RESEARCH ARTICLE

Utilization of agricultural production waste for potential bioethanol generation

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Throughout the process from growth of fruit and vegetable to the hands of final consumer, a lot of food waste is produced. All these wastes contain valuable biomass that can be utilized to produce valuable bio products including bioethanol. They contain plenty of fresh produce that makes it adequate for fermentation, hence producing ethanol and preventing the waste from building up in landfills, which would otherwise cause impact to the environment and human health. Besides, it can also further help with reducing the rate of global warming since bioethanol as an alternative fuel produces much less greenhouse gas emissions than the current conventional fuel. The ethanol that can be produced is also an excellent additive for biofuel considering its transportability, bendability with gasoline and the higher oxygen content, making it a suitable additive for fuel. The utilization of these much unwanted wastes for a greener production of clean fuels serves as a potential transformation of waste and effective management.

Key Words: *Agricultural waste; Bioethanol; Additives; Fermentation*

INTRODUCTION

Fruit and vegetable waste is internationally produced, even though the nature of the waste is dependent on the location and the local fruit and vegetable there that dominate the markets. Approximately 60 million tonnes of fruit and vegetable waste are disposed daily across Asia, while in the United Kingdom alone it is estimated that food and drink waste reach up to 14 million tonnes [1]. These fruit and vegetable wastes are derived from food processing, distribution and retail, where ineffective estimation has resulted in overproduction and wastage [2]. Losses incurred from food disposal could be reduced by up to 47% with proper management and this would indirectly reduce the global consumption waste by 86% in regions where there is less necessity for extra food supply [3]. This fruit and vegetable waste represents wastage of food commodities in a time where world hunger is prominent, apart from that, it also encompasses the excess resources utilized such as water sources, land area, chemicals and fertilizers, energy and labor, which further reflect negatively upon the environment when these sources are discarded [4]. Biofuels can be defined as liquid fuels that are produced from biomass that usually consists of starchy or sugary produce, mainly agricultural and forest products (United States Environmental Protection). Specifically vegetables and fruits which offer the opportunity to be a renewable energy resource and has significant potential to produce ethanol [5]. They high sugar which can be utilized in the production of ethanol by through fermentation using Saccharomyces cerevisiae [6]. Ethanol has proven itself to have attractive features to be an alternative fuel; this is due to its transportability and blend ability with gasoline to increase the octane rating within fuel. As fuel prices have been fluctuating in these past years, research in alternative fuels has proven to be beneficial, as the world looks towards renewable fuel options. Sustainable methods have been analysed to provide ethanol, a possible way has been the fermentation of fruit and vegetable [7]. Currently ethanol is a common additive for biofuel and can be synthesized from fruits, ethanol contains 34% higher oxygen by weight thus it is more as a fuel since it is more combustible and furthermore, supplementing biofuel with it makes it more combustible [8]. Moreover, as an additive reduced the emissions of NO, CO, CO_2, PM, during combustion, this is beneficial as it lowers the carbon emission. Furthermore, it was found that blends of different fuels and ethanol led to more stable mixtures, hence spiking interest into further research into ethanol [9].

MATERIALS AND METHODS

Applications of agricultural crops

There are many applicable usages for agricultural crops; the waste from these crops can be used to extract the bioactive compounds, sugars, proteins, enzymes and dietary fibers. After which it can be used in multiple industries such as the pharmaceutical, cosmetics, food and biofuel industries [10]. In that way the waste is not left to rot in a landfill creating hazards and environmental issues and it can be used to make profit. Furthermore, there are more beneficial extracts we can obtain from fruit and vegetable waste. There are flavoring agents and aromas that can be used in the skincare and perfume industry [11]. There can also be phenolic compounds which can be used as antioxidants, structural polymers and as a chemical defence response [12]. The dietary fibers found within the waste are commonly used to relieve constipation pain, if extracted properly it could be used to support this cause once more [13]. There are also enzymes and proteins present in fruit and vegetable waste, in normal conditions enzymes and proteins are used in industrial applications and they are used in medicines as well as a wide range of industries in their processes and products. A common and currently wide spread application of fruit and vegetable waste is to compost the waste and it was found that we could achieve high grade compost usable in agricultural applications [14]. Lastly the essential application discussed in the outline is as a biofuel and biofuel additive, by utilizing the sugars within the waste can be fermented using enzymes to produce ethanol which can then be used as a biofuel additive or as bio-ethanol fuel in it [15]. On the other hand, fruits and vegetable waste are susceptible to microbial spillages which can cause odours and fouling of the waste, therefore, the waste needs to be processed thermally or non-thermally using heating technologies, ultrasound and other methods. Unfortunately, the growth of biofuels is hindered by the food versus fuel debate, since there is a currently a large amount of people who don't have enough food, is it ethical to use farmable land to grow crops for

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any other purpose than food. Especially since the decrease in land available to grow food could lead to a price hike in food crops. On the other hand the arguments against biofuel crop growth do not take into account that the issue of food security is not unique to biofuel crop growth and it doesn't take into account the natural growth rate of food prices, moreover the direct effect is to be felt amongst the poorest of people of which there are many farmers who actually could largely benefit from growing biofuel crops [16]. This whole argument could be avoided with the use of fruit and vegetable waste, since it doesn't require extra land use or replacing the crops' main purpose.

RESULTS

Potential of fruit and vegetable waste for bioethanol production

As it was observed that as the amount of sugar in the fruit increased the conversion to ethanol was higher, therefore this shows a high potential of ethanol production by using Saccharomyces cerevisiae, therefore fruit and vegetable waste will through processing have the ability to produce a renewable fuel. It can be seen that there are common useful compounds found in fruit and vegetable waste such as polyphenols, dietary fibers, enzymes, proteins and bioactive compounds [17]. Indicating that there is large potential in waste from fruits and vegetables, since the compounds in reference are used in the pharmaceutical industry, the food industry, healthcare sector and the chemical industries. This is in addition to the aforementioned amount of sugars within which can be fermented and turned into ethanol to be used as an additive or as bio-ethanol, this could aid and support replacing fossil fuels with biofuels as the source is readily available and is a supposedly greener alternative, because of its potential to reduce greenhouse gas emissions in several everyday aspects.

On the other hand, second and third generation biofuels have a higher potential to reduce greenhouses gases as it only uses a marginal amount of land on the other hand no further agricultural growth is required when using waste fruits and vegetables, this is why there is no additional release of GHGs. Notably the use of biofuel in itself will not reduce GHGs that currently exist, the affect can only be observable if there is a simultaneous reduction of the production and usage of fossil fuels. Moreover, the benefits will only be prominent if biofuel emissions and resources don't displace those of fossil fuels.

Processing methods for biomass conversion

The processing technologies of converting biomass into bioethanol can be conducted through two main methods, which are thermo-chemical conversion and biochemical conversion. Within the thermo-chemical processes, there are pyrolysis, gasification and liquefaction. These processes produce biochemical, biogas and syn-oil from waste biomass. While for biochemical conversion, processes like fermentation and hydrolysis are used to produce bioethanol and biodiesel [18,19]. Biodiesel is produced from Transesterification processes, which converts the triglycerides of vegetable oil to fatty acid methyl/ethyl esters by displacing the alcohol from an ester [20]. The characteristic of bioethanol which is comparable to petrol enables it to be used in spark ignition engines, and also to be used interchangeably for diesel that is used in compression ignition engines.

An exemplary process is summarized by the idea that fruits and vegetable waste contain significantly high amount of sugar which is the raw material that can be used to produce bioethanol using Saccharomyces cerevisiae. The initial stage is the pre-treatment step which includes chemical and biological treatment. There is chemical pre-treatment which involves the usage of acids and alkalis (such as dilute acid hydrolysis) working on the biomass, as for physical pretreatment the process converts the biomass to increase surface area accessibility and pore volume. Furthermore, other pretreatment options work on the idea to increase the accessibility and surface area for the enzyme and biomass and decreasing cellulose crystallinity. As for biological pretreatment, micro-organisms are used for the treatment (particularly fungi).

Bioethanol production is dependent on the type of fermentation process. Several types of fermentation include simultaneous saccharification and fermentation, (SSF), simultaneous saccharification, co-fermentation (SSCF) and separate hydrolysis and fermentation (SHF). The fermentation procedure is sensitive to pH changes and when using an acidic medium with moderate pH, a large yield of ethanol is observed. The process can also be undertaken continuously or batch wise. As for batches the amount is limited that can be processed at a time, while for a continuous process it is achieved by continuously adding the culture medium being used. The end results show that vegetables and fruits waste could potentially be utilized for the production of bioethanol from agricultural waste and management process. Saccharomyces cerevisiae showed a higher fermentation capability with a shorter cultivation time. When processing citrus fruits; it was found that after extraction the remainder of the fruits after consumption serves as a high-quality raw material for the fermentation of bioethanol. Bananas and pineapple peels when fermented with simultaneous saccharification, the maximum temperature and pH for the banana peels' fermentation was 30°C and 6, respectively. At these maximum conditions, different concentrations of yeast extract were utilized for the fermentation, and the study showed that the period to complete fermentation reduced drastically [21].

DISCUSSION

Characteristics of biofuels from vegetables and fruits

Properties of biofuel made from vegetables: The properties of biofuel developed from vegetables have the average properties as tested, are as followed and are compared [22] (Table 1). The average results found that the bioethanol content is around 6% less, the methanol content, chlorine and the water content are significantly less than the standard amount. On the other hand, the gum content, flash point, viscosity, density, heating value and the copper content are larger than the standard. The difference was not largely different than the standard values indicating that raw vegetable material can make bioethanol of acceptable quality.

TABLE 1

Chemical and physical properties of biofuel derived from vegetables

Properties	Result	Standard for bioethanol	Properties	Result	Standard for bioethanol
Bioethanol content	93.7%	99.5%	pH	5.03	6.5-9.0
Methanol content	0.0046 mg/l	300 mg/l maximum	Heating value	6,438 kcal/kg	6380 kcal/kg
Water content	0.52% vol	1.0% vol maximum	Density	0.822 g/cm³	0.789 g/cm³
Cu content	0.195 mg/kg	0.1 mg/kg maximum	Viscosity	2.397 cSt	1.525 cSt
Gum content	5.76 mg/100 ml	5.0 mg/ 100 ml maximum	Flash Point	12.24ºC	12ºC

Properties of biofuels made from fruits: With regards to the biofuel properties that are derived from fruits it can be seen from examples of a mix of rotten fruit. The physicochemical properties of biofuel derived from rambutan, pineapple, banana and mango waste was compared to the bioethanol standard, it was found that the pH is similar but not quite with the fruit having pHs of 4-6 while the standard starts from 6.5. As for the viscosity which is observed for the spray characteristics within the engine, the average viscosity is around 1.51 cST compared to 1.53 cST which is the standard discovered. Copper was found only in the rambutan waste; however it was also close to the standard at around 0.1 mg/kg. Although the findings on biofuels from fruits are scarce, the waste fruit still shows suitable characteristics for potential biofuel production [23].

Future prospects: There are many advantages of having biofuel to be produced from biomass, firstly it removes the waste biomass that would otherwise be discarded into landfills which causes much harm when left in landfills it produces a large amount of methane which contributes to global warming. Biofuel production also provides the opportunity to expand the range of agricultural products and provides further income for farmers however, the current food vs. fuel debate that suspects that if farmers' attentions were diverted from food to fuel then food prices will hike higher than they already are, which would further inflate the world hunger and world poverty issues. Thus, waste produce is considered as an alternative to fresh agricultural biomass [24]. Moreover, using vegetables and fruits waste to produce bioethanol will support sustainable disposal of agricultural waste. Potato peels for example were taken into account and they showed great potential to be able to produce ethanol as an additive for biofuel, since it is a zero value waste that is consistently produced, and has shown prospects of being able to produce large amounts of ethanol because of its large quantities of starch, cellulose, hemicellulose and fermentable sugars, it can be fermented with Saccharomyces cerevisiae, to produce ethanol with the ability to be blended with traditional gasoline in amounts of up to 10% [25]. It also has the potential to create biogas as a byproduct, which can be burned and the heat can then be used for distillation processes and electricity production, this provides a further benefit to using fruit and vegetable biomass for the production of bioethanol [26]. It has also been shown that using fruit and vegetable waste biomass is highly economical since it is a low cost method to produce bioethanol [27].

CONCLUSION

The evaluation of agricultural products being suitable for ethanol and additive to biofuel is an essential part of the discovery to promote its utilization. This will result in the sustainable usage of fruit and vegetable waste. Through the use of fermentation using Saccharomyces cerevisiae, and the available waste disposed of in several ways by the whole life cycle of fruits and vegetables, new products can be generated. Considering that the amount of fruit and vegetable waste being produced is immense and hence the crops are not effectively used, thus showing large economical potential and the potential for developing a more sustainable process of handling and disposing of the fruit and vegetable waste. Moreover, it was also found that the use of fruits and vegetables produced a bioethanol of similar quality to the standard bioethanol being produced. With further research and developments of the process it is possible to provide ethanol derived from fruit and vegetable waste in a sustainable, efficient and economical way.

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CONFLICT OF INTEREST

All authors of this manuscript affirm that there is no conflict of interest

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