5th International Conference of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Virtually from Québec City, Canada – May 11-14, 2021

DEVELOPMENT OF BIOETHANOL PRODUCTION PROCESS USING YOUNG COCONUT HUSK EXTRACTS AS FEEDSTOCK

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CSBE21793

ABSTRACT The growing consumption of young coconut has resulted in an increased generation of by-products such as husks and shells that are dumped in bulk and left in the open field as waste. The young coconut husk extract has an initial sugar concentration of 7 ^{0}Bx and available moisture of 30 % extracted per 1000 gram of husk. The process of producing bioethanol from young coconut husks includes decorticating, extracting, boiling/concentrating, fermenting, and distilling. The different processes involved were accompanied by design, fabrication, and evaluation of machines. The young coconut husks decorticator was evaluated having a capacity and efficiency of 100.95 kg.hr^{-1} and 90.53 %, respectively. Young coconut husks juice extractor has a capacity, extraction rate, and juice recovery of 145.67 kg.hr^{-1}, 44 L.hr^{-1}, and 30 %, respectively. Saccharomyces cerevisiae was used in the fermentation process. The extraction of coconut extracts from the husks by mechanical pressing, without undergoing destructive methods such as boiling or addition of acids, will preserve the quality of coconut fiber that can be used for the development of other value-added products like ropes. The study revealed that to produce one liter of bioethanol, an equivalent of 64 kilograms of young coconut husks at 16 ^{0}Bx was needed. It entails a large amount of feedstock to produce a liter of bioethanol but considering the dilemma in fossil fuel and greenhouse gas emissions, a feedstock that does not compete with food production, renewable, and available all year round can contribute to the production of bioethanol and waste reduction.

Keywords: bioethanol, young coconut husk extracts, fermentation, renewable

INTRODUCTION The growing demand for bioethanol as a clean energy source drives researcher to determine the potential feedstocks that will sustain the needed energy. The abundance of the feedstock whole year-round, does not compete in the area for food production, can be classified as sugar-based, starch-based and lignocellulosic biomass are the key factors considered in the selection of biomass as feedstock for bioethanol production. The biomass sources identified that will aid the continuing demand of bioethanol production in the Philippines includes sugarcane, sweet sorghum, cassava, rice straw, corn stover, and macroalgae (Gatdula et al., 2021). Several studies derived the bioethanol from corn residue (Manyuchi et al., 2018), sugarcane molasses (Raharja et al., 2019), sugarbeet (Salazar-Ordóñez et al., 2013), coconut husk fiber (Cabral et al., 2016);(Vaithanomsat et al., 2011), etc. Coconut husk is a lignocellulosic residue and had the potential of high bioethanol productivity derived through simultaneous saccharification and fermentation process (Vaithanomsat et al., 2011).

In this study, the young coconut husk that is considered as waste after the coconut meat has been removed for consumption was used as feedstock for the production of bioethanol. Coconut is considered an economic crop in the Philippines with an estimated volume of production of 14.8 million metric tons (Sanchez, 2020). The coconut utilization depends upon its maturity at which matured coconut was typically used for copra production and young coconut can be used for food production. The young coconut that is consumed in the market and food processing facility produced waste products including husks and shells. Unlike other processing facility, the normal process for extracting the meat and juice of the coconut was done through splitting. The coconut shell was normally attached to the husk and upon removal of juice and meat, it is dumped in landfills. Several projects and studies have already proven that coconut husk particularly coconut fiber and coconut dust can be processed to produce ropes, coir boards, fuel, blocks, insulating materials, etc. Moreover, the young coconut husk still has a high moisture content which takes too long to dry if left in an open field and produces a foul odor during decomposition.

The process for the production of bioethanol is dependent on the feedstock used. Sugar-based feedstock like sugarcane molasses can undergo immediate fermentation and distillation process satisfying the needed parameters like pH, agitation time, and temperature (Nassereldeen et al., 2012). Starch-based feedstock like corn undergoes the conversion of starch into fermentable sugars followed by fermentation and distillation (Mohanty and Swain, 2019). The bioethanol production process for lignocellulosic biomass is more complex which includes pretreatment, enzymatic hydrolysis, fermentation, and distillation (Zafar, 2021). The development of advanced technologies and processes and economical ways for bioethanol production showed a promising sustainable energy source.

This study aimed to use the extracts derived from young coconut husks. Along the extraction process, the moisture in the husk was significantly reduced resulting to a shorter drying time. The by-products like coir fiber and dust can still be used for the development of value-added products because it does not undergo any addition of chemicals that disrupt the fiber composition.

MATERIALS AND METHODS

Sample Collection The young coconut husk samples were collected from the coconut processors in Bataan, Philippines. The samples were collected immediately after the removal of coconut juice and meat. Typically, young coconut processors cut the coconut at the top to obtain the juice then cut it in halves to remove the meat. The survey conducted to the coconut vendor and processors showed that the husks and shells were collected on a daily or weekly basis and dumped in landfills.

Size Reduction The collected husks cannot be immediately processed for juice extraction because it is hard and compact. The design of a coconut decorticator for decorticating young coconut husks into coir fibers and dust was made in the study. The young coconut that was cut into halves was fed in the hopper consecutively. The machine is consists of the following components: (a) inlet hopper, where the young coconut is fed into the decorticating cylinder; (b) the decorticating cylinder where the young coconut was beaten up by the blades and hammers to reduce the size and to produce quality fibers; (c) the discharge chute, where the fibers and dust are discharged; and (d) the transmission assembly, where the prime mover is an 8 hp diesel engine running at a speed of 1000 rpm to 1200 rpm connected in a belt and pulley. The machine capacity and machine efficiency were determined following equation 1 and equation 2, respectively.

$$Machine\ capacity, kg.hr^{-1} = \frac{Intial\ weight,kg}{operating\ time,hour} \quad (1)$$

$$Machine\ efficiency, \% = \frac{Output\ weight + retained\ materials}{unshredded\ materials} \quad (2)$$

Juice Extraction The coconut fiber and dust which contain high moisture was loaded into the juice extractor at 9 to 10 kilograms per batch. The juice extractor used a floor jack as a pressing mechanism for extraction. The input weight, output weight, operating time, and volume of extracts were recorded and the data was used to compute for the machine capacity, extraction rate and juice recovery, and computed using equations 1 3, and 4, respectively. The fine particles like coconut dust that blended in the extracts were filtered and deducted to the actual weight of the juice collected.

$$Extraction\ rate, L.hour^{-1} = \frac{Volume\ of\ extracts,L}{operating\ time,hour} \quad (3)$$

$$Juice\ recovery, \% = \frac{Volume\ of\ extracts,\ kg}{Weight\ of\ young\ coconut\ husks\ ,kg}\ x\ 100 \quad (4)$$

Fermentation and Distillation The sugar concentration of the extracts collected was determined using a handheld refractometer. The fermentation process was done in a twenty-liter capacity container at which 75 % of its volume was filled with the fermentation broth and the 25 % served as space for the buildup of carbon dioxide. The initial sugar concentration of the extracts identified was 7 ^{0}Bx at which it is subjected to a boiling process to reach the target sugar concentration of 16 ^{0}Bx. Saccharomyces cerevisiae or also known as baker's yeast at 1.50 grams per liter was used to facilitate the conversion of sugar into bioethanol and carbon dioxide. The amount of yeast used is 0.5 % higher compared to the 1 % (w/v) used in the bioethanol production from sugarcane molasses using a commercial baker's yeast by (Jayus et al., 2016). The yeast was activated before pouring in the container then thoroughly mixed within three minutes following the anaerobic fermentation. The container was sealed allowing only the escape of carbon dioxide via a small opening that was connected to a tube dip into water that prevents the entry of oxygen. The initial sugar concentration (^{0}Bx), final sugar concentration (^{0}Bx), and the fermentation time (hours) were recorded to determine the theoretical ethanol yield and computed using equation 3. After the fermentation, the fermented broth was distilled using a locally made batch type ten liters capacity distiller. The distiller was composed of (a) reflux kettle, which serves as a container for the fermented broth; (b) 4 columns with 3/8-inch diameter, where it was attached at the top of the reflux kettle serving as passageway for the bioethanol in a vapor state, (c) coil type condenser, wherein the bioethanol in the vapor state is condensed. Water was used as a cooling medium. The use of batch-type distiller is economical for small-scale bioethanol producers (Coelho et al., 2012). A cookstove using LPG as fuel was used in the distillation process. The designed distiller aimed to produce 95 % bioethanol. The following parameters were observed during the distillation process: operating time (hours), and actual ethanol yield. Equation 5 and 6 was used to compute the theoretical ethanol yield and ethanol conversion efficiency.

$$Theoretical\ ethanol\ yield, mL = \frac{0.511\ x\ Initial\ sugar\ content}{0.789\ x\ Volume\ of\ fermented\ broth\ (mL)} \tag{5}$$

$$Ethanol\ conversion\ efficiency, \% = \frac{Actual\ ethanol\ yield, mL}{Theoretical\ ethanol\ yield, mL} \tag{6}$$

RESULTS AND DISCUSSIONS The machinery and methods developed in this study target the coconut producers at the farmer's level. It aimed to recover value-added products from the waste material and provide knowledge to the farmers that the husks can be used to produce quality products like bioethanol as fuel, coconut fiber as rope, and coconut dust as boards and others. The processes involved in the production of bioethanol from young coconut husks extracts include decorticating, extracting, boiling, fermenting, and distilling.

Performance characteristics of the machines Table 1 showed the performance characteristics of the machines used in the production of bioethanol. The decorticator has a capacity of 100.95 kg/hour and an efficiency of 90.53 %. The performance of the decorticator is comparable to existing decorticating machines; however, the machine was designed to be compatible with the target production per day and can handle the high moisture content of the sample product. The machine can also be utilized for other purposes such as shredding other biomass materials which will make it profitable for the farmers. The juice extractor has a capacity of 145.67 kg/hour, an extraction rate of 44 L/hour, and juice recovery of 30%. It can be noticed that the extractor capacity is higher compared to the decorticating capacity. The higher machine capacity of the juice extractor was intended to reduce the time of extraction compared to the decorticating time. The juice recovery reached 36.11 % however, it can be reduced to 30 % since some of the fine particles were not filtered and noticed to be present in the extracts. The initial sugar concentration of the extracts is 7 ^{0}Bx and it was subjected to boiling to reach a 16 ^{0}Bx. Higher sugar concentration was not used in the production because it will reduce the volume of fermentation broth, more energy is required which will make the production process uneconomical. The fermentation broth has an initial sugar concentration of 16 ^{0}Bx and a final sugar concentration of 13.50 ^{0}Bx. The computed ethanol conversion efficiency was 84.42 % which is lower compared to the study of (Vaithanomsat et al., 2011). Lower conversion efficiency was due to the low sugar concentration of the fermentation broth, higher water content, and low efficiency of the designed distiller due to the accumulated heat causing an increase in the temperature required for distillation.

Table 1. Summary of the data collected from the production of bioethanol using young coconut extracts as feedstock.

Machine/device	Performance parameters	Value
1. Young coconut decorticator	1.1 Machine capacity	100.95 kg/ hour
	1.2 Machine efficiency	90.53 %
2. Young coconut juice extractor	2.1 Machine capacity	145.67 kg/hour
	2.2 Extraction rate	44 L/hour
	2.3 Juice recovery	30 %
3. Fermenter	3.1 Theoretical ethanol yield	1036.25 mL
	3.2. Initial sugar concentration	16 ^{0}Bx
	3.3 Final sugar concentration	13.50 ^{0}Bx
4. Distiller	4.1 Actual ethanol yield	874.84 mL
	4.2 Ethanol conversion efficiency	84.42 %

Actual bioethanol yield The result of the study indicates that 64 kilograms of husk are needed to produce one liter of bioethanol using the extracts derived from the husk of the young coconut. A low volume of ethanol was produced corresponding to approximately 16 L of bioethanol per ton of young coconut husk. The estimated cost of bioethanol produced from young coconut husk extract as feedstock was Php 204 per liter. It can be noted that the production of bioethanol using the said feedstock is straightforward and does not undergo the optimal process of extraction like typical lignocellulosic biomass. A higher volume of bioethanol can be extracted employing various technologies and methods available for treating lignocellulosic biomass as feedstock for bioethanol production.

CONCLUSION The study revealed that young coconut husks extracts can be potentially used as feedstock for bioethanol production. However, the feasibility and efficiency of the production process can be further improved by optimizing the extraction process and further used of techniques for lignocellulosic biomass to use the sugar present in the fiber. The study proved that bioethanol can be produced from the husks extracts and by products such as coconut fiber and dust is available for further use. The drying time required for drying the fiber was reduced and a whiter product can be achieved for the development of value-added products such as ropes and other valuable items.

Acknowledgment. The authors are thankful to the Research and Development Office (RDO) of Bataan Peninsula State University for funding the study.

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APPENDIX A

Figure 1. Coconut samples

Figure 2. Decorticating machine

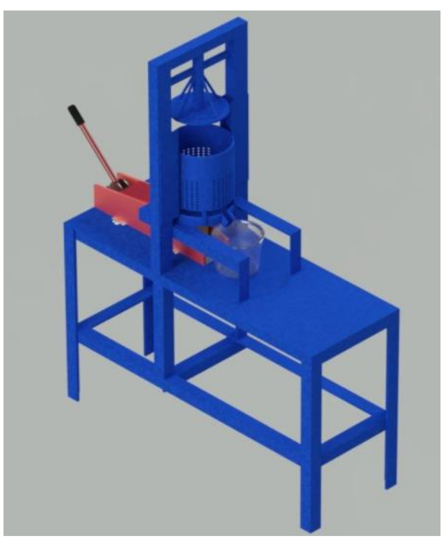

Figure 3. Juice extractor

Figure 4. Ten liters capacity distiller

Figure 5. Coconut fiber after juice extraction