Prospects for Tapioca in Thai Ethanol Industry

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1. Introduction

Presently, Thailand has encountered energy disadvantages due to high consumption of imported fuel oil for local transportation. With the situation of the high crude oil price in the global market which is likely to be continuously rising, Thailand, thus, unavoidably faces economic disadvantages. As a result, the exploration of new energy sources is an important policy that has continually been supported by various agencies. In particular, the development of renewable energy sources from agricultural raw material locally produced enable Thailand to strengthen sustainable stability in the areas of energy, agriculture and economics.

Biomass is one of the world important renewable energy sources. Biomass is created from plants and animals including by product and waste from living things such as husk, dung etc. With the outstanding character of being environmentally friendly renewable energy. Biomass energy used as fuel for automobiles is divided into 2 types including Ethanol and Biodiesel.

2. What is Ethanol?

Ethanol or Ethyl alcohol is organic compound of alcohol composed of Carbon, Hydrogen and Oxygen. Ethanol can be used as beverage alcohol and fuel alcohol. Beverage alcohol is any from of distilled Ethanol that is appropriate and legal for consumption but limited to the production via natural fermentation process instead of chemical synthesis process. In contrast, Fuel alcohol is Ethanol with drained water content or the so-called Anhydrous Ethanol, which contains 99.5% of pure Ethanol and can be used as fuel oil in the following 3 formats:

(1) Fuel oil to replace gasoline and diesel.

(2) blend of gasoline and Ethanol, which is called Gasohol or a blend of diesel and Ethanol, which is called Diesohol.

(3) Octane increasing substance for automobiles such as Ethyl Tertiary Butyl Ether [ETBE]

Currently, the use of pure Ethanol as fuel oil with modified engines is a blend of gasoline and Ethanol with proportion of 5-30% Ethanol in volume. The mixed Ethanol can be used to substitute MTBE [Methyl Tertiary Butyl Ether] to increase Oxygen and Octane of gasoline. At present Ethanol is used as fuel oil in many countries, for example, In Brazil, the product in the name of "Proalcohol" is a blend of 99.5% intense Ethanol in volume and 20% gasoline in volume. Besides, In the US, the product of "Gasohol" is a blend of 10% Ethanol and 90% unleaded gasoline and in Australia, the product of "Petranol" is a blend of 15% Ethanol and 85% gasoline. Lastly, in Philippines, the product of "Alcogas" is a blend of 20% Ethanol made of cane and 80% of gasoline.

2.1 Ethanol production process

The production process of Ethanol consists of 2 main types including chemical synthesis process and fermentation process.

1. Chemical synthesis process. In this process, Ethanol is produced from coefficient petroleum substance via dehydration reaction.

2. Fermentation process-In this process, Ethanol is produced from sugar by yeast through the following 2 stages: in the first stage, Monosaccharide is digested by yeast and changed into Ethanol via Glycolysis process under the Oxygen free condition, as shown in the equation below:

$$\underset{100}{C_6H_{12}O_6} + \text{ยีสต์} \longrightarrow \underset{48.89}{2CO_2} + \underset{51.11}{2C_2H_5OH} + 28.7 \text{ kcal}$$

3. Theoretically, 100% glucose is transformed into Carbondioxide and Ethanol of 48.89% and 51.11% in weight respectively. However, practically, loss during the process might emerge and other compound is made for creation of yeast cell, which 48% Ethanol is produced. In the stage, Ethanol is intensified and purified through distillation

2.2 Raw material for Ethanol production

In the present Ethanol industries worldwide, 93% Ethanol production is implemented via fermentation process. The raw material used for Ethanol production includes Carbohydrate compound like Monosaccharide. The raw material for Ethanol production can be divided into 3 types. [Picture 1] as follows:

(1) Sugar such as cane juice, molasses, beet sugar, all or which can be directly digested by yeast without any processing.

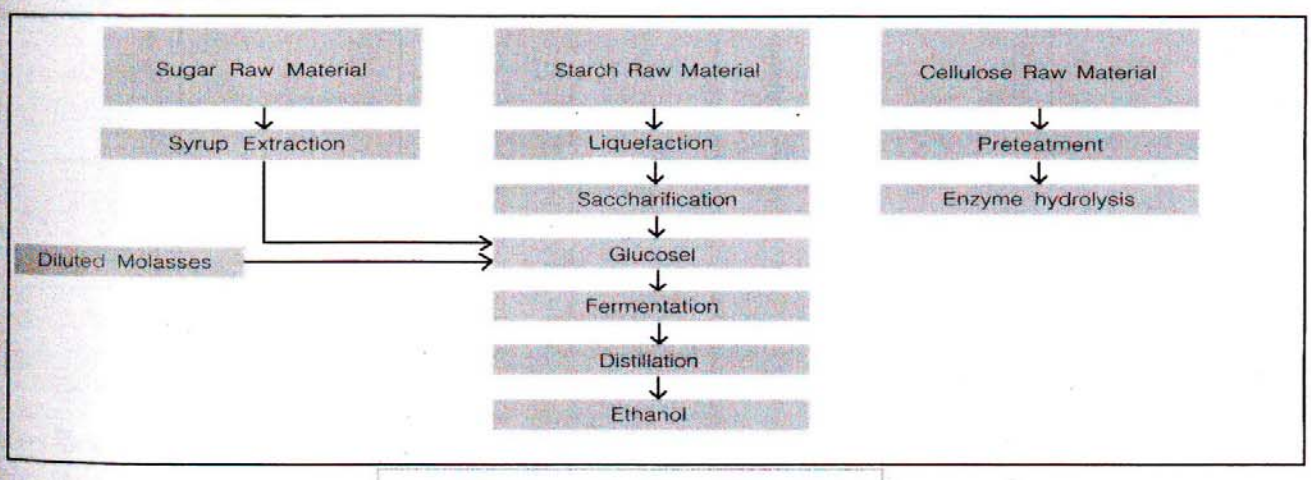
(2) Starch such as cereal, corn, tapioca and potato. In the production process of Ethanol, the starch of these materials is digested through starch hydrolysis and Monosaccharide glucose is produced and then transformed into Ethanol by yeast. The starch hydrolysis process comprises 2 stages, which can be described as follows:

- Stage 1: Liquefaction-In this process, Amylyse Acid or Alfaamylase Enzyme is used to fuction starch hydrolysis at the temperature of 80-95 degrees celcius to create the liquid with small molecules and lower viscosity, and its Dextrose Equivalent [DE] lies between 10-15, which is called Dextrine.
- Final stage: Saccharification-In this process, Glucoamylase enzyme function digestion of Dextrine to create glucose with single or small molecules to be used by yeast. In general, These enzyme function digestion at the average temperature of 55-65 degrees Celsius.

(3) Lignocelulose-the raw material of this type mostly includes by-product from agriculture and agro-industry such as rice straw, cane trash, corncob and waste from paper pulp industry. These a materials contain 4 main elements including Cellulose, Hemicellulose, Lignin and others. The production of Ethanol from these raw materials consists of 3 major stages as follow:

Stage 1: Pretreatment-In this process, the strong structure of cellulose is destroyed to allow Cellulose enzyme to access the Cellulose for easy digestion. The process can be conducted by chemical method

- such as digestion by diluted and intense acid and potash, and by physical method such as explosion, steaming or both methods can be jointly conducted depending on types of raw materials.



Picture 1: Ethanol Production by

- Stage 2: Hydrolysis-This process can be conducted in 2 methods including digestion by acid and enzyme. The digestion process by acid includes 2 stages. In the first stage, Hemicellulose is digested to create Pentose. Then in the second stage, Cellulose is digested to create glucose. As for the digestion process by enzyme, Cellulose is digested by enzyme to create glucose.
- Stage 3: Fermentation-In this process, Ethanol is made via glucose fermentation by microorganism.

The technology of Ethanol production from starch and glucose has been developed from the conventional batch system to continuous technologies. The newly developed Know-how technology which is widely used worldwide include the following types:

(1) "BIOSTIL" This technology was developed by Alfa-Laval AB Company in Sweden and firstly used in an Ethanol distilling factory in Australia with production capacity of 12,000 litres/day. The technology was later introduced into India, France, Germany, Brazil and Pakistan. The outstanding mark of this technology is the use of Schizosaccharomyces pombe, a special specie yeast that can digest molasses with 40-45 degrees Brix intensity.

With high intensity of molasses, it lessens other contaminants. After the fermentation process, the yielded solution is processed into a hi-speed swinging machine to separate the cream yeast which is revolved into the fermenting bucket where the yeast is fully grown up so it dose not require nutrient fill-in into the system, the yield of Ethanol remains high, though. The performance efficiency in transforming glucose into Ethanol and of distillation accounts for 91-92% respectively. In addition, with the only one fermenting bucket utilized in the system, a few areas are needed in the operation of this technology. With an easily automatic control of the system and a little equipment used, it results in low fixed cost. However, the restriction of this technology is the *Ethanol yielded with the low intensity of 5-7% in volume*, which consumes a great amount of energy in distillation.

(2) "HIFERM-GP" or "Cascade" This technology is developed by vogelbusch Ges.m.b.H. in Austria and mostly used in Europe, Indonesia, the U.S. and Canada. Given the high efficiency of 90% in fermentation with the yield of highly intensity Ethanol of 8.5-9.5% in volume, it consumes low energy in distillation and the production cost is low. Besides, the Cascade technology is endurable to highly intensity calcium and its fermentation process is time-saving'

(3) "HOECHST-UHDE" the outstanding function of this technology is the use of flocculating yeast in fermentation and the fermenting bucket is a type of loop reactor which rapidly completes the fermentation process and stores the highest yeast intensity all the process. The Ethanol yielded in the process has 7.5-8.0% in volume. The Ethanol distilling factory uses this technology is Diana Factory, the largest distilling factory in Brazil, which can yield 75,000 litre of Ethanol in a day. The advantages and disadvantages of this technology are similar to those of "Biostill"

(4) "LURGI" this technology developed by Mess. LURGI Company is a continuous system with six buckets placed in order, which the yeast is fixed on sodium - alginate or [immobilized]. The raw material used in the process flows into the first bucket with Ethanol intensity that is continually high and the fermented liquid from the sixth bucket is further processed into fermentation. The yeast in each bucket is adjusted to Ethanol intensity. However, with the restrictions of this technology, the yeast in each bucket needs some nutrient fill-in to grow up, some of which can be let out with the fermented liquid during the process. Therefore, in *producing Ethanol with this technology, it has to prevent* sucrose or invert sugar from letting out during the process as it can cause the lower yield of Ethanol.

(5) "STARCOSA" This technology developed by Starcosa Company in Germany is a two-stage continuous Fermentation process. During the production process, the micro-filtration membrane is used for germ disposal of raw material before fermentation and the membrane can also prevent the yeast from letting out of the fermenting bucket. In the first stage, the fermenting bucket is used to increase yeast cells with high intensity. In second stage, the Ethanol is fermented with revolving yeast between the two fermenting buckets. The Ethanol intensity yielded in the process is 6.5-8.0% in.volume. However, this technology is restricted to high production cost.

Factor	Batch	Cascade	BIOSTI	LUHDE	LURGI	STARCOCA
Yeast Intensity (Gram/Litre)	3-8	6-10	40-55	50	35-45	120-150
Percentage of Yield (%)	88-92	90-92	90-92	90-95	85-95	94
Ethanol intensity(% in Volume)	7-9	8-10	5-7	6.5-7.5	8-9	7-8
Productivity (1 Eth./ m^3h)	1.5-7	3-30	7	15-17	12-15	21

Table 1 : Summary and Comparison of Production Technologies from Starch and Glucose

3. Prospects for tapioca in Thai Ethanol Industry

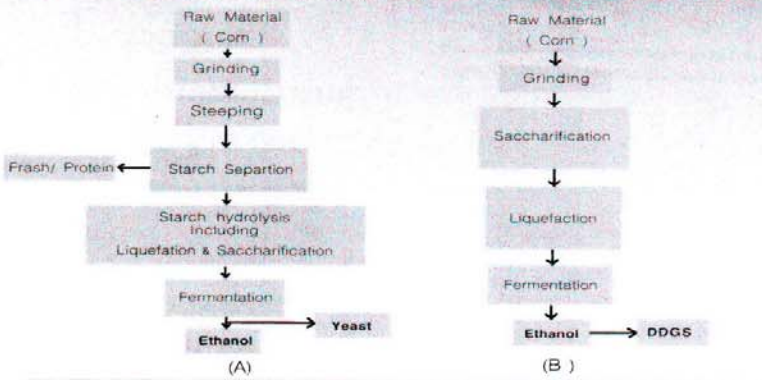
Tapioca is one of important agricultural crops to Thailand economy as it annually yields approximately 16 to 18 million tons of fresh roots. A tapioca fresh root contains high starch content [about 70' 85% in weight. As a result, Tapioca is used as agricultural raw material in Ethanol industry. In the process of Ethanol, the harvested tapioca is transformed into tapioca chips in order to ease and lengthen the life, time of raw material storage as well as to facilitate transportation. However the use of tapioca as raw material in Ethanol industry is problematically cost ineffective production process. In other words, during the production process, the starch is transformed into glucose and then alcohol respectively. The next process is distillation of burnt Ethanol is less than the energy used in the production process of Ethanol.

However, with a great number of tapioca and its cheap price which are two main factors supporting Thai Ethanol industry including the U.S. advanced technology of Ethanol fermentation from high starch content crops, the outlook of Ethanol industry is likely possible.
Ethanol production technology from corn is divided into two types as follows:

(1) Wet milling process–the production process starts from corn seed steeping, grinding and separating other contents of corn like oil, trash, Protein. Next, the liquid starch is adjusted to the condition of pH. Balance equivalent to 6 [depending on enzyme types], which is suitable for the function of enzymes. Then, the first starch hydrolysis function using Alfa-amylase enzymes which is heated with jet cooker system at the temperature of 80–90 degrees Celsius for Gelatinization process and the fixed temperature also helps the function of enzyme. After the first hydrolysis, the liquid starch is made cool and adjusted to the condition pH. Value on a scale of 4.5 to 5.0 to fit the second hydrolysis. In the second hydrolysis, Gluco-amylase enzyme is used to transform starch into glucose and the glucose is then processed to fermentation and distillation.

(2) Dry grinding process–the production process starts from raw material grinding with a hammer mill. Then, the ground material is mixed with water and adjusted to the condition of pH. Balance equivalent to 6 [depending on enzyme types], which is suitable to the function of enzyme. Next, the first starch hydrolysis functions using Alfa-amylase enzyme which is heated at the temperature of 80–90 degree Celsius for Gelatinization process

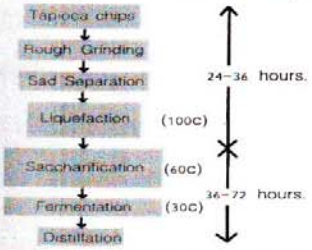
and the fixed temperature also helps the function of enzyme. After the first hydrolysis, the liquid starch is made cool and adjusted to the condition of pH. Balance on a scale of 4.5 to 5.0 to fit the second hydrolysis which transforms the starch into glucose and the glucose is processed to the next fermentation. The fermentation process lasts by 48–72 hours and the yielded fermented liquid contains Ethanol of 12% intensity in volume. The fermented liquid is processed to distillation to intensity 95% Ethanol and purify it. Indistillation process, the yielded stillage can be intensified and mixed with the fermented trash and then dried to produce Distiller Dried Grains with Soluble [DDS], which is highly nutritious and can be used as animal feed

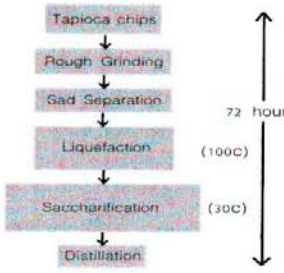


Picture 2: Ethanol Production Process by Wet Milling Process dry Grinding process

With technology development to enhance efficient production process, the prospects for tapioca in Ethanol production will be rising. To boost the efficient production process, the stage of Saccharification has to be merged with the stage of fermentation, the process of which is called Simultaneous Saccharification and Fermentation [SSF]. In this process, the enzyme producing glucose function starch hydrolysis in the same condition as fermentation at the

temperature of 30 degrees Celsius with the average pH. Value on a scale of 4 to 4.5. This helps save time for the stage of starch hydrolysis, which results in energy saving process of production.





PICTURE 3:Ethanol production process from Tapioca Chips by (A) Normal process and (B)

Simultaneous Sacharification and Fermentation (SSF)

The cost of Ethanol production from tapioca is likely to reduce due to development of important technology including;

1. Biotechnology – with the advanced technology, the enzyme is developed with high performance, convenient use and cheaper price. Moreover, the yeast development is conducted to create the type more suitable for fermentation process such as the yeast endurable to high temperature [Thermosac by Altech, Co.]

2 Production technology of Anhydrous Ethanol – The conventional distilling process in purifying 95% to 99.5% Ethanol is called Azeotropic Distillation, which is a distilling process of mixed content using Aceotropic property of mixed contents. Presently, the conventional distillation process is not popularly used as it needs a distillation stimulant like Benzine which is inflammable and can cause cancer. Besides, This process comprises complicated working system and needs high construction cost as well as uses lots of steam to energize distillation. Currently, the production technology of Anhydrous Ethanol has been considerably developed, which contributes to lower cost and less complicated function as the newly developed technology uses Molecular Sieve Dehydrator, Zeolyte substance which normally suck air moisture to suck the liquid from distilled Ethanol. Moreover, This technology uses membrane pervaporator which functions by permeate membrane and evaporation process.

Summary

In the past, Ethanol industry from tapioca hardly became true. But with present advanced technology which has been continually developed, the prospects for tapioca in Ethanol industry are likely to become true. Various development has been conducted to encourage the prospects of Ethanol industry such as development of more tapioca starch content, reduction of energy consumed by 30% by improving hydrolysis process of SSF system and development of the use of fermented and distilled residue.

Source : Year Book 2005 .Thai Tapioca Starch Association.