BIOCONVERSION OF FOOD WASTE INTO ETHANOL USING ENZYMATIC HYDROLYZATION – MINI REVIEW

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Abstract: Globally, fuel demand is increasing day by day. The depletion of fossil fuel and its impact to the ecosystem as pollution is a serious issue. In solid-waste management, food waste disposal is a challenging one due to one-third of the food used for consumption is discharged as waste. Landfilling and incineration of FW is considered as dangerous one to the environment. FW consists of various Biomolecules such as carbohydrates, starch, proteins, lipids, cellulose, vitamins, etc. Through hydrolyze, these polysaccharides into monosaccharide such as glucose can be further fermented using microorganism can be producing ethanol. Our food system is rich in carbohydrate and starch notably that can be promising resources for the production of ethanol. Further, fermented FW broth is subjected to distillation for the separation of ethanol. Thus, this review aims to investigate the whole process to produce ethanol from food waste using enzymatic hydrolyzation.

***IndexTerms* - Food waste, Pretreatment, Enzymatic Hydrolysis, Ethanolic fermentation, Bioethanol.**

I. INTRODUCTION

Now a day, fossil fuels are decreasing due to the massive consumption Biofuels are categorized in to three generation till date, based upon substrates used, those are (i) First, (ii) Second, (iii) Third, and (iv) Fourth generation biofuels. In particular, petroleum based fossil fuels is a challenging one to deal with. Bioethanol has been introduced as an alternate source through blending along with petrol in consider amount. To manage with the global demand of biofuel particularly bioethanol has been produced from corn and sugarcane that replacing gasoline. Around 62% of production has been produced at Brazil and USA (Karmee et al. 2016). According to 2016 report done in India shows that demand of petrol in India is about 2.1 million tons. So, alternate to petrol ethanol can be used (Gundapalli et al. 2015)**.** First generation ethanol production has been focused on fermenting corn, sugarcane, soybean and other raw food material. It results in dramatically increased prices of food crops. It also leads to food depletion among worldwide. In second generation biofuels, lignocellulosic biomass involved having limitations in numerous processes and high processing cost (Naik et al. 2010). In third generation biofuels, various algal materials are used as substrate for the ethanol production. It having initial implementation and low chance of ethanol production as its limitation (Thapa et al. 2017). Further, fourth generation biofuels ethanol involves microbial cell (Jambo et al. 2017). For current situation, ethanol production from organic waste is preferred and various research has been undertaken.

Food waste is a sort of organic waste that is generated from household, restaurants, industrial sectors, cafeteria and other fields where the number of people are in taking food. Mostly, these FW are disposed by land filling, incinerating and other composting. But these are unfriendly to the environment. Other utilization of FW includes, (i) animal and cattle feed, (ii) biogas production and valorization. But these are producing only gaseous form of fuel not liquid fuels (Yang et al. 2014). In contrast, food depletion is also an important issue. According to the report of WHO in 2018, no. of hungry people growing and reaching 821 million in 2020. In Asia and Africa, 512 million and 286.5 million people are affected by food famine [WHO, Sep-2018]. In that India produce 81, 760 tons of FW annually**.** When compared to agricultural raw material wastage, processed FW after consumption have high value. Basically, FW used for ethanol production are mixed food waste, Wheat-rye bread mashes, kitchen wastes, banana peels, potato peel, instant noodles waste,etc., Multiple biomaterials are present in FW as polysaccharides such as carbohydrates, proteins, starch, lipids, cellulose, vitamins, and amino acids. These valuable biomaterials should be the promising source for the production of bioethanol. But these are polysaccharides in nature cannot be fermented by microorganism directly to ethanol. It requires hydrolyzation process to hydrolyze polysaccharides into monosaccharide such as glucose. There are various hydrolyzation processes are performed before ethanolic fermentation such as Acid hydrolyzation (Hafid et al. 2014), Enzymatic hydrolyzation (Yang et al. 2014), and Cellulose hydrolyzation (Yan et al. 2014). Before, that raw corn and sugarcane requires pretreatment. It includes physical and acidic pretreatment before hydrolyzation to degrade raw material. Physical pretreatment includes hydrothermal treatment, grinding, filtration. Acidic pretreatment includes various acids such as HCl, H2SO4, and other acids. While using FW, in most of the cases it doesn't requires such pretreatment in most of the cases, because hydrolyzation itself act as a pretreatment. Hafid et al,(2017) developed a modified acid-enzymatic pretreatment to obtain increased amount of fermented sugar (Hafid et al. 2014).

After hydrolyzation polysaccharides are converted into monosaccharide and that can be further fermented by microorganism to get ethanol. Till now, *Saccharomyces cerevisiae* is used as efficient organism for the conversion. Instead, microorganism grown within the mixed food waste can be used.

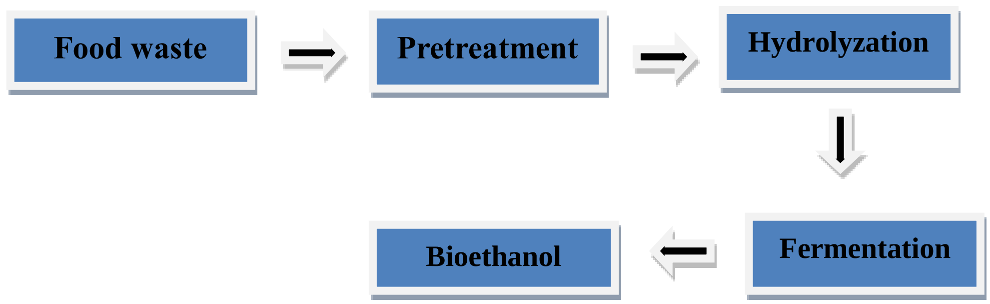

Fig: 1.1 Overall process flow of ethanol production

In this review, production of bioethanol from solid food waste using different types of FW as a raw materials are discussed. From the previous studies, enzymatic hydrolyzation reported as promising method for the polysaccharides Saccharification. After that, fermentation using microorganism is discussed. Finally, the approach of low cost raw material FW can be the better solution for the production of bioethanol. Bioethanol recovery is mostly done using distillation. Several studies reported Vacuum recovery technology to separate ethanol from FW fermented broth.

II. PRODUCTION OF BIOETHANOL

2.1. PRETREATMENT

Food waste is in multiple form. It can be either cooked or non-cooked. Because it is considering as waste it requires some pretreatment to processing it to make them ready for the ethanol production (Tang et al. 2014). In that way, physical, chemical, and physio-chemical pretreatments were implemented. Based upon the nature of the FW, pretreatment can be implemented. In most of the cases, vigorous pretreatment is not required previous to enzymatic hydrolysis. Even some modified hydrolysis along with enzymatic hydrolysis were performed to increase the yield of ethanol. Instead, autoclave of FW before fermentation is commonly needed for rising product yield and purity, but at the cost of energy and water consumption. It ought to be noted that thermal treatment could result in partial degradation of sugars and different biological process parts, further as aspect reactions (e.g. Mailard reaction) through that the amounts of helpful sugars and amino acids square measure reduced (Sakai et al. 2014). Moreover, recent and wet authority seem to be a lot of effective than rewetted dried FW (Kim et al. 2014). This is primarily because of dried substrate's surface area that reflects in the reaction efficiency between the substrate and enzyme (Koike et al. 2014). As a result, drying FW is preferable to yield ethanol in high amount with controlled microbial contamination. In acidic condition, without any thermal sterilization microbial contamination can be prevented (Ye et al. 2014). So that, acid tolerant ethanol microorganism such as *Zymomonas mobilis* has been used for the fermentation (Tao et al. 2014).

2.2. SACCHARIFICATION

As microorganism cannot convert polysaccharides directly into ethanol, it requires some additional Saccharification otherwise known as Hydrolyzation (Tubb et al. 1986). Most commonly, α-amylase, β-amylase, and glucoamylase are used to achieve more effective saccharification of molecules having higher molecular weight (Tomasik et al. 2012). Fermentable sugars (amylose, glucose, maltose, and fructose) with small molecular structures are produced from simple saccharification process (Ducroo et al. 1987). Saccharification is performed to break down the polysaccharide molecules in to monosaccharide. It is also known as Hydrolysis. Most of the saccharification of FW includes enzymatic hydrolyzation due its efficiency, commercial availability, increased productivity and minimal quantity requirement for large amount of substrate (Kim et al. 2011).

2.3. ENZYMATIC HYDROLYZATION

Kim et al., (2011) performed ethanol saccharification using enzymatic hydrolyzation by implemented carbohydrase, glucoamylase, and cellulase and protease commercial enzyme to hydrolyse food waste prior to fermentation. They have obtained yield of 0.63 g glucose/g total solid after hydrolyzed FW (Kim et al. 2011). Moon et al., (2008) reported that two commercial scale enzyme were involved to achieve hydrolyzation. They were used Amyloglucosidase extracted from genetically modified *Aspergillus niger* and Carbohydrase, a multi-enzyme complex containing arabinase, cellulase, b-glucanase, hemicellulase, and xylanase extracted from *A. aculeatus* in their studies. From that they obtained 52 and 44 g/ L of glucose yield from Amyloglucosidase and Carbohydrase respectively (Moon et al. 2009). Glucose yield was calculated by using the following formula,

$$Y_G = \frac{(G_{Final} - G_{Initial})}{Substrate\ (g)} \qquad (2.1)$$

Kiran et al., (2015) has implemented fungal mash which has rich in hydrolytic enzyme produced from waste cake and that was used for hydrolyzation of mixed food waste. In addition to glucose, Free Amino Nitrogen (FAN) was obtained. After hydrolyzation 127 g/L glucose and 1.8g/L FAN was produced (Kiran et al. 2015). Matsakas et al., (2015) implemented hydrolytic enzyme to minimize the processing cost for hydrolyzation. They were produced thermophillic fungus *Myceliophthora thermophile* for cellulose hydrolyzation. From that they were optimized 0.28 FPU/ mL of enzyme activity in extracellular broth (Matsakas et al. 2015). Su et al., were used glucoamylase and protease for enzymatic hydrolyzation of food waste (Churairat et al. 2013).

III. ETHANOL FERMENTATION

Ethanol fermentation of food waste hydrolysed broth were mostly involved into fermentation for the ethanol production. Followed by hydrolyzation of polysaccharides into monosaccharide, microorganism were involved to convert glucose into ethanol. In common commercial yeast was used to culture *Saccharomyces cerevisiae* for fermentation [Kim et al (2011), Moon et al (2009), Kiran et al (2015), Matsakas et al (2015)]. Before the inoculation of *S. cerevisiae* hydrolyzed broth was sterilized under 121°C for 15mins. Due to the availability and easy to handle condition shows interest towards it rather than other microorganism. Kim et al., compared Simultaneous saccharification fermentation (SSF) and separated hydrolysis and fermentation (SHF) for the better ethanol yield from enzymatic hydrolysed broth. From these operation, they were obtained 0.43g ethanol/g total solids and 0.31g ethanol/g total solids from SHF and SSF respectively. Their results showing the higher ethanol yield efficient from SHF (Kim et al. 2011). Moon et al., has taken sterilized FW hydrolysate into Erlenmeyer flask and the cultured S. cerevisiae strain KCTC 7107 was inoculated. This was kept at 30°C at 4.5pH with mild agitation of 100 rpm. The ethanol yield was calculated by using the following formula,

Table 3.1: Ethanol production from various food waste

Food	Fermentation	Vessel type	Pre treatment	Hydrolyzation	Microorganism	Fermentation time (h)	Y (g/g FW)	References
FW	Separate Ethanol Fermentation	500 mL flask	None	Enzymatic Hydrolyzation	*S. cerevisiae* KA4	16	0.12	(Kim et al. 2008)
FW	Simultaneous ethanol fermentation	Flask with 100g FW	None	Acid flocculation	*S. cerevisiae*	48	0.08	(Ma et al. 2007)
Bakery waste	Simultaneous	14L dfermentor	None	Enzymatic Hydrolyzation	*S. cerevisiae*	14	0.25	(Kumar et al. 1998)
FW	Fed batch fermentation	400 mL ethanol production medium	Mechanical Chopping	Enzymatic hydrolysis	*S.cerevisiae* H058	48	90.72	(Yan et al. 2012)
FW	Batch fermentation	BioAge fermenter	None	Acid Hydrolysis	*Saccharomyces cerevisiae*	60	13.7	(Thapa et al. 2019)
Potato peel waste	Batch Fermentation	250 mL Erlenmeyer Flask	None	Enzymatic and Acid Hydrolysis	*Saccharomyces cerevisiae* var. *bayanus*	48	7.58	(Arapoglou et al. 2010)

$$Y_{E/S} = \frac{Ethanol\ produced}{Substrate} \qquad (3.1)$$

They were obtained highest ethanol yield of 29.1 g/ L was achieved after 24h (Moon et al. 2009). Kiran et al., were performed fermentation in both Erlenmeyer flask and bioreactors by inoculating yeast at a ratio of 10% (v/v) under aseptic condition. Erlenmeyer flask was taken 100mL of working volume at 30°C for 72h in mild agitation of 100rpm and bioreactor was taken 1L of working volume at 30°C for 48h under 100rpm of agitation speed. At the result, FW hydrolysate contained 127 g/L of glucose and 1.8 g/L FAN sole substrate (58 g/L) was produced 0.5 g ethanol/g glucose (Kiran et al. 2015).

IV. CONCLUSION

Thus, the production of bioethanol from solid FW should be the promising approach to meet with global demand for ethanol as well as solid waste management. Most of the studies performed under this stream has successfully. Ethanol yield has been obtained within few steps. All the process from beginning to ending is comparatively simple than other. FW as a substrate is the suitable one to reuse the organic matters. So, the bioconversion of FW into ethanol using enzymatic hydrolysis will be uncomplicated to do scale-up.

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