

**ANALYSIS OF MATERIAL BALANCE IN THE APPLICATION
OF DIFFERENT SOURCES OF BIOMASS FOR BIOETHANOL PRODUCTION**
PHÂN TÍCH CÂN BẰNG VẬT LIỆU TRONG VIỆC SỬ DỤNG
CÁC NGUỒN BIOMASS KHÁC NHAU ĐỂ SẢN XUẤT ETHANOL

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ABSTRACT

Biomass could be used as a cellulosic material in bioethanol production. Nevertheless, the application capability depends on its cellulose percentage as well as its structure. The article analyzes the chemical composition, structure and the availability of rice husk, rice straw, and sugarcane waste, and evaluates their application availability in bioethanol production. Among all the components of plant-based biomass resources, cellulose structure and its percentage are most important for ethanol production.

Keywords: Biomass, bio-ethanol

TÓM TẮT

Biomass có thể sử dụng làm nguồn nguyên liệu chứa xen-lu-lô để sản xuất ethanol. Tuy nhiên, khả năng sử dụng phụ thuộc vào thành phần xen-lu-lô cũng như cấu trúc của nó trong nguyên liệu. Bài báo trình bày các kết quả phân tích thành phần hoá học, cấu trúc và khả năng cung cấp các loại chất thải nông nghiệp như rơm rạ, trấu, bột bã khoai mì, bã mía, và đánh giá khả năng sử dụng chúng trong việc sản xuất ethanol. Trong các thành phần cấu tạo nên biomass thực vật, xen-lu-lô và tỷ lệ phần trăm của nó trong vật liệu là yếu tố quan trọng nhất quyết định khả năng ứng dụng nó vào mục đích sản xuất ethanol.

I. INTRODUCTION

Nowadays, too much dependence on fossil fuel of the world make future of the human have to bear difficult tasks. During centuries, the human have developing basis on the fossil energy consume and release into the environment a very huge of pollution gas and industrial dust without any hesitance.

Petroleum has been refined for centuries. In principle, organic material could also be refined for practical application as petroleum. Among the accessible organic substances, cellulosic biomass attracts one's attention more and more, for its availability, technological-possibility and prospected economy. One of the available targeted products of cellulosic biomass is bio-ethanol. It has been widely known that bioethanol could be used to partly replace or mix with gasoline as industrial fuel.

Basically, Vietnam is an agricultural country, whose production releases a huge volume of biomass as by-products/wastes, such as rice husk, rice straw, coconut-fiber powder,

sugarcane baggase, cassava waste, etc. These by-products are quite possible important material for industrial bioethanol.

II. ANNUAL POTENTIALITY RESOURCE OF AGRICULTURAL RESIDUES IN VIETNAM

Vietnam is a tropical country with an area of about 331,688 km². The plain area of 20% of the total area mainly concentrates in the two river deltas of the country: the Red River Delta in the North and the Mekong River Delta in the South. The rest areas consist of hills, forested mountains and tropical forest. The Red River Delta is a flat, triangular region of 15,000 km². The Mekong River Delta, covering 40,000 km², is a low-level plain, not more than three meters above the sea level, supported with a maze of canals and rivers [2]. Agriculture, of which the main products are rice, maize, sweet potato, peanut, soybean, cotton, coffee, cashews, etc., is the main economic production of the country. Total cultivated land of Vietnam is about 12.2 million hectares, of which 21% is arable, 28%

is seized by forest and woodland and the rest 51% is used for other purposes [3].

Agricultural production contributed about 20.4% of GDP of the country, based on the data of the year 2006. In 2007, rice yield reached 35.8 million tons, including 4 million tons for export; maize yield - 2.8 million tones and cassava - 5.5 million tons. [4]. Together with the main products, an enormous agricultural byproducts and wastes are produced. Some figures about the main agricultural products and residues are pointed out in Tables 1 and 2.

Table 1. Potential of agricultural production of Vietnam 2007 (unit: million tons)(a)

Sugar cane	Cassava root	Rice
17.34	7.96	35.8

(a) Based on the published data from General Statistics Office, Vietnam, 2007

Table 2. Potential of agricultural residues as biomass resources of Vietnam based on above data (unit: million tons) (b)

Bagasse	Cassava fiber waste *	Rice husk	Rice straw **
2.4	1.3	7.16	43

(b) Based on the published data from General Statistics Office, Vietnam, 2007

* Provided that total cassava roots is used for starch production.

** Without stubbles.

Among the listed agricultural residues, huge amount is counted for rice straw and rice husk. Up till now, most of the rice wastes have been burned on the field, aiming at returning

some minerals to the soil. Sugar cane waste is used as family fuel in countryside. Cassava residues are dispersed as solid wastes could be using for heat supply in sugar drying.

A question raised from the situation is if and how energy could be collected from the wasted biomass resources as organic substances. One of the possible options for the answer is bioethanol which is technologically available and usable for industrial furnaces as direct burning fuel and for static/mobile engine in the single form or in the form of mixed fuel with gasoline.

III. MATERIAL COMPOSITION OF BIOMASS

“Lignocellulosic biomass” refers to plant biomass that consists of cellulose, hemicelluloses and lignin. In the structure of the plant-based biomass, the carbohydrate polymers (cellulose and hemicelluloses) are tightly bound to the lignin by hydrogen and covalent bonds [5]. Ethanol feedstock material from agricultural byproduct components is pointed out in Table 3.

Necessary basic starting material for ethanol production from biomass is cellulose. It is important to know the percentage of cellulose in the biomass and the total ability/efficiency to convert from starting material into final bioethanol product. Figure1 showed the total efficiency to convert it into ethanol form different starting materials.

The concrete composition of popular starting biomass resources is shown in Table 3.

Table 3. Dry composition (%) of some cellulose-based biomass resources as agricultural residues, based on dried weights [6, 7, 8, 9].

	Cellulose	Hemi-Cellulose	Lignin	Ash & others	Starch
Rice husk	38.5	20.5	20.24	20.76	0
Rice straw	43.96	22.39	4.65	29.00	0
Cassava fiber waste	23.74	27.16	4.16	13.16	31.78
Bagasse	46.53	21.36	11.14	20.97	0

IV. TECHNOLOGICAL METHODS AND MATERIAL BALANCE OF ETHANOL PRODUCTION

Lignocellulosic material is a kind of composite, mainly consists of cellulose, hemicellulose and lignin. Ethanol can be produced from glucose which produced from cellulose. Ethanol could be also made from hemicellulose but much more difficultly, less effectively and hence less economically. In the biomass structure, cellulose component is covered by lignin layer and linked together by hemicellulose, so that lignocellulosic frame is very stable. It is necessary to be broken out to make cellulose fiber exposed which called active fiber, so that the cellulose could be attacked by chemicals or enzymes then.

There are a lot of methods to treat cellulosic material for saccharification of cellulose before ethanol fermentation. Among the known possible methods, steam explosion is one of the considered options [6-9]. Compared with the chemical treatment, the steam explosion method does not require chemical reagent, so that no equipment corrosion need to be taken care, no chemical wastes will be released to the environment, and no special treatment dealing with chemicals need to be done before further processing. For the future biomass-based bioethanol production in Vietnam, this method is priority chosen for its advantages to other methods.

Most of plant-based biomass sources will undergo the procedures described above, except cassava fiber waste, from which starch has to be removed beforehand by amylases enzymes. Compositions of different components of various types of biomass are described in Table 3.

The efficiency of the ethanol production depends on the efficiency of each step in the whole processes (Figure 1 and Figure 2). In the whole process of ethanol production, the efficiency in pretreatment and saccharification processes is the lowest and depends very much on the procedures and applied conditions. Typical efficiencies of processes from different types of biomass are presented in Figure 3.

Consider the ethanol fermentation process from the saccharified glucose, it has been known that one molecule of cellulose could produce two molecules of carbonic gas and two molecules of ethanol as described in the following equation:



Based on the equation, it is easy to calculate the mass and energy balances of the biomass conversion reaction. The calculated data are pointed out in Table 4.

Table 4. Mass and energy balances in the glucose - ethanol conversion.[13]

	Molecule masses	ΔH^0_{298} (kJ)
Glucose	180	2807
Gained ethanol	92	2738
Released CO ₂	88	0
Balance	0	-69
Recovery efficiency (ethanol/glucose)	0.51 (kg/kg)	0.975 (kJ/kJ)

By the laboratory tests, practical efficiency of the process is about 95%, provided that the fermentation process with *Saccharomyces Cerevisae* yeast is applied.

V. EVALUATION OF THE BIOETHANOL POTENTIAL FROM AGRICULTURAL BIOMASS RESOURCES

As describe before, there are several processes which could be applied to produce bioethanol from biomass. One of the most practical methods is the process based on the steam explosion, followed by enzymatic saccharification and yeast fermentation to get ethanol. The flow sheet of the method is described in Figure 1. Based on the experimental results is show in Table 3 and Figure 3, it is easy to evaluate the consumption of raw material, and therefore the possible potential of biomass-based bioethanol production in Vietnam. The calculated data are shown in Tables 5 and Table 6.

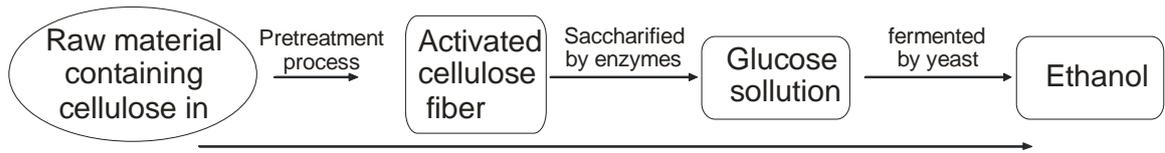


Fig. 1 Basic flow-sheet of ethanol production from cellulosic starting material.

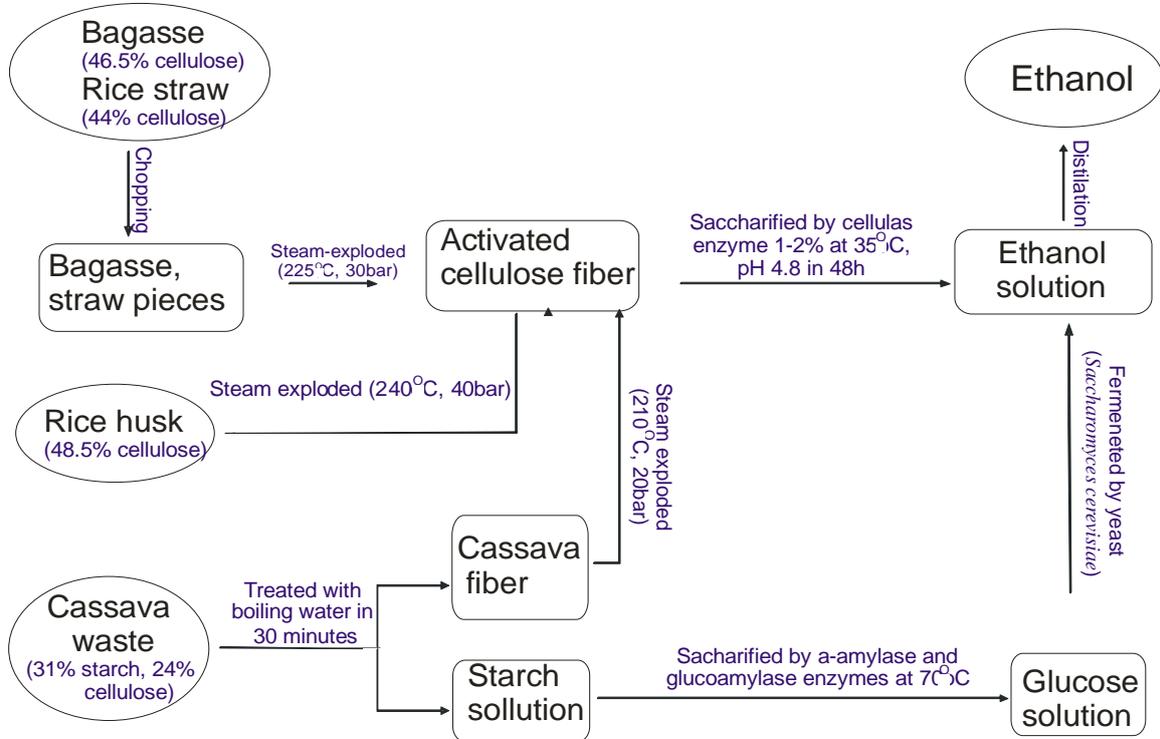


Fig. 2 Flow-sheet of bioethanol production from different cellulosic biomass sources.

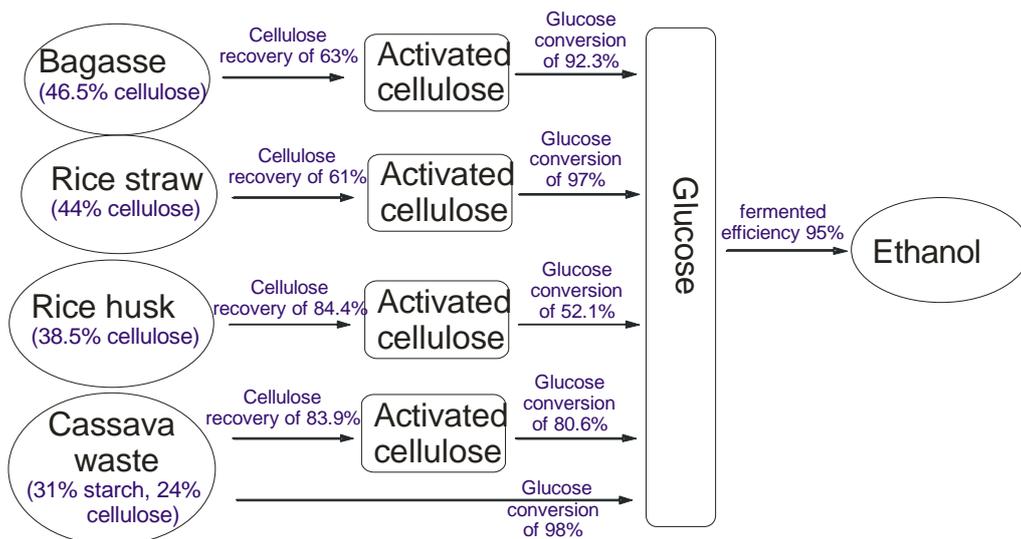


Fig. 3 The efficiency of each step during ethanol production from different starting materials [6,7,8,9]

Table 5. Biomass consumption in bioethanol production (kg biomass/kg bio-ethanol)[6, 7, 8, 9].

Bagasse	Cassava fiber waste	Rice husk	Rice straw
8.01	4.4 *	12.19	7.9

(* Ethanol is produced from both remaining starch and cellulose)

Table 6. Biomass-based bioethanol potential from biomass resources of Vietnam based on the calculated data. (thousand tons)

Bagasse	Cassava fiber waste	Rice husk	Rice straw	Total
299	295	587	5443	6624

VI. DISCUSSION AND CONCLUSIONS

Vietnam is basically an agricultural country with a rather high productivity of agricultural products. As a result, produced biomass as agricultural residues, which are valuable resources of energy. When biomass-based bioethanol is chosen as the targeted fuel, rice straw is the highest available biomass material. Even though, collection of rice straw from rice fields is always a problem, and it will contribute to increase production cost of bio-ethanol. Next comes rice husk, which is concentrated near rice mills and hence helps to diminish transportation expenses. Nevertheless, rice husk contains high concentration of silica,

which causes essential difficulties in processing technology. Cassava fiber waste powder could give high yield of bio-ethanol, but environmentally harmful able, and the wastes difficult to be well treated from this production might be a key disadvantage of the material type. Although a less productivity could be expected, sugar cane waste is much easier to process. By the way, sugar cane and rice straw could help to supply minerals to the soil after processing. In the viewpoint, these two biomass types could be considered the most important biomass resources for biomass-based bioethanol production.

At the moment, Vietnam consumes about 7 million tons of gasoline per year. For mixing with the gasoline to make bio-fuel, at least an amount of 700 thousand tons of ethanol annual is necessary for E10. This creates a considerable market for biomass-based bioethanol production, not destroying the existing picture of food production and consumption. To do it, further attempts to make the technology available and the production cost remarkably diminished are necessary.

Acknowledgements

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