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## Chapter

# Bio-Ethanol Production from Fruit and Vegetable Waste by Using *Saccharomyces cerevisiae*

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## Abstract

Waste from the food is a challenge to the environment all over the globe, hence there is need to be recycled. Vegetables and fruits biomass is a resource of renewable energy with significant fuel source potential for the production of electricity and steam, fuel for consumption and laboratory solvents. Bioethanol derived from biomass contributed 10–14% of the total world energy supply and solved the world crisis such as global warming and depletion of fossil fuel. Presently, bioethanol is a global issue on the efforts to reduced global pollution, contributed significantly by the petroleum or diesel combustion or combination of both. Vegetables and fruits waste significantly contains high sugar which can be utilized and serve as a raw material in the production of renewable energy using *Saccharomyces cerevisiae*. Though 80% of the current bioethanol are generated from edible materials such as starch and sugar. Biomass from lignocellulosic gathered more attention recently. The objective of this review is to account for the procedures involved in the production of bioethanol from biomass of fruits and vegetable waste through a fermentation process using *Saccharomyces cerevisiae*. In this chapter, we discussed the biomass preparation and fermentation techniques for bioethanol and reviewed the results of different fruits and vegetable waste. We found pineapple and orange fruit biomass contain a higher amount of bioethanol and easier to extract than the other fruit and vegetable wastes. Recent review coined out that dry biomass of fruit and vegetable is a promising feedstock in the utilization of bioethanol production.

**Keywords:** fruit, vegetable, waste, *Saccharomyces cerevisiae*, bioethanol

## 1. Introduction

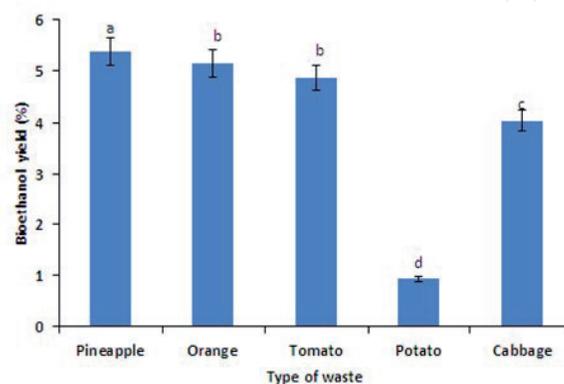
The globe needs urgently to resort another option of sources of energy as a result of the rapid world energy supply exhaustion [1]. As a result of the depletion in oil, the world global warming and the effects of greenhouse making the earth on the condition of alarming [2]. Despite seeing the world are completely dependent on the limited sources of fossil-based petroleum that can later not withstand to meet future demands.

The world depletion fossil fuel happened, resulting in the continual price rising and the pressure for independence of oil and environments concerns lead to strong

markets for biofuel [3]. The utilization of natural resources fuel leads to the vast side problem. The rapid increased of CO<sub>2</sub> level in the environment resulted in the global warming resulting to the negative results of the burning of fuel from petroleum-based [4]. The worlds are concern about the climatic change and the consequent need to decreasing of greenhouse emissions gasses leading to the encouragement of the usage of bioethanol as an alternative or replacement [5]. Another challenge is as a result of the arise waste dumping in an open place resulting in malignant to the natural habitat at surrounding environments of the dumpsite. The concept of producing energy in the form of a solution by utilization of the waste is affordable, cheap and efficient. Recently, an enormous number of renewable sources of energy is rapidly growing technologies of renewable energy including solid biomass, liquid fuels and biogases [6]. A biofuel is a generated fuel through biomass rather than the one produced from the formation of the geological process of oil and fossils fuel. As a result of biomass can be technically utilized directly as fuel. The term biofuel and biomass are interchangeably used. Biomass with complex or free sugar that can later form soluble sugar is used for the production of bioethanol. The feedstock is divided mostly into three major groups; starchy crops, (sugar crops and by-products of sugar refineries) and lignocellulosic biomass (LCB), they differ respectively from the sugar solutions in them [7]. Production of bioethanol from the conventional feedstock like starch-rich feedstocks (corn, potato) and sugarcane has been previously reported as the first-generation process. Nevertheless, they have economic and social barriers [8]. Bioethanol second-generation process is gaining momentum. Lignocellulosic biomass (corn stover, sugarcane bagasse, straws, stalks and switchgrass) are used for the second-generation process. One of the significant alternative processes of bioethanol production with easy adaptability of this biofuel to prevailing engines with better octane rating [9, 10]. Any plant material with significant amounts of sugar is utilized as a source of raw materials in bioethanol production. Sugarcane, pineapple and potato are one of the major plants that resulted in a high yield of bioethanol as byproducts due to the presence of a high amount of sugarcane in it [11] (**Figure 1**).

## 2. *Saccharomyces cerevisiae*

Yeast is described as basidiomycetous or ascomycetous fungi responsible for reproducing through fission or budding and formed spores which are not enclosed in the fruiting body [12]. *S. cerevisiae* is the most popular yeast in the production of ethanol due to its wide tolerance of pH making it less susceptible to infection. The ability of yeasts in catabolize six-carbon molecules is the bedrock to the production



**Figure 1.**

The amount of bioethanol production depends on the substrate used as shown in the figure above. Adapted from Khandaker et al. [11].

of bioethanol without proceeding to the final products of oxidation which is CO<sub>2</sub>. Diauxic shift and fermentative metabolism are the process of the production of bioethanol dependent Alcohol dehydrogenase (EC 1.1.1.1) enzymes which is encoded on the ADH1 locus. During the fermentation of glucose, ADH1 catalyzes led to the production of ethanol and reduction of acetaldehyde, similarly, the reverse reaction can be catalyzed: is the process of conversion of ethanol to acetaldehyde, albeit with lower catalytic efficiency [13].

### 3. Fruit wastes as a source of bioethanol

Fresh citrus fruits are consumed or the citrus juice is mostly preserved which it's in ready form of consumption or concentrated form. After the extraction of citrus fruit juice, the remaining parts of the fruits serve as a rich source of lignocellulosic material and also utilized as a raw material for the fermentation of bioethanol. Simultaneous saccharification and fermentation from plantain, banana and pineapple peel through the cultured of *S. cerevisiae* and *A. niger* [14]. Different temperature (20–50°C) was used to be examined the simultaneous saccharification and fermentation of banana peels to obtain bioethanol using co-cultures of *S. cerevisiae* and *A. niger* at different pH of 4 to 7 for seven days.

The present study observed that the maximum temperature and pH for the banana peels fermentation was 30°C and 6. With these maximum conditions of temperature and pH, different concentrations 3 and 12% of yeast were utilized for performing fermentation. The study found the period for the whole fermentation to complete reduced drastically [15]. The high glucose content in pineapple and orange resulted in the excellent yield of bioethanol [11] (Figure 2).

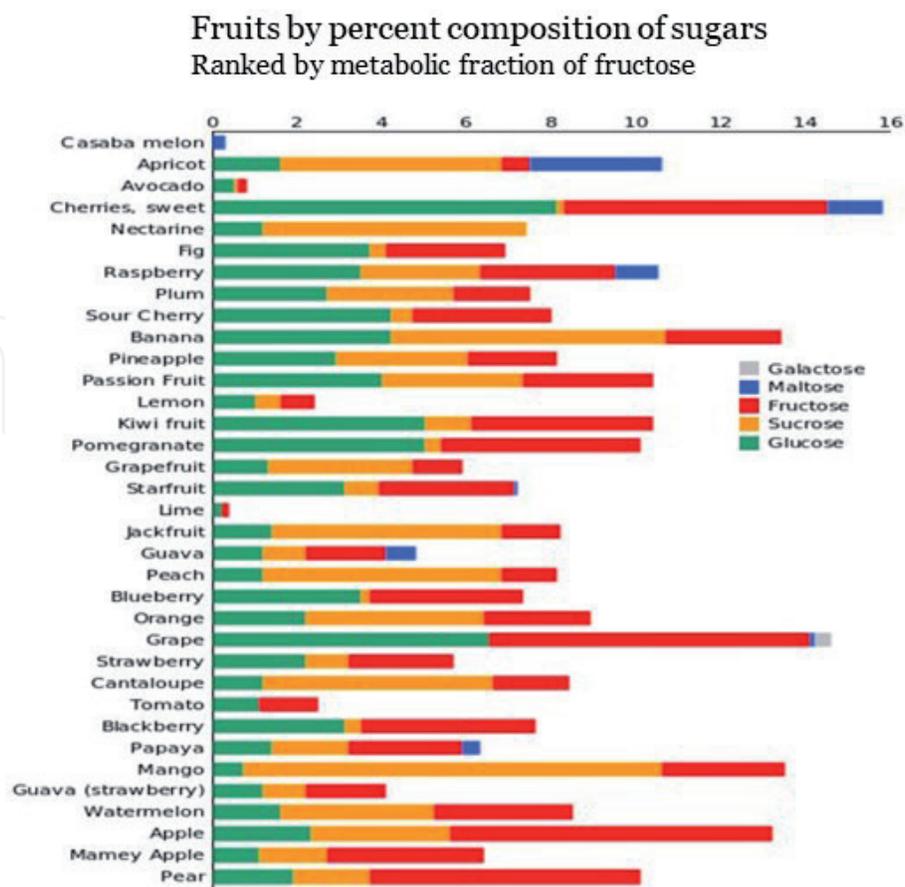


Figure 2. Percentage of sugar composition in various fruits and vegetables [16].

#### 4. Vegetable waste as a source of bioethanol

Rotten, peels, shells and a scraped portion of vegetables is one kind of biodegradable vegetable waste that generated in large amounts, usually dumped on ground for rotten near the household area. This act not emits an obscene odor but also creates a big irritation by attracting pigs, rats and bird as well as vectors of various human diseases. Vegetable waste mainly generates during the processing and packaging of vegetables, after preparation of cooking and post-harvest losses due to lack of storage facilities. Bioethanol can be produced through fermentation under controlled conditions. Microbial decomposition of vegetable waste generates bioethanol with high humus content. Many researchers have stated that vegetable waste is carbohydrate-rich biomass one of the potent substrates of renewable energy generations.

Research on the usage of fruit and vegetable wastes for the manufacture of biofuel is fetching attractive in different countries. Sulaiman et al. [17] abstracted a halal biorefinery for the production of bioethanol and biodiesel and value-added products in Malaysia. Vegetable wastes arise throughout the supply chain from the producer to consumer and vary widely depending on its harvesting, processing and marketing [18]. Vegetable waste can be raw, cooked, inedible and edible; parts are generated during production, harvesting, precooling, grading, storage, marketing and consumption at the consumer place. All the cut-down vegetable waste goes to landfill. Landfills spread offensive smells, produce methane which is a common greenhouse gas, and also produced a large amount of harmful leachate that can contaminate water and soil. Nevertheless, microbial digestion of vegetable waste can be used to produce bioethanol, renewable bioenergy. Vegetable waste has chemical potentials due to the high amount of saccharide in the form of lignocellulose. Promon [19] reported that vegetable waste as a high source of lignocellulose could be hydrolyzed into D-xylose and glucose.

Vegetable waste is a renowned nonedible source of lipids, amino acids, carbohydrates, and phosphates [20, 21]. All of these nonedible lignocellulose biomasses can also use for the production of bioethanol. Lignocellulose contains of 30–50% of cellulose, 20–40% of hemicellulose and lignin around 10–15% [22]. Cellulose is the main assembly of lignocellulosic built biomass which is a glucose homologous polymer associated by  $\beta$ -1,4 glycosidic bond [23]. After, glucose and other simple sugars production from all the sugar sources, the bioconversion endures till bioethanol is produced. Vegetable waste is widely used raw material for the production of bioethanol because it contains hemicellulose and cellulose, which can be changed into sugar by the hydrolysis method in presence of microorganisms [24]. The sugar content in vegetable waste extracts around 5% [25]. Yeast, fungi and bacteria can be used for the fermentation process [26].

#### 5. Production of bioethanol from dry fruits and vegetable waste biomass

**Pretreatment:** The pretreatment is the most costly and complicated step in the conversion of LCB into ethanol. The LCB in cellulose is usually sheathed or coated by hemicelluloses resulting in hemicellulose complex cellulose that works as a chemical barrier and attacked and prevent the chances of complex enzymes under its natural condition [27]. The complexes cellulose-hemicellulose are further subjected encapsulated with signs leading to the production of physical, physical barrier to the biomass of hydrolysis to produce fermentable sugars [28].

**Chemical pretreatment:** Primarily acids and alkali working on the biomass of the delignification, the degree of decreasing of crystallinity of cellulose and

polymerization.  $\text{HNO}_3$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{HCl}$  and  $\text{H}_2\text{SO}_4$  are utilized during acid pretreatment of biomass in the process the major alkali used is  $\text{NaOH}$ . Pretreatment of acid is applied in the stabilization of the fraction of hemicellulosic in the biomass, thereby making cellulose enzymes more accessible [29]. Physical pretreatments: This process convert the biomass through the increased surface accessibility area and pore volume, decreased in the degree of the polymerization of cellulose, hydrolysis of hemicellulose, partial depolymerization of lignin and its crystallinity. Physicochemical pretreatment: The exploitation of the usage of conditions and chemical compounds that affect the chemical and physical properties of the biostimulants including a large number of technologies example fiber explosion ammonia, steam exploitation,  $\text{CO}_2$  explosion, ammonia recycling percolation wet oxidation, soaking aqueous ammonia etc. Similarly, other pretreatments methods like technologies from physicochemical also increased the accessibility area surface of the enzyme biomass, cellulose crystallinity decreased and removal of lignin and hemicellulose during pretreatment.

Biological pretreatment: Microorganisms are used are utilized particularly fungi as brown rot, white rot and soft fungi rot, the most efficient among them are white fungi rot. The above treatment became effective through the alteration of the cellulose and lignin structure and separates them from the lignocellulosic matrix. While white, soft rot and brown rot fungi attack cellulose and lignin [30].

Detoxification: Pretreatment is an important aspect of converting LCB into ethanol.

It has a significant effect on the complete process leading to the generation of lignocellulose-derived by-products under the conditions of pretreatment such as acetic acid, sugar acids, levulinic acid, formic acid, furfural and hydroxymethyl furfural acts as enzymes inhibitors for the microorganisms fermentation for the subsequent stage if the accumulation is sufficiently high [31].

Inhibitors can be checked out by:

- Chemical approach: by addition of alkali such as  $\text{NaOH}$ , reducing agents such as (sulfite, dithionite and dithiothreitol)  $\text{Ca}(\text{OH})_2$ ,  $\text{NH}_4\text{OH}$ , Reducing
- Treatment using enzyme: peroxidase, laccase
- Vaporization and heating: heat treatment, evaporation
- Extraction using liquid–liquid: Supercritical fluid extraction such as (Trialkylamine, supercritical  $\text{CO}_2$ ), Ethyl acetate,
- Extraction using liquid–solid: Lignin, Ion exchange and Activated carbon,
- Treatments using microbes: thermospheric, *Coniochaeta ligularia*, *reibacillus* and *Trichoderma reesei* [7].

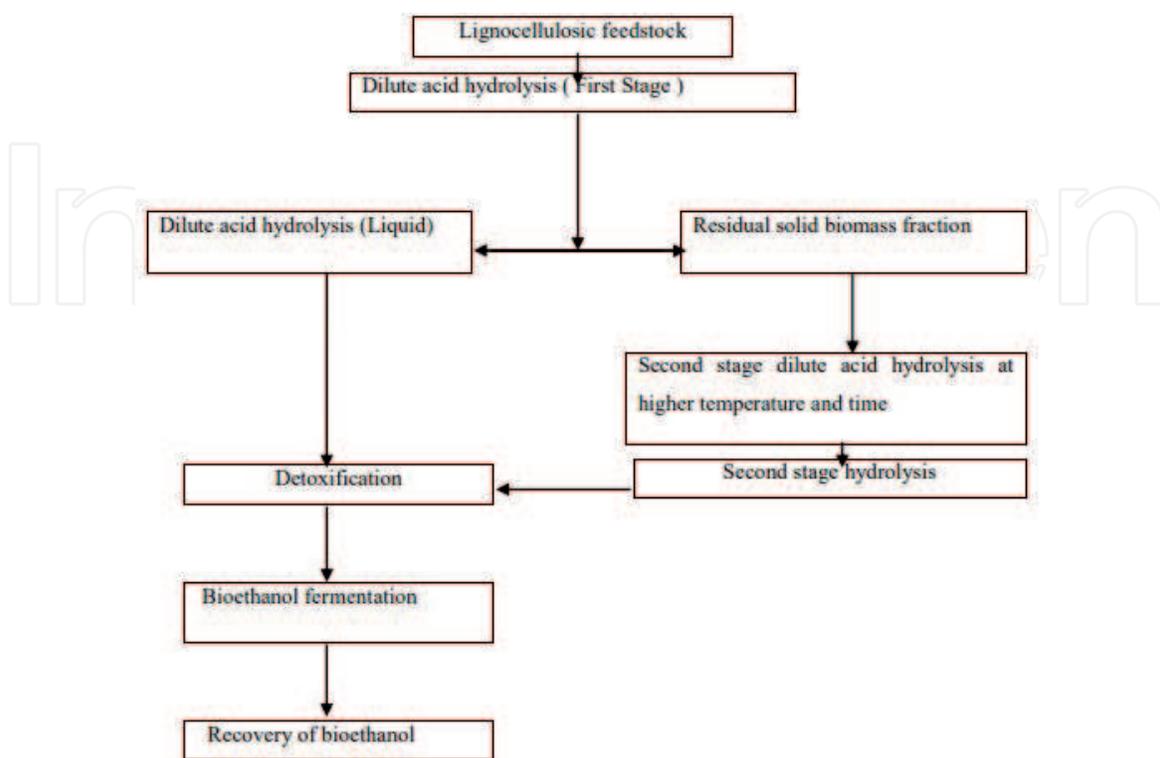
Hydrolysis: Hydrolysis is described as an industrial process where hemicellulose and cellulose present in the feedstock are converted to fermentable sugars. The fermentable sugars are maltotriose, maltose, sucrose, glucose, fructose they are generally accounting to 60–70% of the total solid dissolved. Enzymatic hydrolysis, alkaline or either acid is utilized in the conversion of cellulose and hemicellulose into their monomers sugar.

Acid hydrolysis is the oldest technology for cellulose biomass conversion to ethanol [32]. The acid hydrolysis is basically classified into two: concentrated acid hydrolysis and dilute acid. The diluted acid procedure is conducted through high

pressure and temperature with a reaction time scale of one minute, reactivating continues process. The procedure of the concentrated acid utilized relatively low pressure and temperature with a much longer reaction time [33] (**Figure 3**).

Dilute acid hydrolysis the following method it is used for hydrolysis of hemicellulose and as a cellulose pretreatment to make it most accessible for the enzymes. However, both the polymers of carbohydrate are hydrolysed using acid dilution under two stages, hydrolysis process: the following stage is carrying out at a minimum temperature to utilized the hemicellulose conversion as the fraction of hemicellulose biomass for the depolymerization at a low temperature than the portion of cellulose due to the difference in the structure between these two polymers of carbohydrate [34]. The dilution of acid involved a process of a solution of sulfuric acid 1% concentration in a reactor with continues flow at a temperature of 215°C [35]. Most of the process of the acid dilution to a sugar recovery is limited to efficiency of about 50%. The most paramount challenge in the hydrolysis of acid dilution is the raising of glucose yields greater than 70% in a viable economical industrial process with a maintaining high rate of cellulose hydrolysis with minimization of decomposition of glucose. Shrinking bed reactor countercurrent technologies have been 100% success in the yielding of glucose from cellulose [36].

Concentrated Acid Hydrolysis the method provide rapid and complete cellulose of hydrolysis to glucose and sugars of hemicelluloses to 5-carbon with a little bit of degradation. The concentration of the acid process utilized mild temperature relatively, the pressure created from the pumping pressure from vessel to vessel is utilized. Dilution acid process is shorter than the reaction time [35]. Depolymerization of the cellulosic fraction is the next step. Soaking and dewatered of solid residue from the first stage was carried out in 30–40% sulfuric acid for 50 minutes. For furthering of cellulose hydrolysis is carried out at 373 k [37]. Recovery of higher sugar efficiency was the primary advantage of the concentrated acid process [38]. The process of concentrated acid offers significant cost reduction than the process of dilute sulfuric acid [39].



**Figure 3.** Dilute acid hydrolysis flow chart of recovery bioethanol [37].

Alkaline hydrolysis the major significant from pretreatment of alkali is the removal of lignin, which greatly improved the reactivity of the remaining aspects of polysaccharides [40]. In the biomass, the aligning structure is altered by glycosidic and ester degrading side chains of the biomass through the alkaline solvents, resulting in swelling as well as cellulose decrystallization [41]. Hydrolysis of alkaline is a very slow process that requires neutralization and the recovery of the added alkali is needed. Hydrolysis of alkaline is very suitable for agricultural residue and herbaceous and woody biomass is not suitable due to its high contents of lignin [42]. Previous experiments results confirmed that hydrolysis of alkaline has the highest reaction rate, followed by hydrolysis of acid and finally degradation of hydrothermal from the glycosidic bond cleavage insoluble water carbohydrate concerned. In other to the obtained significant yield of sugar by hydrolysis of alkaline, it is very challenging as a result of dimeric and mono carbohydrates such as fructose, maltose, cellobiose or glucose are attacked severely by the temperature of alkali at 100°C [42].

Enzymatic hydrolysis for enzymatic hydrolysis to take place it required the feeds to be hydrolysed by the enzyme to become fermentable sugars. Breaking down of cellulose take place using three types of enzymes  $\beta$ -glucosidases, cellobiohydrolases and endo- $\beta$ -1,4-glucanases. The most effective and promising among them is the enzymatic process due to the specificity of the enzyme on the substrate relatively working on the minimum temperature and generating lower inhibitors. LCB enzymatic done usually by using either microorganisms producing an enzyme that secretes directly on the enzymes during their developments in the media or enzymes system that are commercially available where the latter is widely utilized and more feasible. The commercial-scale of cost-effective ethanol its major challenge is the enzymes costs [43]. The type of biomass and the conditions of hydrolysis is the major factors dependable for the conversion of lignocellulosic biomass to fermentable sugars. Many factors are solely responsible for the yield of sugar during hydrolysis of the enzyme. The factors are generally divided into two groups. (1) factors related substrate, and interlinked with one other (2) enzymatic and factors related process. Enzymes hydrolysis is the saccharification preferred method as a result of its; high yield, high selectivity, minimum energy cost and operating milder condition than other processes [14].

Fermentation process: Bioethanol production largely depends on three processes which are simultaneous saccharification and fermentation, (SSF) and simultaneous saccharification and co-fermentation (SSCF) and separate hydrolysis and fermentation (SHF). Ethanol fermentation is completely separated lignocellulosic hydrolysis in SHF fermentation. Hydrolysis enzymatic separation and fermentations enabled the operation of the enzymes at a higher temperature and excellent performance. The organisms in the fermentation process operate at a lower temperature for sugar utilization optimization. SSCF and SSF fermentation and hydrolysis process occur concurrently to keep the glucose concentration low, the whole process occurs in a short process. While the SSF fermentation pentose is separated from glucose while SSCF pentose and glucose are in the same reactor [44]. Both SSCF and SSF are more efficient and preferred over the SHF as a result the operation of the later cannot be performed on the same reactor [37].

Batch, fed-batch, repeated batch or continuous mode are important technology of bioethanol fermentation. Hadiyanto et al. [45] stated that the substrate is provided at the early stages of the process without removal or addition of the medium in a batch process. The process is known as the simple system of a bioreactor with a flexible, multi-vessel and Cassy control system. In a closed-loop system with high inhibitors and sugar concentration at the beginning and ends of the fermentation is maintained and the process carried out with high product concentration [46]. Complete sterilization, require fewer labour skills, can control easily, very easy to manage feedstocks, and flexible to various product specifications are benefits of the batch system [47]. However, the productivity of the system is very low and

need intensive and high labour costs. Both inhibitions of growth of the cells and production of ethanol may come from the presence of significant amount/ high concentration of sugar in the fermentation chamber [48]. However, Fed-batch fermentation overcomes the inhibition and enhanced production of ethanol. In Fed-batch fermentation, combine a form of batch and continuous modes are operated which involves increasing substrate to the fermenter devoided removing it from the medium. The size of culture in fed-batch varies significantly, but the substrate must be fed with the right component properly at a certain rate. When the low substrate concentration is maintained, higher ethanol yield in feb-batch is observed. This is because low substrate concentration permits the smooth conversion of a reasonable amount of fermentable to ethanol [47]. The benefits of this feb-batch include; higher ethanol yield, greater dissolved oxygen in the fermentation chamber, Low fermentation time and medium component exhibit a low toxic effect [48]. Fed-batch is successfully operated in non-uniform SSF system by repeatedly adding pretreated feedstock to achieve comparatively high sugar and ethanol yield [14].

Continuous operation is achieved by unceasing addition of culture medium, substrate and nutrients to bioreactor embodied active microorganisms. In continuous operation mode, the culture size is kept constant and the end products of fermentation are siphoned from the media continuously. Discrete product types such as ethanol, cells and residual sugar could be accessed from the top of bioreactor [14]. The advantages of continuous system over batch and fed-batch; small size bioreactor, higher ethanol yield and cost-effective. However, shortcomings of this technique are; the greater tendency of contamination than other types [37]. The capability of *Saccharomyces cerevisiae* to ferment and produce ethanol is drastically decreasing with longer cultivation time.

## 6. Characteristics/properties of bioethanol

Bioethanol fuel has the following intrinsic quality: high-octane number; this measure the engine performance (**Table 1**). The more the octane number the higher compression that the fuel can endure before ignition. Higher octane number qualifies fuel to be used in high-performance gasoline engines that need compression ratios to be high. Hence, the use of gasoline with a low octane number causes the engine knocking [49]. It drastically decreases the emission of substances that are a threat to human health eg. CO (**Table 2**). The utilization of ethanol does not employ engine modification, it does not emit CO<sub>2</sub>, the cost of production is low, and it is eco-friendly, hence flipside of the solution to global environmental contamination [50–51].

Bioethanol fuel property	Advantages	References
High oxygen content (35% w/w)	i. Increased combustion efficiency ii. Reduced hydrocarbon and carbon monoxide emissions	[52, 53]
High octane number (107) and high latent heat of vaporization (0.91MJ/kg)	i. Prevents premature ignition and cylinder knocking ii. Spontaneous ignition in internal combustion engines when bioethanol petrol blends are used	[54, 55]
Low energy content (21.2MJ/dm <sup>3</sup> )	i. Increased compression ratio ii. Decreased burn time iii. Increased power	[56, 57]

**Table 1.**  
*Advantage of bioethanol.*

Bioethanol	Fossil ethanol
Renewable	Non-renewable
Waste plant material used as feedstock	Fossils source
Cost-effective	expensive
Least pollutants are released	Many pollutants are released

**Table 2.**  
 Difference between bioethanol and fossil ethanol.

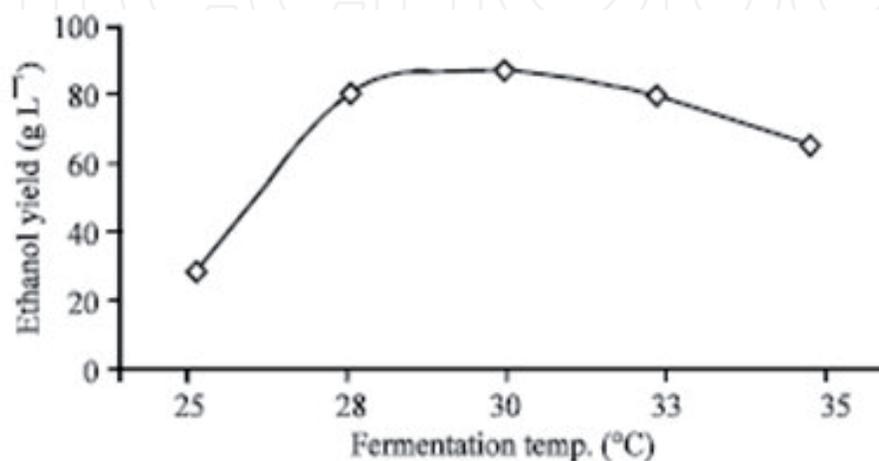
## 7. Factors affecting bioethanol production

**Temperature:** the roles of temperature for *S. cerevisiae* to ferment sugar and the production of ethanol were studied. Results from previous studies show *S. cerevisiae* cells increased exponentially as the incubation begins and then get into stationary phase after prolong incubation for all operating temperatures. Experiments prove that as the temperature is progressively increasing, the time required for fermentation decreases. Nevertheless, at much high-temperature *S. cerevisiae* cells growth is inhibited and decline in ethanol production is drastic [58] (**Figure 4**). This may be due to that temperature affects the transport system or the level soluble substances and solvent in the *S. cerevisiae* cells are saturated which in turn causes the build-up of toxins ethanol inclusive inside cells [58–60].

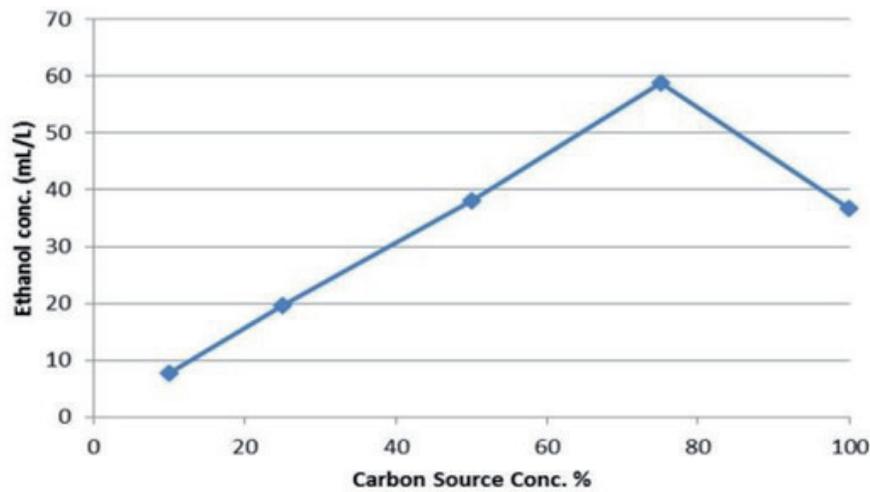
Whereas low temperature slows the growth rate of cells which may be due to their low tolerance to ethanol at lower temperatures [62, 63].

**Effect of Feedstock Concentration:** feedstock encloses nutrients for microorganism's growth during the fermentation process. At high feedstock concentration, the rate hydrolysis is speed up because more compound is bound to enzymes' active site. With fixed number of enzymes and low amount of substrate cause decrease in production of ethanol because bound to enzymes' active site. A small amount of ethanol will be obtained because of low substrates bound to the enzyme's active site. Hence, the increase in feedstock concentration favors the production of ethanol [64] (**Figure 5**). However, according to Lin et al. [58] prolong exposure to a higher concentration of feedstock lead to diminishing the production of bioethanol.

**Effect of pH:** Fermentation process is pH sensitive. In an acidic medium with moderate pH, high ethanol production was observed (**Figure 6**). Moderately acidic



**Figure 4.**  
 Effect of temperature on bioethanol yield [61].

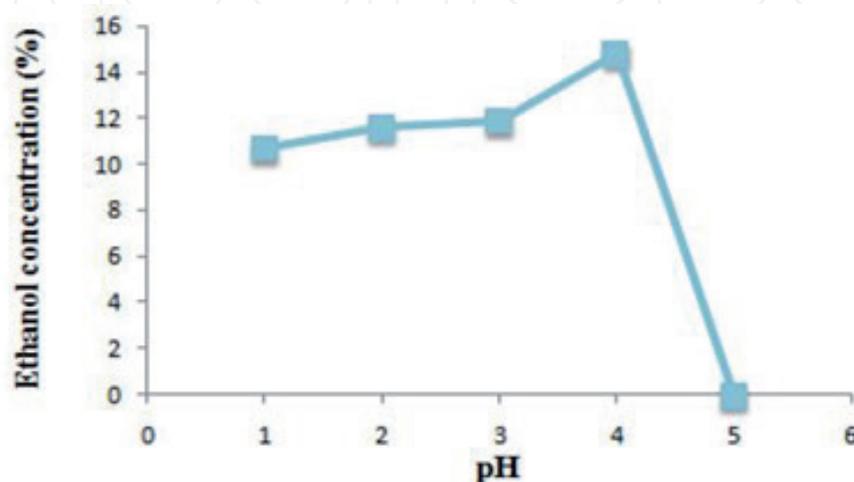


**Figure 5.**  
Effect of feedstock on bioethanol production [65].

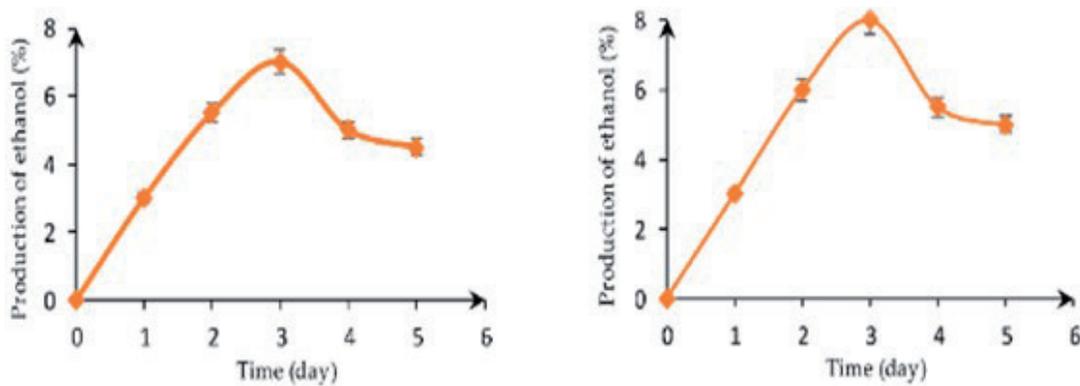
pH, cell permeability to some essential nutrients is influenced by the concentration of  $H^+$  in the fermentation broth [28]. It has been experimentally observed that both growth and survival rate of *S. cerevisiae* is persuaded by pH in the 2.75–4.25 range. However, during fermentation for ethanol production, 4.0–4.25 is the optimum range of pH. When pH is  $\leq 4.0$ , incubation period longer than necessary is required even though it does not cause a significant decrease in ethanol production. A substantial reduction of ethanol production was observed at pH above 5.0 [66, 67] (**Figure 6**).

**Time of Fermentation:** the rate at which growth of microorganisms occurs is affected by fermentation time (**Figure 7**). The shorter the fermentation times the more inefficient fermentation due to inadequate microorganisms growth. Equally, longer fermentation time cause affects *S. cerevisiae* growth due to high concentration of ethanol in the broth. However, using a low temperature and long fermentation result in lowest ethanol yield [28].

**Agitation rate** this controls to regulate the entry of nutrients from the fermentation broth to inside cells and eviction of ethanol from the cells to the fermentation broth. Higher rate of agitation leads to higher production of ethanol. It plays a role in triggering sugar takes up and the inhibition of ethanol to the cell is reduced. The frequently used agitation rate for fermentation by yeast cells is 150–200 rpm. It is inadvisable to use excess agitation rate as it reduces metabolic activities of the cell and hence, unsuitable for smooth production of ethanol [28].



**Figure 6.**  
Effect of pH on bioethanol production [57].



**Figure 7.** The production of ethanol by *S. cerevisiae* in the industrial medium in (a) aerobic conditions and (b) aerobic-anaerobic conditions [68].

Inoculum concentration does not have any significant effect on the production of ethanol but the ethanol consumption rate and sugar yield [69]. When there is an increase in the number of cells from  $1 \times 10^4$  to  $1 \times 10^7$  cells per ml, increased ethanol production is also observed. It has been reported that when inoculum concentration exceeds  $10^7$  and  $10^8$  cells per ml, no significant effect on the ethanol production is observed [28]. At the elevated concentration of inoculum, reduction of fermentation time is observed as there is rapid cell growth.

## 8. Conclusion

The total results revealed that vegetables and fruits waste could be utilized for the production of bioethanol from recycled agricultural waste and management process. The discussions showed that bioethanol optimum yield is produced at pH 4, the temperature at  $32^\circ\text{C}$  and using 3 g/L yeast. The engine cars utilized efficiently bioethanol produced from waste rotten pineapple because it does not have high content and any dangerous elements. The principle or idea of using vegetables and fruits waste to produce bioethanol will aid in keeping the environment clean from the waste of agriculture. The process helped in overcoming the challenges of depletion of fossil fuel with the creation of bioenergy. Bioethanol produced from the agricultural waste of vegetables and fruits is of good quality with making the engine to produce less emission. Vegetables and fruits waste are a good economical choice for the production of bioethanol because of its low cost and availability.

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