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Bio-Ethanol Production Via the Fermentation of Selected Fruits, A Good Perspective in Renewable Energy

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Abstract

There is an urgent serious need to further curb global warming, considering its ongoing catastrophic effects. One way to do this is to use greener/fuels such as bioethanol, to eventually substitute fossil fuels. Bio-ethanol is a cleaner burning fuel, than fossil fuel and will pump less carbon dioxide into the atmosphere. It is one form of renewable energy sources. Bio-ethanol can be obtained via the fermentation of sugar rich sources, such as fruits or the acid hydrolysis of lignocellulosic material, followed by subsequent fermentation of the hydrolyzates. We have explored, the use of fruit pulp and peel as our ethanol feedstock, over the years, with the aid of the bio-catalyst that promote fermentation, Sacchromyces cerivisae. The % yield of ethanol was found to range from from 2 to 25.11%. The latter was obtained via the fermentation of mango, Mangifera indica L) and was reported to be the highest % yield of bioethanol, produced in the literature. We have also gone a step further, in investigating the use of additives such as ZnSO4, urea, ammonium phosphate, promalt, yeastex, ammonium tartrate solution. ZnSO4 was found to be the most effective in augmenting the % yield of bioethanol. This paper surveys our endeavors over the years in the production of green bioethanol from the pulp and peel of fruits. Greener fuels are the way forward for the environmental survival of our planet.

Keywords: Global warming; Catastrophic effects; Bioethanol; Fossil fuels; Fruit and fruit peels

Introduction

With a view to decrease dependence on fossil fuel, as a result of depletion, increasing global fuel price, increasing population and increasing global warming, there has been increased interest in the use of renewable energy sources of which bioethanol is one 1,2,3. Bioethanol (b.p: 78.5 °C) can be used for a variety of purposes, of which blending with gasoline to produce gas alcohol to power automobiles is of current utilization [1-5]. In addition, ethanol is a clean burning renewable energy source [6]. Ethanol is also an important component of alcoholic beverages such as wine, beer, cider, vodka, gin. whisky, brandy etc. It is also an important starting material for aldehydes, ketones, carboxylic acid, carboxylic acid derivatives and the hydroxyl group is a component of many pharmaceutical drugs [7]. Ethanol can be used in the perfume, disinfectant, tincture, biological and biofuel industries. Ethanol production through Fermentation has been one of the world most significant approaches to aid in the Advancement of Commercial Industry.

Ethanol doesn't have significant environmental impact as fossil fuel combustion 3. It has low air polluting effect and low atmospheric photochemical reactivity, further reducing impact on the ozone layer [8]. It contributes little net CO2 accumulation to the atmosphere and thus should curb global warming [8-11]. Ethanol can be used in three primary ways as biofuel, namely, E10 which is a blend of 10% ethanol and 90% unleaded gasoline, a component of reformulated gasoline both directly and or as ethyl tertiary butyl ether (ETBE) and as E85 which is 85% ethanol and 15% unleaded gasoline. When mixed with unleaded gasoline, ethanol increases octane levels, decreases exhaust emissions and extends the supply of gasoline. Bio-ethanol is made by fermenting almost any material that contain starch or sugar. Grains such as corn and sorghum are good sources, but fruits that are high in sugar concentration are excellent sources as well, since they contain ready to ferment sugars [12].

To solve the above problem, emanating from fossil fuel,

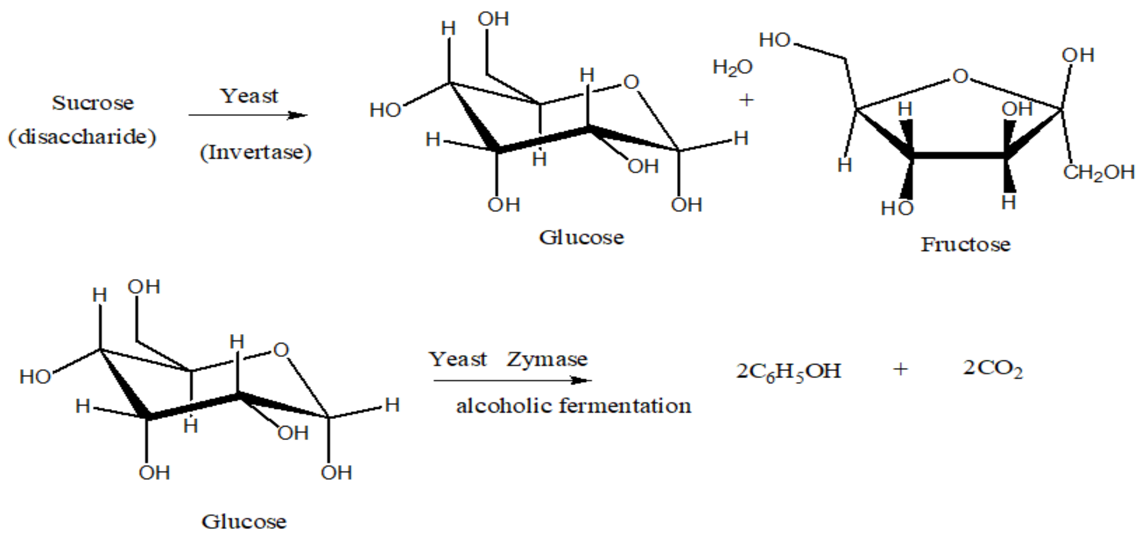

Figure 1

one alternative is to produce bioethanol from fruits, other grown organic matter or waste. Bioethanol can be obtained via the fermentation of glucose, fructose or sucrose under the influence of Saccharomyces cerevisiae at room temperature. Also, acid hydrolysis of lignocellulose material followed by subsequent fermentation [13-23]. Sugar rich sources include ripe fruits etc. Other sources include biodegradable fraction of products, waste and residues from agriculture like vegetables, fruit wastes and animal origin [19-23] etc. The percentage yield of ethanol, ranging from 4.0 -10.0 v/v) have been reported. Fruits that are high in sugar concentration are favorable to the fermentation process, since they can produce high percentage volume of ethanol Fermentation is the process of energy production in a cell in an anerobic environment with the lack of an external electron acceptor [24]. Sugars are the common substrate of fermentation and the products include ethanol, lactic acid and hydrogen. In some instances, compounds such as butyric acid and acetone are produced [24].

The fermentation process begins with the yeast breaking down the different forms of sugar in any fermenting

matrix. Saccharomyces cerevisiae contains two enzymes that is very important for the yeast enzyme activity in the fermentation process. These two enzymes are called Invertase and Zymase and they functions are similar but somewhat prerequisite to each other. Invertase aids in converting any sucrose sugar that is present in any biomass that is used in fermentation to glucose and fructose while zymase aids in the conversion of glucose to ethanol [24], Figure 1. During Fermentation, starch is first hydrolysed to maltose by the action of the enzyme diastase. This enzyme is obtained from germinating barley seeds or malt. Maltose is converted to glucose by the enzyme

maltase. Glucose is then fermented to ethanol via the enzyme zymase [25], Figure 2. Once the sugars are broken down into monosaccharides, the yeast can now use them. Saccharomyces cerevisiae is able to perform both aerobic and anaerobic respiration.

This paper is a mini review of some of the research work undertaken by my research students in bioethanol production from selected fruits. The fermentation of banana (musa acuminata), mango (mangifera indica l.) and pineapple (ananas comosus) mash in the absence and presence of additives have been reported [5]. In this research, the fermentation of pineapple Ananas comosus, mash (500g) with a total soluble solid, TSS of 12.0 was conducted at room temperature (30.8 °C) at a pH of 4-5 over a period of three days in triplicates in the presence of cultured and uncultured yeasts. Experiments were also subsequently conducted in the presence of additives such as 1%, 5% and 10% Urea, Ammonium Tartrate and Zinc Sulphate under the same conditions. In the absence of additives, the alcohol strength was found to be highest with banana, 6.81 ± 0.32 %, v/v and this was with uncultured yeasts. For all three fruit substrates, uncultured yeast produced the highest ethanolic content. In the presence of additives, the average alcohol strength was 5.4 %, v/v for the ZnSO4 solution. Urea, induced, an average alcoholic

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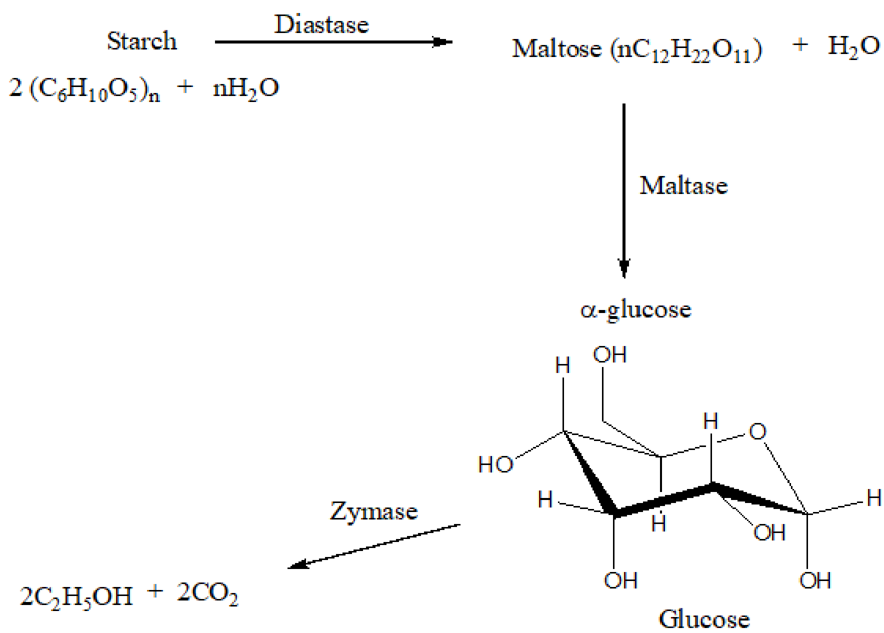

Figure 2

strength of 4.44 %, v/v, whereas Ammonium tartrate induced an average alcoholic strength of 5.13 %, v/v respectively. For both sets of experiments, with non-additives and additives, there was an overall decrease in pH and brix content.

The pulp of Carica papaya (papaya), Magnifera indica (mango) and the peel of Magnifera indica as substrates were fermented for ethanol using Sacchaomyces cervisiae. Experiments were carried out in triplicates in the presence and absence of additives (potassium phosphate) at specific concentration and conditions to study the effects on the yield of ethylalcohol. It was found that Magnifera indica (mango) in the presence of additives produced the highest mean yield of ethanol of 25.16%. Magnifera indica (mango) without additives produced the second highest with an average of 20.56%, while Carica papaya (papaya) without additives having the third highest average yield of 7.537% and Carica papaya (papaya) with the additives present, having the least average ethanol content of 6.69%. The peel of Magnifera indica (mango) in the absence of additives produced an average ethanol content of 1.33% and the reference (glucose), without additives produced an average ethanol content of 11.3%. The mean ethanol content for Magnifera indica with additives, is the highest value reported for any fruit to date and exceed the 15% reported in the literature.

The pulp of watermelon (Citullus lanatus) mash was fermented in the absence and presence of additives such as ZnSO4, promalt, potassium phosphate, yeastex. Fermentation was conducted at a pH of 4.5 at room temperature for 72 hours. In the absence of additives, an average alcoholic strength of 4.23 v/v was obtained. In the presence of additives, ZnSO4, promalt, potassium phosphate, yeastex, an alcoholic strength of 5.10 v/v, 3.37 v/v, 4.09 v/v, 4.19v/v was obtained respectively. For the reference molecule, glucose without additives, an average alcoholic strength of 6.14 (v/v) ethanol was obtained. For glucose molecule with potassium phosphate, promalt, ZnSO4 and Yeastex, an average alcoholic strength of 7.52, 4.19, 7.11 and 5.53, v/v was obtained respectively. The additives did had an effect on the alcoholic strength. ZnSO4 increased the alcoholic strength for the fermented watermelon matrix, whereas for the reference molecule glucose, potassium phosphate and Yeastex did increase the alcoholic strength [26].

The fermentation of sapodilla (Manilkara zapota) and papaya (Carica papaya) was successfully achieved. The mean ethanol content of sapodilla (14.91, v,v) was found to be significantly higher than that of papaya (1.964, v/v). The former equals the highest yield of ethanol, recorded for a fruit to date. In both cases, the final brix was zero, indicating that fermentation has proceeded to completion within the 72 hrs. Also, there was a further decrease in the specific gravity of the fruit. The acidity of the fermenting matrix was found to increase as fermentation proceeded.

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Compared to the reference compound, glucose, the mean ethanol content of both fruits were lowered. Our research shows that the sapodilla fruit can be used as an attractive fruit substrate for the production of ethanol and hence its cultivation should be encouraged as a boost to the Agro Sector of the country and also, a source for the blending with gasoline to produce gas alcohol [27].

The fermentation of sugar rich fruits: jamun (syzigium cumini), soursop (Annona muricata), and Carica papaya in the absence and presence of additives was achieved under anaerobic condition at a pH of 4-5. Initial and final brixs were recorded and showed that fermentation was almost completed. The final pH indicates that the filtrate prior to distillation was acidic, due to the presence of carbonic and acetic acid. The reducing sugar content was measured before and after fermentation. Papaya fruit matrix, without additive, yields the highest volume of ethanol, (4.650 ± 0.255, v/v), whilst soursop, the least (4.100 ±0.245, v/v). The effects of the additives were variable at the different percentages of 0.1, 0.5 and 1%. 0.1% promalt, with 0.5% K3PO4 produced the highest % yield of ethanol (14.163 ± 0.017, v/v), whereas the lowest % yield of ethanol (4.520 ± 0.08, v/v)) was produced by soursop with ZnSO4 additive. At the 0.5% level, promalt with 0.5% K3PO4 produced the highest % yield (9.870 ±0.05, v/v). At the 1% level, K3PO4 additive produced the highest yield (7.690 ±0.055, v/v) of ethanol. Compared to the reference compound, glucose, the mean ethanolic content of the fruits, without and with additives, were lower than that of glucose (9.480, v/v).

Exception being, the mean ethanolic content of promalt at 0.1 % level with 0.5% K3PO4 on soursop (14.163 ± 0.017, v/v) and at the 0.5% level (9.870 ± 0.05, v/v). Gas chromatographic analyses were also done on the distillate, from the fermented matrix, without and with additives. It was found that the distillate in most cases consists of acetaldehyde, methanol, methylacetate, 1-propanol, ethylacetate, 1-butanol, isobutylalcohol, iso-amyl alcohol, 2-methyl-1-butanol, 1-pentanol and furfural in most cases. Our research shows that all of the selected fruits can be used as attractive substrates for the production of ethanol and hence its cultivation should be encouraged as a boost to the agro sector of the country and also, a source for the blending with gasoline to produce gas alcohol. However, future work is necessary to intensify the yield of ethanol beyond the recorded in the literature [28].

The fermentation of pulp of mamme fruit (Pouteria sapota) and cantaloupe (Cucumis mala var. cantalupo) were progressing, when COVID-19 started and so experiments were aborted [29,30]. It would have been interesting to compare the ethanolic content of these fruits with the ones mentioned above from our previous research. In all our research experiments, some trends are noteworthy and these can be discussed. It was noticeable in all cases that the pH of the system decreased, due to the formation of carbonic acid. Also, there was a significant decrease in the brix value to zero, indicating that all of the reducing sugars were fermented to ethanol. The alcoholic yield range from 2% to 26%.

Conclusion

The production of green fuel such as bio-ethanol is the way forward to environmentally save our planet from global warming and its catastrophic consequences. The production of greener fuels, should be one of the world orders. Bio-ethanol production from sugar rich sources, such as pulp of fruits will promote the agroindustry. Our country has vast empty spaces for the planting of fruit trees. The establishment of a fruit-based bioethanol plants are necessary, considering the fruitful results. Fruit pulp and peel can act as one of the main bioethanol feedstock.

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