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BIOETHANOL PRODUCTION FROM AGRICULTURAL PRODUCTS AND FRUITS OF BANGLADESH

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ABSTRACT: Bangladesh is an energy deficient country. Petroleum is the main energy source of Bangladesh imported from the Middle East spending a huge amount of foreign currency. However, the sub-tropical climate of Bangladesh is favorable for the cultivation of different agricultural products and fruits. This research was carried out to find out the potentiality of bioethanol production from different agricultural products and fruits of Bangladesh. In 100 gm of agri-products (boiled) and fruits (ripen), 300 ml of distilled water was added and blended and then sterilized. Alpha-amylase enzyme (1750 unit) was added to degrade the starch into simple sugar compound. For alcoholic fermentation, 200 ml yeast (Sacc*haromyces cerevisiae* CCD) was added to make the total volume of 500 ml and incubated at 31ºC for 6-days. From the fermentation of agri-products (potato, sweet potato, corn, pumpkin and carrot), the highest bioethanol production was observed in sweet potato. The bioethanol production capacity of four fruits (orange, banana, papaya and sapota) was also assessed. A high yield of bioethanol was found from a local variety of banana called Sagorkola (*Musa sapientum* L.). The purity of bioethanol in single distillation for banana and sweet potato was 40% and 35%, respectively. This research proved that Bangladesh has a good prospect of bioethanol production from banana and sweet potato.

Keywords: Bioethanol, Agricultural products, Fruits and Fermentation

1. INTRODUCTION

Fossil fuels are the major energy sources in the world. For rapid consumption of fossil fuels, its reserve will be finished in near future. On the other hand, fossil fuel has resulted in global warming and climate change. Therefore, there is thrust towards replacing fossil fuels with cleaner and renewable fuels such as bioethanol and biodiesel.

Bioethanol is considered to be the most optimistic biofuel. Ethanol fermented from renewable sources for fuel or fuel additives is known as bioethanol. It is most often used as a motor fuel, mainly as a fuel additive for gasoline. Bioethanol, unlike petroleum, is a form of renewable energy source that can be produced from agricultural feedstocks [1]. The first generation of ethanol production used corn as a substrate, later corn was considered as a feedstock lead to the second generation of production of ethanol which used microorganisms and different wastes as a substrate [2]. Bioethanol can be made from common crops such as sugarcane, potato and corn [3]. There are two primary technologies to make bioethanol fuel on an industrial scale. The first option, in wide use today, is to convert the starchy part of foods such as corn into bioethanol through seven steps: starch extraction, liquefaction, saccharification, fermentation, distillation, dehydration and denaturing. When sugarcane is used, only four or five steps are required: milling, pressing, fermentation and distillation; and dehydration only in the case of alcohol blends. Although bioethanol has the advantage of being derived from renewable sources it is also not environmentally sustainable, especially regarding greenhouse gas emissions [4].

At present, countries like Brazil and the USA are the world's largest producer of bioethanol, with approximately 62% of world production [5]. The major feedstocks used by these countries are sugarcane and corn. In Europe, ethanol production is based on beet molasses and it is still very sharp due to lack of available feedstocks that can support local ethanol production plants [6].

Development of ethanol in Brazil has been running 30 yr with from sugar cane as raw material and in the United States the development of ethanol from corn. Germany used wheat starch and corn fiber as renewable alternative energy sources, while Canada successfully in cultivating grass as an alternative energy source. Indonesia has developed the process production of ethanol from cassava and molasses [7].

Ethanol production worldwide in 2011 reached 23.4 billion gallons, where 80% of that produced by fermentation [8]. The worldwide production capacity of ethanol in 2005 and 2006 was about 45.42 and 49 billion liters per year, respectively. In 2011, all over the world bioethanol production is increased to 85 billion liters [9]. The total projected demand in 2015 is over 115 billion liters [10].

Bioethanol has a great advantage over conventional fuels. It has a higher octane rating and it is safer to use. Air quality will improve for its clean and proper burning quality. There are national policies for blending 20-30% ethanol in gasoline in different countries by 2030, accessed on September 15, 2016. However, the availability of ethanol at the desired scales is still a challenge. In fact, petroleum crude oil is consumed at much larger scales of 95 million barrels/day in the world. National policies are being framed to replace the use of oil with renewable biofuels such as biodiesel and bioethanol. However, production of these fuels from crops such as wheat, corn, rice, sugarcane etc. at such larger scale would be another challenge because of the availability of feedstock at that much scales. The cheapest and easily available source for the production of bioethanol is fruit wastes. It is a potential energy source, from which ethanol can be obtained. Fruit waste which is thrown away has very good antimicrobial and antioxidant potential. Out of the global food waste, 40-50% arises from fruits, root crops and vegetables. In Asia, fruits and vegetable wastes alone account for 37% of the total agricultural waste. Every year, there is a loss of about 35-40% of fruits and vegetables as wastes. Even after consumption, fruit storage and industrial processing plenty of fruit waste are generated and its management is also a problem. Bioethanol production from fruits and vegetable wastes may be a good option. Fruit wastes are rich in cellulose and hemicellulose and have low lignin contents. This makes these wastes interesting for bioethanol production [11].

The rapid increase of population and exponential growth on industrialization load on fossil fuel resources and the resources are being depleted very fast. Therefore, it is required to discover alternative cheaper sources of fuel for the fulfillment of worldwide demand. The main task is to develop easier techniques by using cheaper source for the production of bioethanol so that the common people can also produce it by themselves. At present, sugar and starch-based raw materials and cereal grains are used for the production of bioethanol. In Bangladesh, a population already reached about 160 million and thus food security is a national priority and hence Bangladesh cannot afford to use cereal grains for ethanol production as is commonly done in other biofuel promoting countries in Europe and USA. Waste is an inheritable consequence of the food industry [12]. So, the available sources are some selected agro-products and rotten fruit wastes which is an abundant and renewable source of energy-rich carbohydrates & sugars which can be efficiently converted by microbes into biofuels.

Bangladesh is amongst rapidly expanding large economy and fulfillment the energy demand of the growing population has become the most challenging sector for Bangladesh. Bangladesh needs to generate more energy than the current output. Bangladesh has shown good economic growth, rapid urbanization and industrialization in recent years. As a result, the numbers of bus, truck, taxi and auto-rickshaws have been increasing day by day. These high numbers of automobiles are consuming a huge amount of fuel oil (diesel, petrol and octane) every day. Bangladesh imports most of the oil from the Middle East by spending valuable foreign currencies. The huge spend on oil import has created tremendous pressure on Bangladesh’s annual budget. However, Bangladesh can easily reduce its oil import with the production of renewable fuel like bioethanol from sugarcane, corn, potato and sweet potato. At the current level of production and consumption, it seems to be a highly difficult target to meet. Thus, it is a good option for countries like Bangladesh to invest into renewable energy sector.

Bangladesh is an agricultural country and produces many agricultural products every year. For huge production and the prevailing cold storage charge is too high, all farmers can not avail the facility of cold storages due to their financial insolvency. As a result, farmers are compelled to sell a major portion of their produce during harvest time relatively at lower prices. The price becomes very low during peak harvesting period while it becomes too high before planting period.

In this research work, we used some selected agricultural products that are unmarketable, small in size, bruised, cut or damaged otherwise from the harvesting process, supplied by a local farmer. The cost of the bioethanol production would be much lower if we use waste agricultural products that are left in the field due to physical damage during harvesting and the highly perishable rotten fruits and vegetables, which are low cost and easily available. For this purpose agri-product and fruit, wastes were taken as a substrate for the ethanol production with the use of yeast *Saccharomyces cerevisiae* [13].

The main objective of this study was to determine the bioethanol production efficiency of different agri-products (potato, sweet potato, corn, pumpkin and carrot) and ripen fruits (banana, papaya, orange and sapota) of Bangladesh.

2. MATERIALS AND METHODS

2.1 Raw Material Collection

The agri-products (potato, sweet potato, corn, pumpkin and carrot) and fruits (orange, banana, papaya and sapota) were collected from the local market of Rajshahi city, Bangladesh.

2.2 Yeast Strain and Culture Media

Yeast strain (*Saccharomyces cerevisiae* CCD) was collected from the Spirit Section of Carew and Co., Darsana, Bangladesh. For yeast culture, modified YMPD (Yeast-Malt-Peptone-Dextrose) broth culture media was used. The YMPD media was prepared with yeast extract (3.0 g), malt extract (3.0 g), peptone (5.0 g) and dextrose (10.0 g). All of these ingredients were dissolved in 1000 ml of water and adjusted to pH 6.0.

2.3 Bioethanol Production of from Different Agri-Products

About 100g of agri-products (potato, sweet potato, corn, pumpkin and carrot) was boiled blended in 300 ml distilled water. About 1750 unit of α-amylase enzyme and 200 ml of 2-days old yeast were added to each treatment and adjusted to pH 6.0, and incubated at 31˚C for 6-days. After the incubation period, the turbidity of the solution and produced ethanol were measured.

2.4 Bioethanol Production from Different Ripen Fruits

Different ripen fruits like banana, orange, papaya and sofeda pulps were extracted by blending with blender machine. The fruits fresh or blanched were mashed. Then it was used as raw materials for bioethanol production. For optimum bioethanol production 200 ml of 2-days old yeast was added in 300 ml fruit pulp solution (20%), adjusted to pH 6.0, and incubated at 31˚C. After 6 days of fermentation, the crude fermented fruit solution was first centrifuged at 12,000 rpm to remove the unused starch and yeast cell. Then, the clear solution was taken into the rotary evaporator for separation of ethanol at 78.5˚C for five minutes.

2.5 Estimation of Total Sugar before and after Fermentation

Total sugar content was determined by the sugar measurement machine named "On Call Plus". Sugar concentration before and after fermentation was measured.

2.6 Distillation Process

Distillation was carried out using a distillation apparatus (Witeg, Germany). Heating of fermented materials was carried out at 78.5°C.

2.7 Measurement of Purity of Produced Alcohol

The percent of purity of produced bioethanol from agri-products and fruits was measured by using an alcohol meter (Jiujingnongduji, China). This meter can measure alcohol purity from 0-100%.

3. RESULTS AND DISCUSSION

3.1 Production of Bioethanol from Different Agri-Products

Bioethanol production from five different agri-products (potato, sweet potato, corn, pumpkin, carrot) were assessed. The sugar content in sweet potato was 13.96 mmol/L, which is higher than other four agri-products (Table 1).

Table 1 Sugar concentration in agri-products

Name of Agri-products	Sugar concentration before fermentation (mmol/L)	Sugar concentration after fermentation (mmol/L))
Potato	8.63	6.63
Sweet Potato	13.96	4.97
Corn	8.23	5.33
Pumpkin	6.47	5.46
Carrot	8.96	7.46

Sweet potato produces a large amount of bioethanol (95 ml) with 35 % (v/v) purity and after fermentation, the sugar concentration was reduced to 4.97 mmol/L from 13.96 mmol/L. The lowest amount of bioethanol was produced from the pumpkin with a purity of 6% (Table 2).

Table 2 Bioethanol production from different agri-products

Name of Agri-products	Volume after fermentation (ml)	Volume after distillation (ml)	Purity % (v/v)
Potato	465	67	18
Sweet Potato	487	95	35
Corn	449	82	15
Pumpkin	466	64	6
Carrot	459	70	10

Ethanol production from spoiled starch-rich vegetables by sequential batch fermentation was studied by Satish [14] and Kumar *et al.* [15] using sweet potato as raw material for the production of ethanol and the production was only 0.15%. This vast variation may due to the larger amounts of fermentable sugars are present in agri-products. The maximum yield of ethanol 5.2% was obtained from the red potato variety in Nepal [16].

The present study obtained 15% ethanol from corn which is higher than the study of Buratti *et al.* [4] which reported 10% alcohol from the fermented mash of corn. They observed that a plant produces 7300 liters of bioethanol from 160 ton of corn grain; therefore bioethanol yield is equal to 0.46 liter/kg of corn grain. Removal of water from ethanol is the main challenge for bioethanol production from corn and other agricultural products. Burrati et al. [4] described a method for making anhydrous ethanol from 10% raw bioethanol of corn. For removal of water, fermented mash is pumped through a multi-column distillation system where the alcohol is removed from the solids and water. The alcohol leaves the top of the final column at about 96% strength and residue mash, called stillage, is transferred from the base of the column to the co-product processing area, where is centrifuged and evaporated to obtain animal feed and condensate, that is recycled in the steeping phase. The alcohol again passes through a dehydration system, with zeolite molecular sieves, where the remaining water is removed. The alcohol at this stage is called anhydrous (pure, without water) ethanol and is about 99.3% strength. Finally, ethanol used for fuel is denatured with a small amount (5%) of gasoline to make it unfit for human consumption. However, due to lack of facility, the present study could not produce the anhydrous ethanol from studied agricultural products.

3.2 Bioethanol Production from Different Ripen Fruits

The study of bioethanol production from ripening fruits like orange, banana, papaya and sapota has not been done widely, so the present investigation was carried out for the production of ethanol with these ripen fruits. Productions of bioethanol from four different ripen fruit pulps (orange, banana, papaya, sapota) were assessed during this study. Sugar content in banana (27.53 mmol/L) was higher than other three fruits (Table 3) and it produces a large amount (95 ml) of bioethanol with 40 % (v/v) purity and after fermentation, sugar concentration is reduced to 13.33 mmol/L from 27.53 mmol/L. The lowest amount of ethanol was produced from sapota, 53 ml with purity of 17% (v/v) (Table 4).

Table 3 Sugar concentration in ripen fruits

Name of Agri-products	Sugar concentration before fermentation (mmol/L)	Sugar concentration after fermentation (mmol/L))
Orange	18.30	14.46
Banana	27.53	13.33
Papaya	14.80	9.93
Sapota	12.97	10.30

Table 4 Bioethanol production from different ripen fruits

Name of Fruits	Volume after fermentation (ml)	Volume after distillation (ml)	Purity % (v/v)
Orange	479	83	35
Banana	496	95	40
Papaya	461	65	25
Sapota	435	53	17

These results are quite similar to some studies of banana waste [17]. The amount of produced ethanol in the present study is higher compare to the studies of Kumar *et al.* [15] and Hossain *et al.* [18].

3.3 Bioethanol Production from Different Varieties of Banana

The bioethanol production from four different varieties of banana (sagor, sabri, champa and bitchikola) was assessed. It was found that the sugar content in sagorkola (27.9 mmol/L) is higher than other three varieties of banana (Table 5) and it produces a large amount (97 ml) of bioethanol with 40% (v/v) purity and after fermentation the amount of total sugar was reduced to 13.8 mmol/L from 27.9 mmol/L (Table 6). The lowest amount (81 ml) of ethanol was produced from bitchikola with a purity of 20% (Table 6).

According to Hossain *et al.* [18], 900g of rotten banana with 35% distilled water adding 3g/L yeast and adjusted pH at 5.8 was incubated at 35ºC for 3 days and found the bioethanol purity only 7.1% (v/v).

Janani *et al.* [19] observed the rate of ethanol production through fermentation of apple, grapes, papaya and banana waste by *Saccharomyces cerevisiae* at pH 5.4 and temperature 30ºC, bioethanol and observed the yields 4.73%, 6.21%, 4.19% and 5.4%, respectively.

Table 5 Sugar concentration in different varieties of banana

Banana Varieties	Sugar concentration before fermentation (mmol/L)	Sugar concentration after fermentation (mmol/L))
Sagor	27.9	13.8
Sabri	21.5	11.0
Champa	23.9	12.5
Bichikola	16.5	10.4

Table 6 Bioethanol production from different varieties of banana

Banana Varieties	Volume after fermentation (ml)	Volume after distillation (ml)	Purity % (v/v)
Sagor	493	97	40
Sabri	486	87	30
Champa	460	83	35
Bichikola	445	81	20

Kumoro *et al.* [20] used jackfruit juice and the ethanol production was 12.13%. Ethanol yield in fruit pulps varied significantly between the fruit samples and the highest yield was 35.86% in the mixed fruit pulps sample, followed by 28.45% in banana pulp and the lowest yield was 26.5% in mango pulp. The fermentation of enzymatic hydrolysis of acid pretreated mixed fruit pulps (banana and mango) by yeast showed an incubation period of 48 hr as optimum for maximum ethanol of 35.86% corresponding to a fermentation efficiency of 70.33%. In peels samples, the maximum yield was 13.84% in banana and 9.68% in mango at 42 h of incubation. The results of present ethanol yield are similar to the observations of Sirkar *et al.* [21] in the case of banana. This observation is consistent with the report of Akin-Osanaiye *et al.* [22], which indicated that the amount of yeast influenced ethanol production in agro wastes. The current observations are in good agreement with similar results reported by Pramanik and Rao [23] for grape waste.

4. CONCLUSIONS

From this study we conclude that sweet potato and banana are the good and cheaper sources for bioethanol production. These sources can be used for small and large scale production of bioethanol because sweet potato and banana are available everywhere in Bangladesh.

The production of ethanol from the agri-products and fruits can be improved further by using genetically engineered yeast strains that are capable of converting multiple sugars into ethanol, and using of high-grade distillation process is required for the preparation of anhydrous bioethanol to be used as fuel in vehicle.

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