BIOFUEL PRECURSOR FROM POTATO WASTE

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Abstract

Depleting fossil fuels and alarming rise in levels of green house gases in the atmosphere has forced for the search of alternative renewable sources of energy. With agricultural activities spreading across the globe, biomass residue generated can indeed form a useful energy source. And also the 'wastes' from specific kinds of agricultural industries have great potential to be converted into fuels. Biofuels especially ethanol produced from biomass has already received world wide attention and along with solving energy problems it is also proved to be environmental friendly.

Since ours is an agricultural country where agricultural wastes are dumped in large volumes, ethanol derived from biomass may serve as a viable option. And stream pollution by waste effluents from food processing plants has also become one of the major importances in today's world. The potato starch processing industry contributes considerably to this problem. The objective of this work is utilization of the waste i.e starch which is an effluent of various processes of a ,potato starch processing industry, by converting the starch into ethanol which can be used as an energy source for that particular industry itself. While sugar based raw materials like cane juice or molasses can be directly fermented, a two step process needs to be followed for the production of alcohol from starch based raw materials. The starch is liquefied using alpha-amylase and then saccharified using amyloglucosidase. The fuel ethanol is recovered by distillation after anaerobic fermentation using yeast primarily species of Saccharomyces cerevisia. The process described would reduce the amount of waste and ethanol used as energy source would cover the cost of the process. Further improvement in the process is being developed by changing the reaction environment to increase the rate constant of the reactor system.

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1. INTRODUCTION:

Rapid increase in volume and types of waste agricultural biomass, as a result of intensive agriculture in the wake of population growth and improved living standards, is becoming a burgeoning problem as rotten waste agricultural biomass emits methane and leachate, and open burning by the farmers to clear the lands generate CO2 and other local pollutants. Hence improper management of waste agricultural biomass is contributing towards climate change, water and soil contamination, and local air pollution. Furthermore, this waste is of high value with respect to material and energy recovery. In an agro-based country like India, where agricultural wastes are dumped at large capacity, ethanol produced from biomass may represent a sensible substitute for fossil fuel. According to United States department of energy, for every unit of energy put towards ethanol production 1.3 units are returned (Hill et al., 2006). The problem of stream pollution by waste effluents from food processing plants has also become one of major importance in today's world. The potato starch processing industry contributes considerably to this problem.
While sugar-based raw materials such as cane juice or molasses can be fermented directly, this is not possible for starch-based raw materials (Anselme et al. ,1833) They have to be converted to fermentable sugars first. Although the equipment is different, the principle of using enzymes to produce fuel alcohol is similar to that for producing potable alcohol (Anselme 1833 ,Aschengreen 1969)

Ethanol fermented from renewable sources for fuel or fuel additives are known as bio-ethanol. Additionally, the ethanol from biomass-based waste materials is considered as bio-ethanol. Bioethanol as an alternative source of energy has received special attention worldwide due to depletion of fossil fuels. (Liimatainen et al.) Recent years have seen the introduction of large scale processing in the bioconversion of biomass resources especially starchy raw materials, to ethanol, which is expected to find a wide range of uses as a bio fuel and as a starting material for various chemicals. Bio-ethanol production from potatoes is based on the utilization of waste potatoes. Waste potatoes are produced from 5-20 % of crops as byproducts in potato cultivation.(Liimatainen et al.)

The chemical breakdown or hydrolysis of starch may be performed in several different ways. It is susceptible to hydrolysis under the influence of heat, acid, certain salts, and a variety of enzymes. Each method produces its own characteristic set of hydrolytic products as the process breaks up the groups of hexoses (Hagen 1981, Lyons 1983).The hydrolysis is complex and affected by many outside conditions. It therefore does not necessarily proceed in strict conformance to a single rule. Thus a hydrolysis performed by acid may not necessarily produce the same intermediates as one using enzymes as the hydrating agent (Hagen 1981). However, the final result of a hydrolysis of starch, regardless of method, will always be glucose. When performed by acids, heat, and certain other materials, the path of hydrolysis leads through a group of dextrines, a group of still lower compounds and then final product glucose (Lewis 1996).

In relation to the hydrolysis of starch, it should be pointed out that most cereals carry a set of enzymes which will act on starch under conditions of heat and water prior to gelling (Sejr 2006). Thus slurry of corn in water can be heated and held at temperature permitting these enzymes to work before the gelling temperature is reached. In so doing, sufficient starch may be altered that gelling will not take place when the slurry is boiled.

The present process for ethanol production from starchy materials via fermentation consist of two or three steps and requires improvement if it is required to produce efficient product at low cost. However the present process of ethanol production from starchy material via fermentation consist of two or three steps and requires improvement if it is to realize efficient production at low cost. There are two main reasons for the present high cost: one is that as the yeast Saccharomyces cerevisia cannot utilize starchy materials, large amount of amylolytic enzyme namely, glucoamylase and α- amylase need to be added, the other is that the starchy raw materials need to be cooked at a high temperature (140o-180o C) to obtain high alcohol yield (ASABE. 2008, Bryan 2005). To reduce the energy cost for cooking of starchy materials the non-cooking and low temperature cooking fermentation system have succeeded in reducing energy consumption by approximately 50 %, but it is still necessary to add large amounts of amylolytic enzyme to hydrolyze starchy raw materials to glucose(Eckhoff 1995). Raw materials such as corn (maize), wheat, barley, rye or sorghum need mechanical and enzymatic pre-treatment to release the starch in a free form and to make it suitable for hydrolysis to fermentable sugars, mainly glucose and maltose. Current technology for ethanol production using Starch-based raw materials

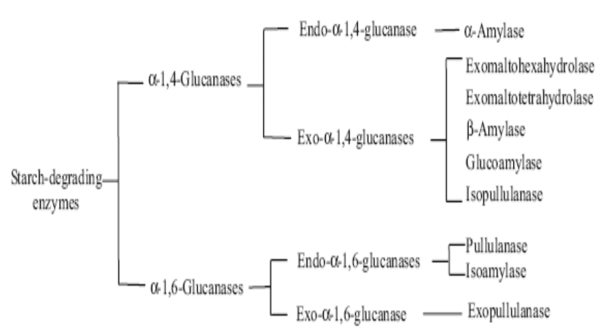

Fig.1: Classification of starch splitting enzymes (Lin & Tanak 2006);

The main process stages in alcohol production from starch-containing crops can be summarized as follows. First, the raw material is treated with viscosity reducing enzymes, then gelatinized with steam and liquefied with alpha-amylase to dissolve and dextrinize the starch carbohydrate. This treatment is referred to as "cooking" (Moreau 1996).Then, the resulting crude mash is saccharified with glucoamylase, and fermented with ordinary yeast. Finally, the fermented mash is separated by distillation into alcohol and stillage.

The starch may be liquefied and pre-saccharified using first alpha-amylase and then glucoamylase. The resulting sugar is cooled and transferred to the fermentor where yeast is added. If the fermentation processes are performed continuously the fermentation time is around 24-30 hours. After fermentation, ethanol and yeast is separated (Moreau 1998). The ethanol stream is transferred to the distillation process where the ethanol is separated from the remaining stillage. The ethanol is concentrated using conventional distillation and dehydrated. The anhydrous ethanol is blended with denaturant, often gasoline, ready for shipment into the fuel market.

Fuel ethanol is recovered by distillation after anaerobic fermentation using yeast, primarily species of Saccharomyces cerevisia.

In India, sugarcane molasses is the main raw material for ethanol production but now the short supply and increased cost is the main hindrance for its use. There are about 342 distilleries in India with an installed capacity of over 3 billion liters of ethanol annually (Narde, 2009) which is short of requirement and is met through imports. The efficiency of ethanol production largely depends on the availability of suitable substrate, yeast strain and method employed.

However, as alcohol production from starchy materials remains not so feasible economically, the development of a more effective and high-yield ethanol fermentation process is required to bring the necessary dramatic reduction of production costs. (Kondo et al. 2002). The sugary substrates available are comparatively expensive than molasses but can be easily used for ethanol production with some modification in the process. On the other hand cellulosic materials are cheaper and available in plenty but their conversion to ethanol involves many steps and is expensive. The starchy substrates are promising due to their economic viability and availability. Starchy crops like corn, barley, wheat, rice and tuber crops viz. potato, sweet potato are being exploited for the production of bioethanol world wide (Szambelan et al., 2004; Shigechi et al., 2004). The world over production of potatoes in 2007 was 325.3 million tones while in India it was approximately 26 million tons (Rani et al., 2009) showing this as a promising crop but is being used for production of ethanol in some countries (Kobayashi et al., 1998). Moreover, potatoes are rich in starch, which makes it a cheap substrate for ethanol production. The problems associated with its processing will also be less than in other grains. It is also semi-perishable food which can be stored for considerable period without spoilage. Good quality alcohol can be produced from potato which can be used for both fuel as well as potable purpose. Therefore there is a need to explore the possibility of ethanol production from potato after suitable processing and this study was planned to develop a suitable technology for conversion of potato starch into ethanol.

Table 1: Composition of potato flour under study

Composition of the Potato Flour under study	
Parameters	Percentage present
Moisture	7.20
Starch	86.90
Protein	2.76
Ash	2.00
Sugar	0.30
Fat	0.84

2. MATERIALS & METHODS:

The potato slurry (38% moisture) was gelatinized. The gelatinized mass was liquefied and pre-saccharified using first alpha-amylase and then glucoamylase before charging into the fermentor. The resulting sugar is cooled and transferred to the fermentor where yeast is added. Before transferring, the broth is diluted to attain a sugar percentage of 13%(w/v). If the fermentation processes are performed continuously the fermentation time is around 24-30 hours. After fermentation, the fermented broth and yeast is separated. The fermented broth is transferred to the distillation process where the ethanol is separated from the remaining broth. The ethanol is concentrated using conventional distillation and dehydrated. The anhydrous ethanol is blended with denaturant, often gasoline, ready for use as a biofuel.

The potato slurry can be dehydrated to powder form (7.2% moisture) for storage purpose or to transport it from one plant to another. The feasibility of reconstitution of the powder to the slurry was studied. The reconstituted slurry gave the same result as before.

2.1 Improved yeast efficiency provides increased ethanol yield

The bottleneck in an alcohol plant is often the fermentation tanks. The effect of addition of enzymes, which improve the nutritional status of the yeast, may result in a higher production capacity of the other unit operations. Improving the yeast nutrition by addition of enzymes has been shown to be able to secure that a higher intake of corn per hour in the plant can be made without extra investments in tanks, distillation towers etc. It is thus assumed that capacity increase based on corn up to 20-30 % may be implemented without extra investments that change the investments costs. Cereals, in particular maize (corn), tend to be low in soluble nitrogen compounds. This results in poor yeast growth and increased fermentation time, which can be overcome by adding ammonia, urea, or a protein-degrading enzyme, to the mash. A way to do this may be by reduction of yeast flocculation effects, by increase of the content of free amino acids and yeast nutritious compounds like minerals and vitamins.

Alcohol Production from Potato Starch by Enzymatic Process (Laboratory Experiment)

50 gm of Starch powder is mixed with 150 cc of Distilled water.

↓

Gelatinized by heating at 63oC for 15mins

↓

Enzyme Alpha-amylase (liquezyme) is dosed at 1% v/v of slurry & it is heated at water bath at 65oC for 3 hrs. liquefaction is also knows as dextrinisation of starch.
Sugar is estimated to be about 18%

↓

Saccharifying enzyme Amyloglucosidase is applied at about 0.8% v/v volume of slurry. It is heated in a water bath at about 90 – 92oC for 2 hrs.

↓

After 2 hrs. sugar content of the slurry 32%.

↓

Then fermentation medium is made and is inoculated by 10% v/v Growth Culture.
Fermentation is carried out for 48 hrs.

Enzyme for liquefaction and saccharification: commercial α-amylase for liquefaction at 65oC and amyloglucosidase saccarifying enzyme at 85oC. α-amylase: can be used for both fuel as well as potable purpose. Therefore there is a need to explore the possibility of ethanol production from potato after suitable processing and this study was planned to develop a suitable technology for conversion of potato starch into ethanol. Enzyme is also called Liquezyme.

Amyloglucosidase: - These enzymes hydrolyze 1-4 and 1-6 α-linkages from the non-reducing end of starch and dextrin molecules which produce single glucose molecules. This process set up is called Saccharification. The enzyme used is called SPIRIZYME.

Gelatinization of powdered sample: potato starch powder was mixed with water (ratio 1:3 dilution) and kept in water bath at above 65oC for 20 minutes. This gelatinized sample is further used for liquefaction and saccharification. Microbial fermentation: A fast fermenting strain of Saccharomyces cerevisia was used.

2.2 Preparation of yeast growth medium

Yeast extract- 5.0g
Peptone- 5.0g
Diluted saccharified slurry to attain an overall sugar percentage of 1%
Volume made up to 1000ml
pH-5.0
Post Fermentation, the fermented mash is distilled and alcohol % is estimated.
Percentage of Alcohol in Distillate =9%

3. RESULTS & DISCUSSIONS:

According to Hiesler et al(1970), the secondary (soluble) wastes are present in relatively low concentrations in the large volume effluents from potato starch factories. They are composed roughly as follows: protein 15%; amino compound 30%; organic acids 30%; sugars 15%; and potassium 10%. The biochemical oxygen demand of this mixture is extremely high and, therefore, requires an efficient type of sewage or waste treatment. The potato starch industry itself is a disposal operation operating on a slim margin. It cannot absorb added waste treatment costs because of heavy market competition from other starches. The process described would reduce the amount of waste, and the return for starch recovered and used as bio fuel precursor may cover the cost of the process.

3.1 Starch conversion – Liquefaction

In the cooking stage the individual characteristics of different raw materials are significant. Because the dry-milling process is automated and highly controlled in a plant the liquefaction step is highlighted. Some of the concerns of the dry-milling industry for a liquefaction amylase include consistent conversion at decreased calcium ion levels and at lower pH values. Furthermore a rapid viscosity reduction in the mash, energy cost reductions, and efficient utilization of recycle streams is demanded.

3.2 The Liquefying Amylases

Liquefaction is easily accomplished at 35-38% solids when using Liquozyme® SC from Novozymes. However, above 38 % solids the slurry becomes increasingly viscous. Liquozyme SC is a liquid enzyme preparation containing a heat-stable alpha-amylase expressed in and produced by a genetically modified strain of a Bacillus microorganism. Liquozyme SC can operate at lower pH (pH=4.5) and at lower calcium levels than conventional thermos table alpha-amylases. This brings advantages to its application which all result in reduced operating cost. Liquozyme SC was used to decrease viscosity rapidly. A maximum of 51.2 g/l ethanol was produced in 48 h as compared to 56.8 g/l ethanol in 48h when potato starch was saccharified simultaneously during fermentation which suggest that carrying out saccharification and fermentation simultaneously is equally effective as separate hydrolysis and fermentation (Fig.2).

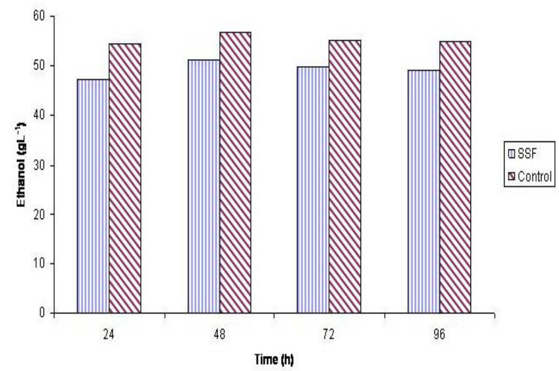

Fig. 2. Ethanol production from potato flour by simultaneous saccharification and fermentation.

The yield was quite promising at 9% yield of ethanol from the basic fermentation process.

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Publication at Conferences

1. **Adhip Ghosal**, Bidisha Mukherjee, Mehnaz Sarmin, Sayan Chatterjee , Soumitra Banerjee (2011), Environmental Technology For Energy Management: A Case Study , World Renewable Energy Technology Congress & Expo- 2011, New Delhi, India.

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Recent Publication at Conferences(2011)

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