastes are sold out cheaply to farmers to feed pigs while some are left to rot instead of being used to produce ethanol. The potato peel waste contains sufficient amount of starch, hemicellulose, cellulose, lignin and fermentable sugars which make potato peel a suitable feedstock for ethanol production [22].



Fig. 1. Tubers of Sweet potato

Figure 1 shows the picture of potato tuber.

MATERIALS AND METHODS

Sweet potatoes were purchased from the open market.

Microorganism: *Saccharomyces cerevisiae* used for the fermentation of hydrolyzed sweet peel was prepared using [8].

Sweet potato peel: Samples of sweet potato peel were obtained by peeling 5kg of sweet potato. The peels were washed to remove soil and dirt. The edible part of the sweet potato and the peel were weighed separately. The washed peels were then dried.

PROXIMATE ANALYSIS

Determination of moisture content and dry matter

Moisture content was determined by oven drying at 105°C to a constant weight. After 16 hours, the peel was removed from the oven and allowed to cool in the desiccators for 30 minutes and then weighed, sample was returned to the oven for further drying. After one hour, the peel was removed from the oven, cooled in the desiccators and weighed again until a constant weight of dried potato sample was obtained. The peels were finally removed from the oven after constant dry weight was obtained.

W_1 = mass of dish

W_2 = mass of dish and sample

W_3 = mass of dish and cooled dried sample

$$\% \text{ moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (1)$$

$$\% \text{ dry matter} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad (2)$$

Determination of total ash and organic matter

Total ash was determined to obtain the amount of organic and minerals present in the peel of sweet potato. An empty crucible was weighed and 10g of dried milled sample of sweet potato peel was added to the crucible and weighed. The crucible with sample was taken to already heated furnace. The temperature of the furnace was gradually increased from 250°C to 450 °C after every 20 minutes to avoid incomplete ashing. After one hour of ashing, the crucible was removed from the furnace with a tong and put in desiccators for cooling. The crucible with the sample (now ash) was cooled for one hour and then weighed.

W_1 = mass of crucible

W_2 = mass of crucible and sample

W_3 = mass of crucible and cooled dried sample

$$\% \text{ Total ash} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad (3)$$

$$\% \text{ organic matter} = 100 - \% \text{ total ash} \quad (4)$$

Determination of fat

Fat free Muslin cloth was weighed (W_1). Enough samples were added into muslin cloth and weighed (W_2). Washed and pre-dried 500ml round bottom flask was weighed (W_3). Soxhlet extractor was used with the flask filled with petroleum ether up to two-third. The heat source was adjusted so that the solvent (petroleum ether) boils gently and left to siphon for 6 hours. The condenser was detached and muslin cloth removed. The petroleum ether was then distilled. The flask containing the fat residue was oven dried at 100°C for 5minutes. The flask was cooled in the desiccator and weighed (W_4). The muslin was placed in the oven at 50°C and dried until constant weight was obtained, then cooled, dried and weighed (W_5).

W_1 = mass of muslin cloth

W_2 = mass of muslin cloth and sample

W_3 = mass of round bottom flask

W_4 = mass of round bottom flask and fat residue

W_5 = mass of muslin cloth + beaker + dried sample

$$\% \text{ Fat} = \frac{W_4 - W_3}{W_2 - W_1} \times 100 \quad (5)$$

$$\% \text{ Fat} = \frac{W_2 - W_5}{W_2 - W_1} \times 100 \quad (6)$$

Determination of Reducing Sugars

The reducing sugars present in sweet potato peel, hydrolyzed peel, cellulose degraded sweet potato peel and fermented peels were determined.

2.5g of anhydrous sodium carbonate, 2g of sodium hydrogen carbonate, 2.5g of potassium sodium tartrate and 20g anhydrous sodium were weighed into 80ml water and made up to 100ml. 15g copper sulfate was added to a small volume of distilled water. A drop of sulphuric acid was added and made up to 100ml. Arsenomolybdate reagent was prepared by dissolving 2.5g of ammonium molybdate in 45ml water and 2.5ml of sulphuric acid was added. Then 0.3g of disodium hydrogen arsenate was dissolved in 25ml of distilled water, they were all mixed together and incubated at 37°C for 24 hours. Standard glucose solution was made by dissolving 1g of glucose in 100ml distilled. Working standard of 100µg/ml was prepared by adding 1ml of glucose solution to 100ml of water. 0.2, 0.4, 0.6, 0.8, 1.0ml of working standard was measured in to five well-labeled test tubes. 1 ml of water was measured into a test tube labeled "blank". 0.1g of each test sample was measured into three beakers. 100ml of distilled water was added to each beaker. 1 ml of the test samples was measured into four test tubes. Distilled water was added to the first five test tubes to make up 1ml in each of the test tubes. 1 ml of alkaline copper tartrate reagent to each of the test tubes and they were shaken for proper mixing. The test tubes were boiled for 10 minutes and cooled in water. 1ml of arsenomolybdate reagent was added to each of the test

tubes and the test tubes were shaken well. Then 7ml of distilled water was added to each of the test tubes to make up 10ml in each test tube. The spectrometer was put on and set to 620nm wavelength. The absorbance of the bluecolour in each of the samples was determined by the spectrometer. The graph of absorbance against concentration was plotted to obtain the amount of reducing sugar.

$$\% \text{ Reducing sugar} = \frac{\text{concentration of sugar in test sample}}{\text{absorbance of standard sample}} \times 100 \quad (7)$$

$$\text{Concentration of sugar} = \frac{\text{absorbance of test sample}}{\text{absorbance of standard sample}} \times 100 \quad (8)$$

Determination of total carbohydrate and starch

Anthrone reagent was prepared by adding 0.1g anthrone in 100ml of ice cold 95% H_2SO_4 . A working standard glucose solution was prepared by measuring 0.1ml of glucose into 100ml of distilled water. A stock solution was prepared by taking out 10ml of working standard glucose solution into 100ml of distilled water. 0.1g of the test samples was added to 100ml of distilled to make solution of each of the samples. 0.2, 0.4, 0.6, 0.8, and 1.0ml of working standard were measured into five well-labeled test tubes. 1 ml of water was measured into a test tube labeled "blank". 1 ml of the solution of sweet potato peel, hydrolyzed peel and cellulose degraded sweet potato peel were measured into three test tubes. Distilled water was added to the first five test tubes to make up 1ml in each of the test tubes. 4 ml of anthrone reagent to each of the test tubes and they were shaken for proper mixing. The test tubes were boiled for 8 minutes in water bath and cooled in water. The spectrometer was put on and set to 620nm wavelength. The absorbance of the green colour in each samples was determined by the spectrometer. The graph of absorbance of green colour in each test tube against concentration was plotted to obtain the amount of reducing sugar present in the test samples.

$$\frac{\text{Total carbohydrate of test sample}}{100\text{mg}} = \frac{\text{mg of glucose}}{\text{volume of test sample}} \times 100 \quad (9)$$

$$\text{Concentration of test sample} = \frac{\text{absorbance of test sample}}{\text{absorbance of standard}} \times 100 \quad (10)$$

$$\% \text{ Starch} = 0.9 \times \text{total carbohydrate} \quad (11)$$

Starch Hydrolysis

Hydrolysis is a process of breaking down amylopectin and amylose linkages into fermentable sugars which is needed

before fermentation of starchy materials. Starch hydrolysis can either be carried out with enzymes or with acids. Acid hydrolysis or chemical hydrolysis involves the use of acid to breakdown starch into fermentable sugars. The acid use for hydrolysis attacks $\alpha-1,4$ glycosidic bonds and breaks them to glucose unit. For this research work, hydrochloric acid was used to breakdown the samples into fermentable sugars.

Experimental run 1

40g of sample were weighed into five 250ml Erlenmeyer flasks labeled A, B, C, D and E with 5ml of 0.5% ammonium nitrate, 1ml of 0.1% peptone to each of the flasks. A volume of 120ml of hydrochloric acid 0.2M 0.5M 1.0M 2.0M respectively were measured and added to each of the flasks. Each of the mixtures in the flasks was sterilized in the autoclave at 121°C for 15 minutes and the flasks were allowed to cool.

Experimental run 2

40g of sample were weighed into three 250ml Erlenmeyer flasks with 5ml of 0.5% ammonium nitrate, 1ml of 0.1% peptone, and 120ml of hydrochloric acid 0.5M were measured and added to each of the flasks. Each of the mixture in the flasks was sterilized in the autoclave at 121°C for 15 minutes. During sterilization, the starch was broken down to fermentable sugars. The flasks were allowed to cool for 40 minutes, the amount of reducing sugar present in the hydrolyzed sample was determined and then the pH meter was used to correct to 4.15 with sodium hydroxide.

Experimental run 3

40g of sample was weighed into five 250ml Erlenmeyer flasks with 5ml of 0.5% ammonium nitrate, 1ml of 0.1% peptone, and 10ml of hydrochloric acid, 0.5M were measured and added to each of the flasks. Each of the mixture in the flasks was sterilized in the autoclave at 121°C for 15 minutes. The flasks were allowed to cool for 40 minutes. During sterilization, the starch was broken down to fermentable sugars and the amount present were examined.

Experimental run 4

40g of sample was weighed into five 250ml Erlenmeyer flasks with 5ml of 0.5% ammonium nitrate, 1ml of 0.1% peptone, and 120ml of hydrochloric acid 0.5M were measured and added to each of the flasks. Each of the mixture in the flasks was sterilized in the autoclave at 121°C for 15 minutes. The flasks were allowed to cool for 40 minutes. During sterilization, the starch was broken down to fermentable sugars, the amount present were examined. The pH of the hydrolysate was raised.

Experimental run 5

40g of sample was weighed into five 250ml Erlenmeyer flasks with 5ml of 0.5% ammonium nitrate, 1ml of 0.1% peptone, and 120ml of hydrochloric acid 0.5M were

measured and added to each of the flasks. Each of the mixture in the flasks was sterilized in the autoclave at 121°C for 15 minutes. The flasks were allowed to cool for 40 minutes. During sterilization, the starch was broken down to fermentable sugars and the amount present were examined. The pH of the hydrolysate was raised.

Ethanol fermentation of hydrolyzed Sweet Potato Peel

Each set of the starch hydrolysate was fermented with *Saccharomyces cerevisiae* and the hours of fermentation was varied for each sets. The starch hydrolysates obtained from acid hydrolysis were also subjected to fermentation by varying fermentation temperature, pH and inoculum size for 48 hours.

Experimental run 6

The starch hydrolysates from all other sets apart from experimental run 1 were fermented. *Saccharomyces cerevisiae* was harvested and added into each of the flasks. The conditions for fermentation were temperature at 32.5°C and pH 5.0. The inoculum was 6% (v/v) and fermentation was carried out for 0, 10, 24, 36, 72 hours. The fermented peel was tested to determine the amount of reducing sugars present the pH after fermentation peel was checked.

Experimental run 7

The starch hydrolysates obtained from experimental run 2 were transferred into another set of Erlenmeyer flasks. A 48-hour old cultures of *Saccharomyces cerevisiae* was harvested and added into each of the flasks. The flasks were covered and allowed to ferment at 32.5°C and pH 5.0 in Erlenmeyer flasks. The inoculum was 6% (v/v) and fermentation was carried out for 0, 10, 24, 48, 72 hours. The amount of reducing sugar present after fermentation was tested and the pH after fermentation was checked.

Experimental run 8

Saccharomyces cerevisiae was harvested and added into each of the flasks from experimental 3. The conditions for fermentation were temperature at 32.5°C and pH was varied. The inoculum was 6% (v/v) and fermentation was carried out for 48 hours.

Experimental run 9

Yeast was harvested and added into each of the flasks from experimental run 5. Fermentation temperature was varied and pH was kept at 5.0. The inoculum was 6% (v/v) and fermentation was carried out for 48 hours.

Experimental run 10

The starch hydrolysates from all other sets apart from sets experimental run 6 were fermented. *Saccharomyces cerevisiae* was harvested and added into each of the flasks. The conditions for fermentation were temperature at 32.5°C and pH 5.0. The inoculum volume was varied and fermentation was carried out for 48 hours.

Distillation

It is a liquid-liquid separation method. It is based on separating mixture based on differences in volatility of components (components to be separated) in a boiling liquid mixture. It is a physical separation method and does not involve chemical reaction. Distillation is also based on difference in boiling point. The mixture to be separated is added to a distilling pot where it is heated to the boiling point. Lower boiling components will preferentially vaporize first. This vapor passes into a distilling head and then into a condenser. Within the condenser, the vapor is cooled and it liquefies, the resulting liquid is then collected in a receiving flask. Initially, low boiling components are collected in the receiving flask. As the distillation proceeds, these components are depleted from the distilling pot and higher boiling components begin to distil over. Each of the samples from experimental run 7-12 was distilled and collected at 78°C and the volume of ethanol was measured with a measuring cylinder. The density of the produced ethanol was determined.

Determination of Quantity of Ethanol Produced

The distillate collected was measured using a measuring cylinder and expressed as in g/L by multiplying the volume of the distillate by the density of ethanol (789g/L).

RESULTS AND DISCUSSION

Compositional Analysis of Sweet potato

Table 1. Composition of sweet potato

Sweet potato	Weight (kg)	Percentage %
Sweet potato (before peeling)	5	-
Sweet potato (after peeling)	3.5	70
Losses due to peeling	1.5	30

Table 1 shows the composition of sweet potato before and after processing. Abrasion peeling was applied in peeling the sweet potato. 5kg of sweet potato was peeled and 1.5kg was the peel while 3.5kg was the flesh which means that 30% of the sweet potato was the peel while 70% was the flesh. 30% of the sweet potato was lost to peeling which confirms that losses caused by potato peeling range from 15% to 40% [23].

PROXIMATE ANALYSIS OF SWEET POTATO

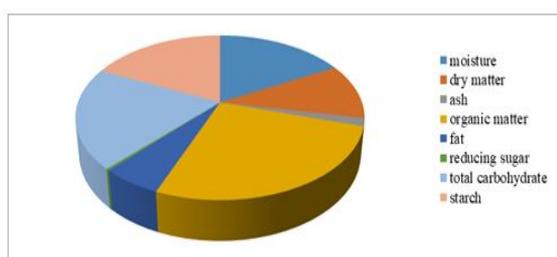


Fig. 2. Chemical composition of sweet potato peel

Figure 2 shows the chemical composition of sweet potato peel; organic matter has the largest percentage (94.4%) while reducing sugar has the least percentage (1.22%). The organic matter present in sweet potato peel shows that there is a lot of carbon element present in the peel due to presence of fat, carbohydrates, sugars and starch in the peel. The moisture content in the peel was 61.2% while dry matter of the peel was sweet potato as 3% to 4% and also reported that the ash content in sweet potato peel was higher than that of the flesh. The ash content of sweet potato peel was found to 5.6% which is higher than 4% which is the amount of ash content present in the flesh of sweet potato. The ash content shows that the sweet potato peels contain minerals. Minerals present in sweet potato peels include calcium, copper, magnesium, sodium, potassium, phosphorous, iron and zinc [24]. Total carbohydrate, starch and reducing sugars were found to be 71.1%, 64% and 1.22% respectively; this shows that sweet potato peel has a high amount of starch and total carbohydrate but very small amount of reducing sugars. Reducing sugars are monosaccharide like glucose, galactose, and maltose which are the fermentable sugars used for fermentation. The fermentable sugars which is the reducing sugar was as low as 1.22% and the starch is as high as 60% so for this reason it is not practical to ferment sweet potato peel because the yield of ethanol will be very small or there may be no yield of ethanol, since this is the case, the carbohydrate in the peels must be broken down to fermentable sugars for more ethanol to be produced. The carbohydrate in the peel was broken down into fermentable sugars by acid hydrolysis.

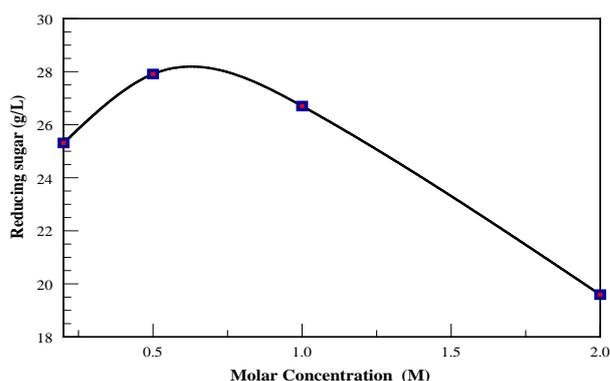


Fig. 3. The effect of acid concentration on reducing sugar after hydrolysis

Figure 3 shows the variation of acid concentration with reducing sugars after hydrolysis. The acid hydrolysis was carried out at 121°C. The graph shows that amount of fermentable sugar produced was increasing with acid concentration and then started reducing as the acid concentration increased. The reason for this variation is at higher temperature concentrated acid produced less sugar.

0.2M and 0.5M acid where able to produce higher amount of sugar because the amount of acid present in them was smaller compared to 1M and 2M. More concentrated acid will breakdown carbohydrates fermentable sugar at lower temperature instead of higher temperature, which implies that 1M and 2M hydrochloric acid produced less fermentable sugars at 121 °C than 0.5M and 0.2M hydrochloric acid because they are more concentrated. 0.5M yielded the highest amount of fermentable sugars for fermentation.

Table 2. Effect of acid concentration of Hcl on reducing sugars and pH after fermentation, reducing sugars consumed and ethanol yield

Molar concentration (M) of Hcl	Reducing sugars after acid hydrolysis (g ^L ⁻¹)	Reducing sugars after fermentation (g ^L ⁻¹)	pH after fermentation	Reducing sugars consumed (g ^L ⁻¹)	Yield Y _{p/s}
0.2	25.31	6.53	3.25	18.78	0.260
0.5	27.91	6.94	3.36	20.79	0.310
1.0	26.70	6.94	3.91	19.76	0.283
2.0	19.59	6.53	3.92	13.06	0.294

Table 2 shows that the reducing sugars left after fermentation is not dependent on the concentration of the acid used but dependent of how much sugar was consumed by the microorganism (yeast) during fermentation and also the conditions at which fermentation took place. The concentration of acid only determines the amount of reducing sugars released for fermentation but not the amount of reducing sugars left after fermentation. The amount of reducing sugars left fermentation determines the amount of sugar consumed and thus the amount of ethanol produced. If the conditions for fermentation are not favorable, the fermentable sugars available for fermentation will not be consumed irrespective of the amount fermentable sugar available for fermentation.

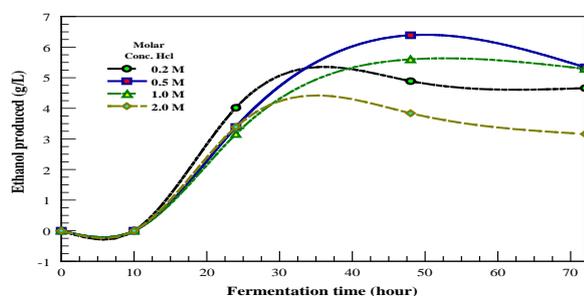


Fig. 4. The effect of fermentation time on ethanol production

Figure 4 display the variation of ethanol produced with fermentation time for different acid concentration. Ethanol

fermentation was carried out at 32.5°C, pH of 5 for 0, 10, 24 48, and 72 hours. It can be seen that the maximum yield of ethanol was produced at 48 hours for all the concentration of acid. The yield of ethanol was increasing with time for 0.2M, 0.5M, 1.0M and 2.0M but after it 48 hours the yield of ethanol began to decline. For this experiment batch fermentation was employed, so the yeast used in fermenting the peels underwent four phases which are the lag, log, stationary and death phase. During fermentation, the yeast cell divides when they grow thereby increasing the biomass (ethanol) and the more the sugar is consumed the more the amount of ethanol. The lag phase was between the hours of 0 to 10. Between 0 to 10 hours, the yeast adapted to the new system (flask) and began to grow but its growth was not significant. Between the hours of 10 and 48, the yeast cell began to consume nutrients in the medium and multiply, at this phase the growth was so fast and exponential. The faster the growth of the yeast cell the rapid the production of ethanol, so as the yeast was growing, it multiplied and feed (consumed) more fermentation and produced more ethanol and at 48 hours the growth stopped and became stagnant. Between 48 and 53 hours the yeast cell growth became stagnant and after 53 hours the yeast cell growth began to decrease and the amount of ethanol decreased. The amount of ethanol produced after 53 hours decreased because the ethanol produced was converted into metabolic products thereby displacing the amount of ethanol produced. The graph shows that 0.5M hydrochloric acid yielded the maximum ethanol at 48 hours because hydrolysate of 0.5M hydrochloric acid produced the highest amount of fermentable sugars for ethanol production, so the higher the amount of fermentable available for fermentation, the higher the amount of ethanol produced if only the conditions necessary for fermentation are met.

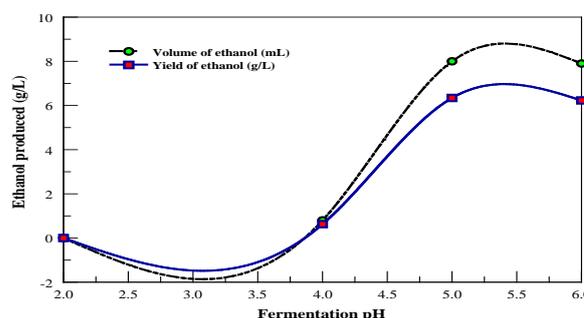


Fig. 5. The effect of pH on ethanol production

Figure 5 displays the variation of ethanol yield with pH during 48-hour fermentation of sweet potato peel with 0.5M hydrochloric acid. The effect of fermentation pH on ethanol production was studied in batch fermentation by keeping the temperature at 32.5°C and the inoculum size at 6% (v/v) and the fermentation hour was 48 hours. It can be

seen that there was no ethanol produced from pH of 0 to 3.9 and ethanol started to increase from pH 4.0 to 5.0 and then decreased. The maximum ethanol yield was at pH 5.0 as 6.39g/L. The yeast cell could not grow in acidic medium thereby not being able to consume fermentable sugar and produce ethanol. The yeast cell grew on a mildly acidic system and slightly alkaline system. In a more acidic alkaline the system, yeast cell will cease to grow.

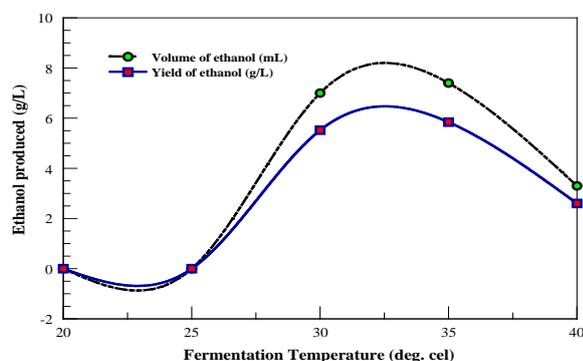


Fig. 6. The effect of temperature on ethanol production

Figure 6 shows the variation of ethanol yield with fermentation temperature during 48-hour fermentation of sweet potato peel with 0.5M hydrochloric acid. The effect of fermentation temperature on ethanol production was studied in batch fermentation by keeping the pH at 5 and the inoculum size at 6% (v/v) and the fermentation hour was 48 hours. The temperature was varied between 20°C to 40°C. There was no yield between 20°C to 24°C. The ethanol started to yields at 25°C until it reached 32.5°C where maximum ethanol was produced then the yield of ethanol started to decline. Increasing the temperature reduces ethanol yield and can denature the yeast cells at high temperature [25, 26]. It can be seen that yeast cells cannot grow at extremely low temperature and at very high temperature. The maximum yield of ethanol (6.39 g/L) was at 32.5°C.

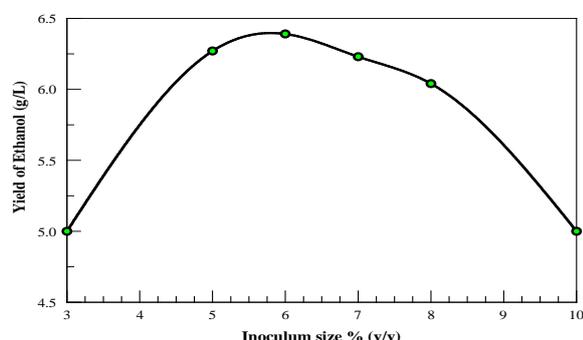


Fig. 7. The effect of inoculum size on ethanol production

Figure 7 shows the effect inoculums size on ethanol production. The inoculums size was varied between 5%

and 10% while the temperature was kept at 32.5 °C and the pH was kept 5 for 48 hours. From the graph in figure 4.6, it can be seen that ethanol yield increased with inoculum size until it reached 6% (v/v) where maximum yield of ethanol was obtained and then started to decline. Inoculums size was increased by adding more yeast cell to the fermentation flask (reactor). When more yeast cell was added to the flask, the yeast cells grew very fast and multiplied which resulted in the rapid yield of ethanol. When more yeast cell was added, most of the substrate (fermentable sugars) were consumed and immediately converted to ethanol. At 6% (v/v), maximum yield of ethanol was reached and when the inoculums size was further increased, the yield of ethanol began to decrease because the yeast cells stopped growing due to many yeast cells in one system (reactor) competing for a limited amount of nutrients in one system, hence the yeast cells could not multiply and yield ethanol because of insufficient nutrients in the reactor.

CONCLUSIONS

It is very evident from the results obtained that temperature, inoculums size, time and pH affects bio-ethanol production. The hydrolysates fermented by *Saccharomyces cerevisiae*, without removing the lignin yielded 6.39g/L of ethanol and the percentage product yield (Y_p/s) 0.31 (31%) was obtained, so it can be concluded that sweet potato peel is an attractive feedstock for bio-ethanol production especially in countries where sweet potato is produced in millions of tonnes per year. The results obtained shows that maximum ethanol yield was obtained at temperature 32.5°C, pH 5.0, and inoculums size of 6% (v/v) after 48 hours of fermentation. Sweet potato peel which is considered a non valuable waste could be efficiently utilized for ethanol production.

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Conflict of Interest

The authors declare no conflict of interest

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