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Simultaneous Production of Sugar and Ethanol from Sugarcane in China, the Development, Research and Prospect Aspects

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1. Introduction

With the ever growing concern on the speed at which fossil fuel reserves are being used up and the damage that burning them does to the environment, the development of sustainable fuels has become an increasingly attractive topic (Wyman & Hinman, 1990; Lynd & Wang, 2004; Herrera, 2004; Tanaka, 2006; Chandel et al., 2007; Dien et al., 2006; Marèlne Cot, et al., 2007). The interest partially caused by environment concern, especially global warming due to emission of Greenhouse Gas (GHG). Other factors include the rise of oil prices due to its unrenewability, interest in diversifying the energy matrix, security of energy supply and, in some cases, rural development (Walter et al., 2008). The bioethanol such as sugarcane ethanol is an important part of energy substitutes (Wheals et al., 1999). This chapter was focused on the development and trends of the sugarcane ethanol in China. Based on the analysis of the challenge and the chance during the development of the sugarcane ethanol in China, it introduced a novel process which is suitable for China, and mainly talked about simultaneous production of sugar and ethanol from sugarcane, the development of sugarcane varieties ,ethanol production technology, and prospect aspects. We hope it will provide references for evaluation the feasibility of sugarcane ethanol in China, and will be helpful to the fuel ethanol development in China.

2. Sugarcane for bioethanol - A new highlight of sugar industry development

The technology of producing fuel ethanol using sugarcane, which has a characteristic of high rate of energy conversion, wide adaptability, and strong resistance, etc, has received extensive attention (Watanabe, 2009). Brazil, Australia and other countries have made breakthroughs in the sugarcane improvement, ethanol fermentation process and its application (Goldemberg et al., 2008; International Energy Agency (IEA), 2004). Brazil is the world's largest sugar producer and exporter of fuel ethanol, which is expected that annual output of 65 billion liters by 2020(Walter et al., 2008). Energy security and environmental stress force China to seek and develop biofuels as a substitute of fossil energy. Meanwhile, China has also introduced policies that encourage the development of fuel ethanol using sugarcane and other non-food crop, to ease pressure on energy demand. Recently, the study and the industrial-scale production of biofuels, particularly, fuel ethanol and biodiesel, have progressed remarkably in China as a result of government preferential policies and funding supports (Zhong et al., 2010).

Fig. 1. Highlight of sugarcane for bioethanol

3. Benefits of sugarcane for ethanol

The reasons why we choose ethanol from sugarcane as the most promising biofuels are illustrated below. Firstly, the balance of GHG emissions of sugarcane ethanol is the best among all biofuels currently produced (Macedo et al., 2008; Cerri et al., 2009; Oliveira et al., 2005). As reviewed in several studies, bioethanol based on sugarcane can achieve greenhouse gas reductions of more than 80% compared to fossil fuel use (Macedo et al., 2008). Figure 2 (BNDES, 2008) showed correspond to the consumption of ethanol produced from maize (USA), from wheat (Canada and Europe) and from sugarcane (produced in Brazil and consumed in Brazil or in Europe). Sugarcane ethanol is much better than ethanol from maize and wheat (a maximum of 35%) in case of the avoided emissions.

Secondly, as we known, cropland is very limited for planting in China. So it is very important that the land use is keeping in a high efficient level. Ethanol from sugarcane is the most productive among different crops. The fortunate experience of ethanol use in Brazil may also be coupled with a superior sucrose yield and a higher potential of biomass production of sugarcane – an average of 87 tons per hectare in South Central Brazil – than observed in other crops. As shown in figure 3, only beets can be compared with sugarcane in terms of ethanol production per cultivated hectare. However, the industrial process of ethanol production from beets depends on an external power input (electricity and fuel) while sugarcane electricity is provided by bagasse burning at the mill. (BNDES, 2008).

Ethanol produced from sugarcane is the biofuel with the best energy balance (see table1). This can be illustrated as the ratio between renewable products and the energy input as fossil fuel for Brazilian sugarcane ethanol is 9.3 (compared with 1.2-1.4 in the case of ethanol produced from American maize, and approximately 2.0 in the case of ethanol produced from European wheat). Apart from these above, other environmental impacts of the sugarcane sector, such as water consumption, contamination of soils and water shields due to the use of fertilizers and chemicals, and loss of biodiversity, are less important in comparison to other crops (Watanabe, 2009). Above in all, Sugarcane is by far the best alternative from the economical, energy and environmental point of view, for bio-fuel production.

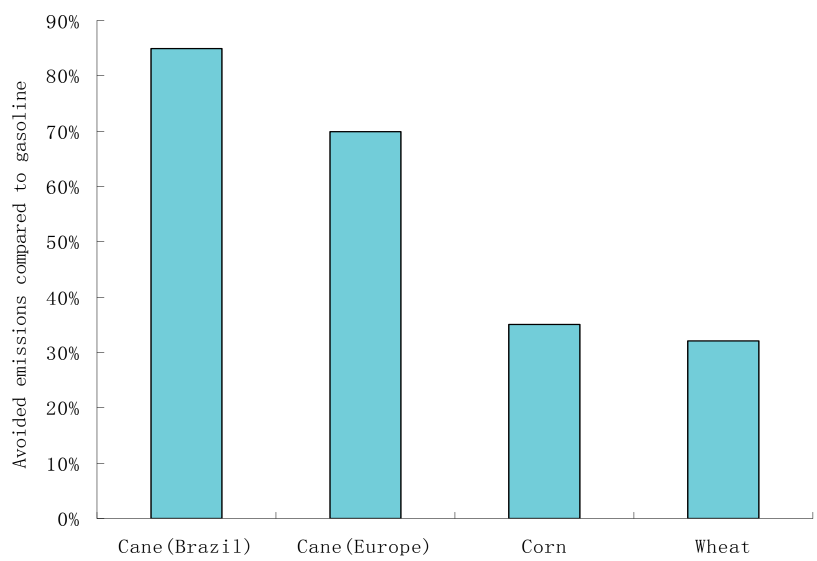

Fig. 2. Avoided GHG emissions in comparison with full life-cycle of gasoline

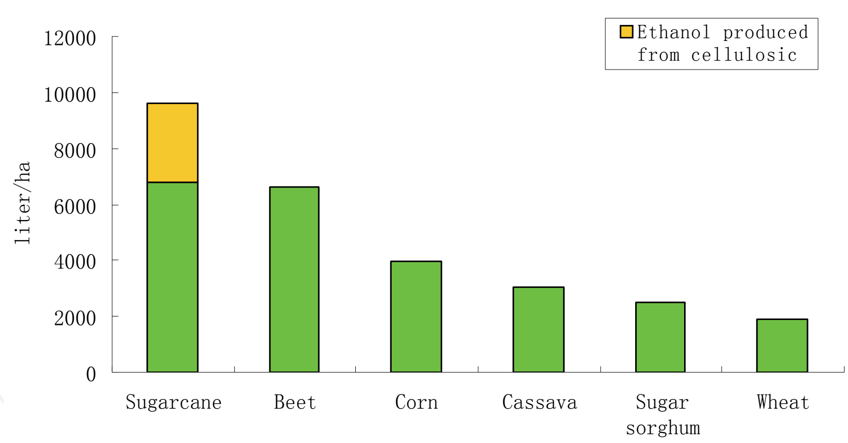

Fig. 3. Average ethanol productivity per area for different crops. Source: BENDES(2008)

Feedstock	Energy ratio
Sugarcane	9.3
Lignocellulosic residues	8.3~8.4
Cassava	1.6~1.7
Beet	1.2~1.8
Wheat	0.9~1.1
Corn	0.6~2.0

Table 1. Comparison of different feedstock for biofuel production. Source:BNDES(2008)

4. The challenge and perspectives to develop sugarcane ethanol in China

Sugarcane is mainly planted in southern China, such as Guangxi, Yunnan, Guangdong, Hainan et al, Its total planting areas were about 20 million acres in 2010 statistically, and Guangxi contribute about 60 percent of the total. Lands suitability for sugarcane is limited. It is very difficult to expand the land for sugarcane production because of the industrialization in China. An additional challenge is the harvesting. High investment requirements and difficulties with mechanization on, for example steep land, increase the risks of the implementation of mechanized harvest. About over 90 percent of the China sugarcane area was still manually harvested. Expansion of sugarcane areas will be affected by the cost/benefit of manual labor. Under the driving of the market opportunities, national policies giving incentives to the sugarcane agri-business, the further expansion of sugarcane areas forecasted for China is expected to about 2 million acres, which mustn't reduce the availability of arable land for the cultivation of food and feed crops.

There are risks of environmental degradation in different stages of sugarcane ethanol production and processing. Negative impacts have been caused by the lack of implementation of best management practices and ineffective legislation and control. Nevertheless, further improvements are necessary.

A major concern of developing sugarcane ethanol in China is the threat to sugar security. Rapid expansion of bioethanol production could potentially reduce the availability of sugar production, causing a reduction in its supply and increase of sugar price. In recent years, the sugar productions are stably at about 12 million tons, the max exceeded 14.84 million tons in 2008. While the total demand for sugar is about 12 million tons in China. With the combination of the further expansion of about 2 million acres sugarcane areas, and applying the advanced technology, for example: genetically modified sugarcane and improved cultivation techniques, yields can be increased from 5 tons to about 6-7 tons . So the sugar productions in China are expected to over 16 million tons. Based on these estimates, without affecting the supply of sugar, the current potential of sugarcane ethanol production reached over 2 million tons.

5. Simultaneous production of sugar and ethanol from sugarcane

As the major raw material, most of sugarcanes are refined into sugar in China now. Also the international sugar price is running in high level, and it needs to balance the domestic sugar supply and demand through imports, so it is impossible to produce large amounts of ethanol by sugarcane. However, it is unfavorable to sugar price stability and its healthy development if only refining sugar. To achieve more economic benefits, a viable option is to explore the "Simultaneous production of sugar and ethanol " mode. In recent years, we have made some progress on the sugarcane breeding, ethanol production technologies and process optimization for simultaneous production of sugar and ethanol.

5.1 Material distribution

At present, sugar is produced following the three stage boiling technology or the three and a half stage boiling technology. It takes a long time and high energy consumption to boil the B sugar and C sugar. The value the by-product is low. There are high costs and weak adaptability to the market.

Generally, it is advantage to regulate sugar production and ethanol production according to market demand the flexibility while applying the "Simultaneous production of sugar and ethanol" mode. It is necessary to distribute the raw material fluxes rationally. However, less literature is related to juice and syrup distribution for simultaneous production of sugar and ethanol. In this paper, material fluxes balance calculation is carried out according to Brazil experience and the parameters of three and a half stage boiling process. The feed syrup is 60 Bx, the purity is 87%, and the feed syrup fluxes are 100 tons. The sugar combined fuel ethanol process is showed as Figure 4:

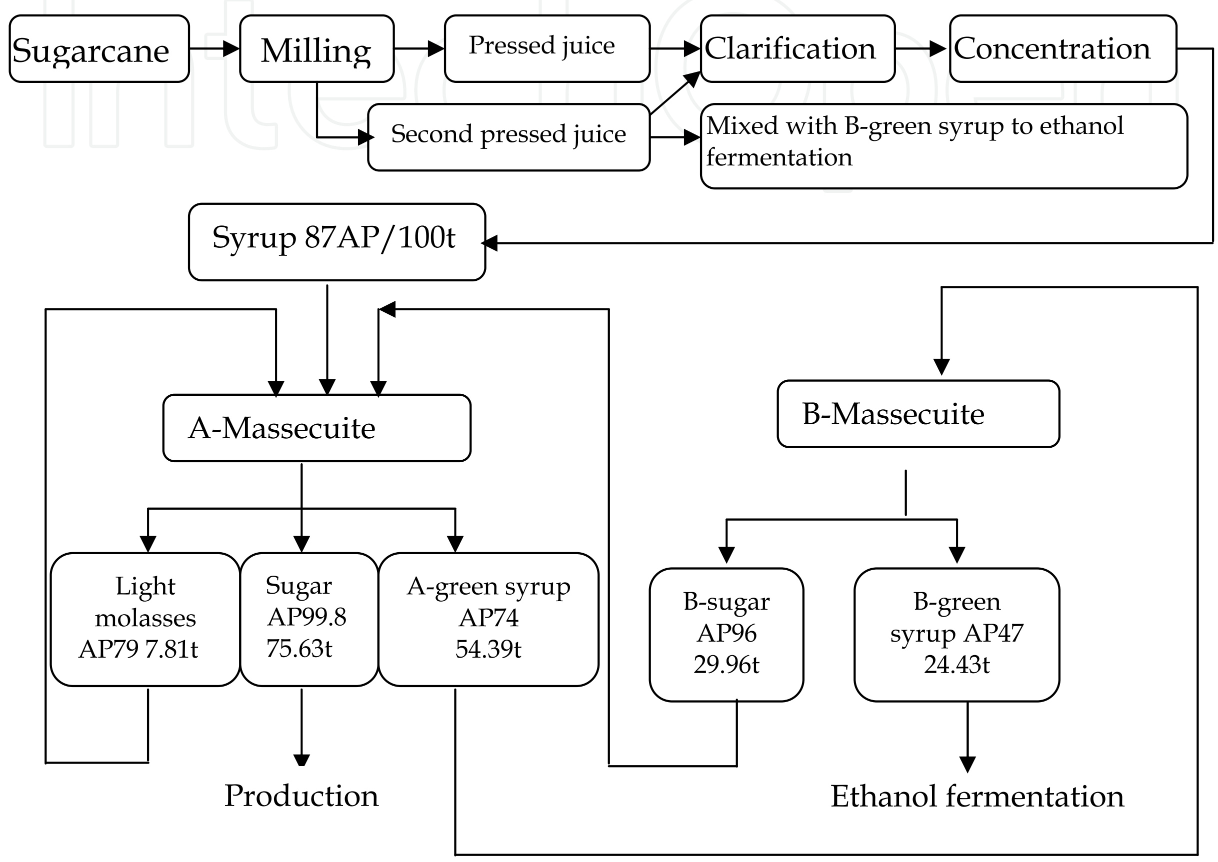

Fig. 4. Sugar combined ethanol process and its material balance

5.2 Sugarcane for simultaneous production of sugar and ethanol

In China, biotechnology research and genetic improvement have led to the development of strains which are more resistant to disease, bacteria, and pests, and also have the capacity to respond to different environments, thus allowing the expansion of sugarcane cultivation. The leading sugar enterprise in charge for applied research on agriculture, together with research developed by state institutes and universities. Efforts have been concentrated in taking advantage of its genetic diversity and high photosynthetic efficiency characteristic, high separation sugarcane population was generated via distant hybridization technology. To obtain the new material of sugarcane for ethanol, we took total biomass, total fermentable sugars as targets and adopted advanced photosynthetic efficiency living early-generation determination technology, molecular markers and cell engineering technology combined with conventional breeding. Then, in order to optimize the selection of energy sugarcane, we took a series of pilot test and technical and economic indexes of evaluation. By 2010, more than 10 sugarcane varieties for simultaneous production of sugar and ethanol are cultivated in China, such as "00-236", "FN91-4710","FN94-0403", FN95-1702","G94-116", "Y93-159", "Y94-128", "G-22" et al.. Although potential benefits are high, there is still a lack of understanding of the potential impacts of genetically modified organisms on environmental parameters.

Fig. 5. Sugarcane for simultaneous production of sugar and ethanol

5.3 Ethanol production technologies for simultaneous production of sugar and ethanol

5.3.1 Genome shuffling of *Saccharomyces cerevisae* for multiple-stress resistant yeast to produce bioethanol

In the fermentation process, sugars are transformed into ethanol by addition of microoganism. Ethanol production from sugars has been commercially dominated by the yeast *S. cereviseae* (Tanaka, 2006). Practically, yeast cells are often exposed in multiple stress environments. Therefore, it is helpful to fermentation efficiency and economic benefits to breed the yeast strains with tolerance against the multiple-stress such as temperature, ethanol, osmotic pressure, and so on (Cakar et al., 2005). Yeast strain improvement strategies are numerous and often complementary to each other, a summary of the main technologies is shown in Table 2. The choice among them is based on three factors: (1) the genetic nature of traits (monogenic or polygenic), (2) the knowledge of the genes involved (rational or blind approaches) (3) the aim of the genetic manipulation (Giudici et al ., 2005; Gasch et al., 2000).

Genetics of Dpt Strategies			Aims
Rational approaches (for known genes)	Monogenic	Single target mutagenesis or cassette mutagenesis	Silencing of one genetic Function
		Metabolic engineering	Inserting a new function, modulating a function already present
	Polygenic	Multiple target mutagenesis	Silencing of many genetic functions
		Metabolic engineering (for a small number of genes)	Inserting more functions, modulating more already present functions
Blind approaches (for unknown genes)	Monogenic	Random mutagenesis	Silencing of a genetic function
	Polygenic	Metagenomic techniques	Inserting genes cluster
		Sexual recombination	Improving Dpt, obtaining a combination of Dpts
		Genome shuffling	Improving Dpt, obtaining a combination of Dpts

Table 2. Summary of the main genetic improvement strategies. Dpt Desired phenotype

It is difficult to improve the multi-tolerance of the yeast by rational genetic engineering technology before its mechanism completely clarified. Nevertheless, for quantitative traits, the number of responsible genes QTLs is so great that a "gene-by-gene" engineering strategy is impossible to perform. In these cases, blind strategies, such as genome shuffling (Zhang et al., 2002), could be applied in order to obtain quickly strains with recombinant traits. Genome shuffling is an accelerated evolutionary approach that, on the base of the recursive multiparental protoplast fusion, permits obtaining the desired complex phenotype more rapidly than the normal breeding methods (Figure 6). Genome shuffling technology can bring a rapidly improvement of breeding a hybrid with whole-genome random reorganization. After the initial strains in various long term evolution experiments (Figure 7), we successfully applied the genome shuffling technology that combines the advantage of multi- parental recursive fusion with the recombination of entire genomes normally associated with conventional mutant breeding to selecting the multiple-stress resistant yeast (Figure 8).

5.3.2 Continuous fermentation

Traditionally, ethanol has been produced batch wise. However, high labor costs and the low productivity offered by the batch process have led many commercial operators to consider the continuous fermentation. Continuous fermentation can be performed in different kind of bioreactors – stirred tank reactors or plug flow reactors. Continuous fermentation often gives a higher productivity, offers ease of control and is less labor intensive than batch fermentation (Cheng et al., 2007). However contamination is more serious in this operation (Skinner & Leathers, 2004). In the fuel ethanol industry, control of bacterial contamination is achieved by acidification and using antibiotics such as penicillin G, streptomycin, tetracycline (Aquarone E,1960; Day et al., 1954), virginiamycin(Hamdy et al., 1996; Hynes et

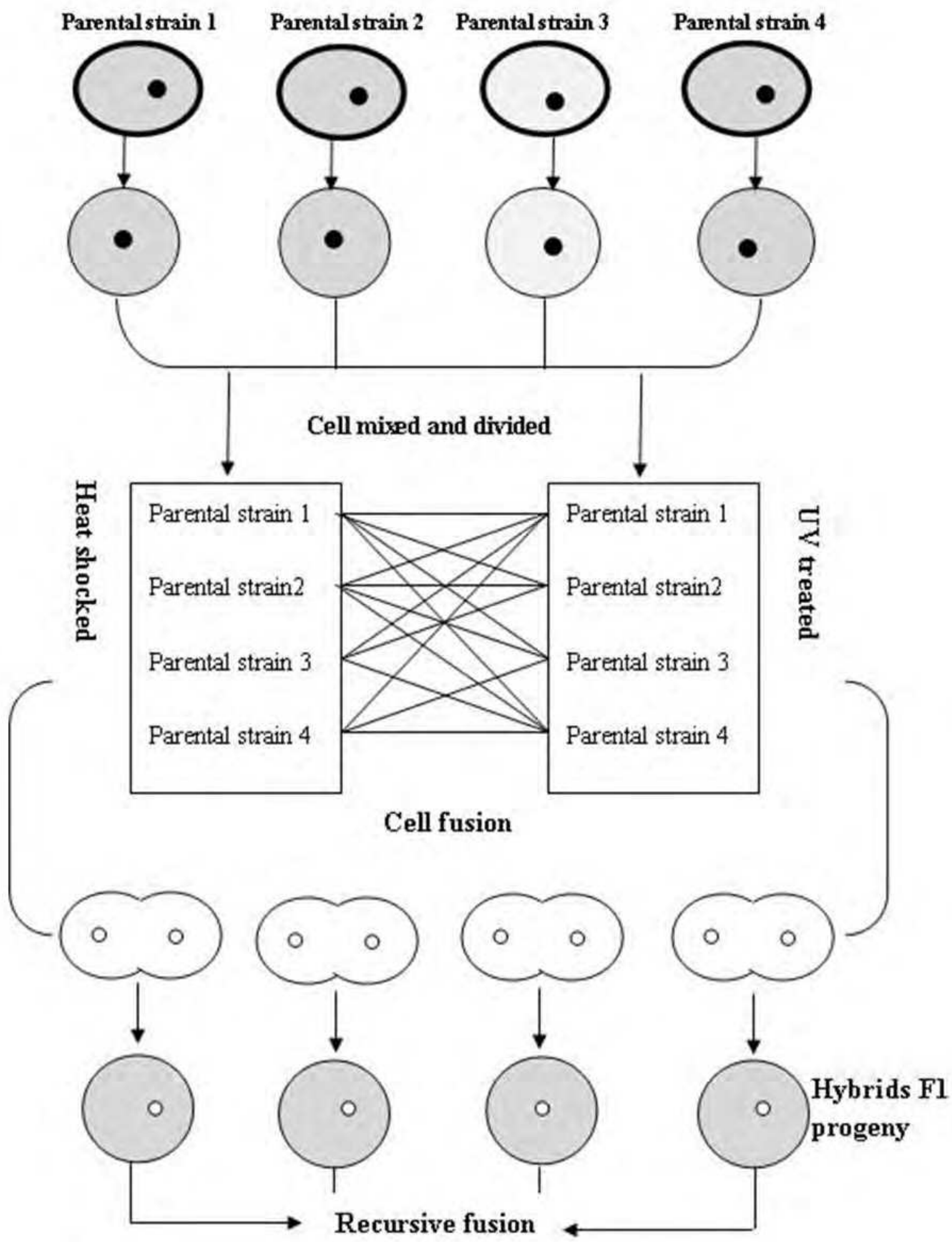

Fig. 6. Protoplast fusion of the genome shuffling process

al., 1997; Islam et al., 1999), monensin(Stroppa et al., 2000), or mixtures thereof. Fig 9 shows the process of continuous fermentation of molasses and sugarcane juice to produce ethanol. A high cell density of microbes in the continuous fermenter is locked in the exponential phase, which allows high productivity and overall short processing of 6 - 12 h as compared to the conventional batch fermentation (30 - 60 h). This results in substantial savings in labor and minimizes investment costs by achieving a given production level with a much smaller plant.

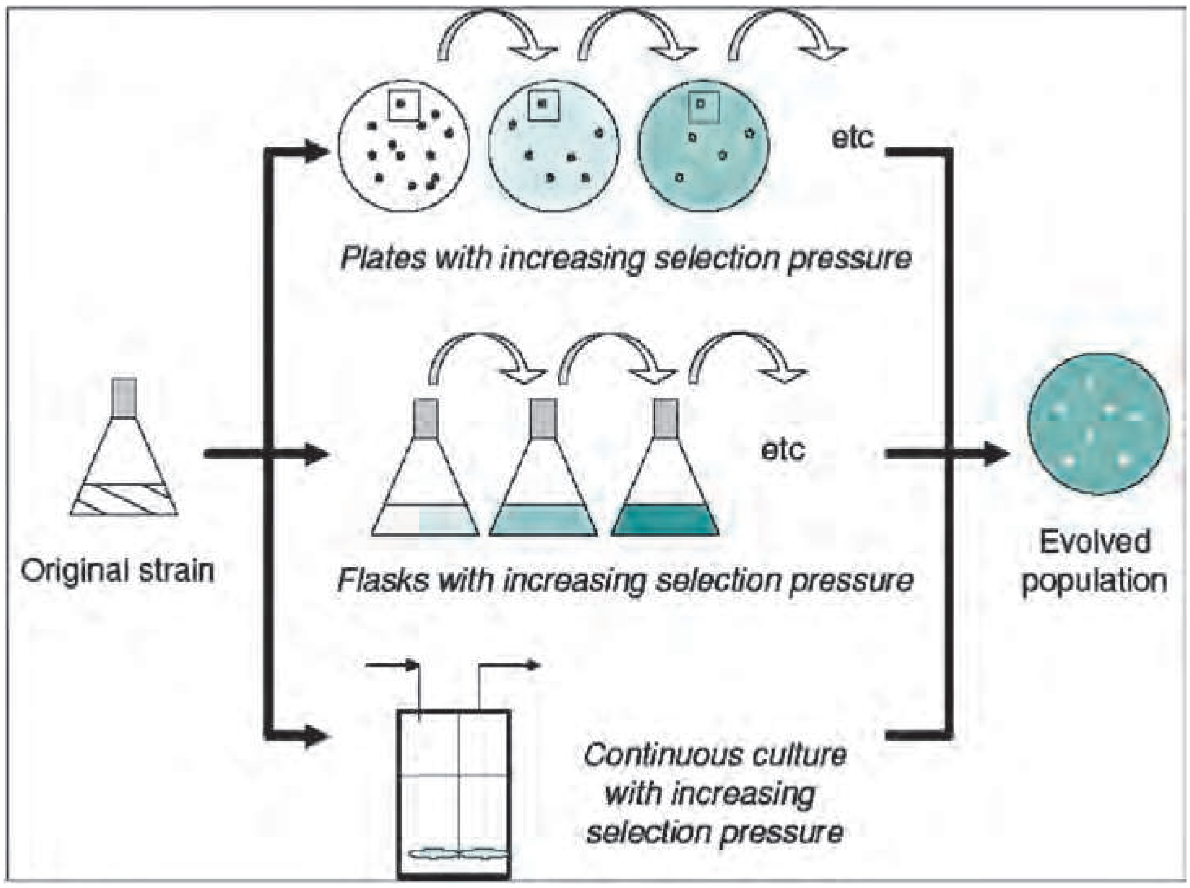

Fig. 7. Approach for evolutionary engineering

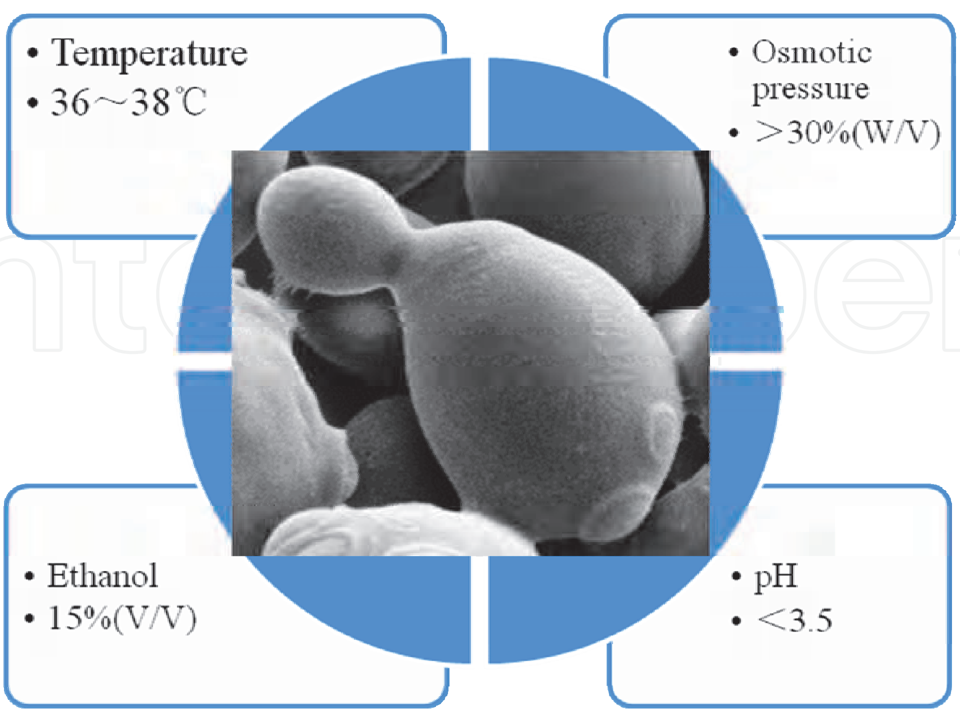

Fig. 8. Multiple-stress Resistant Yeast

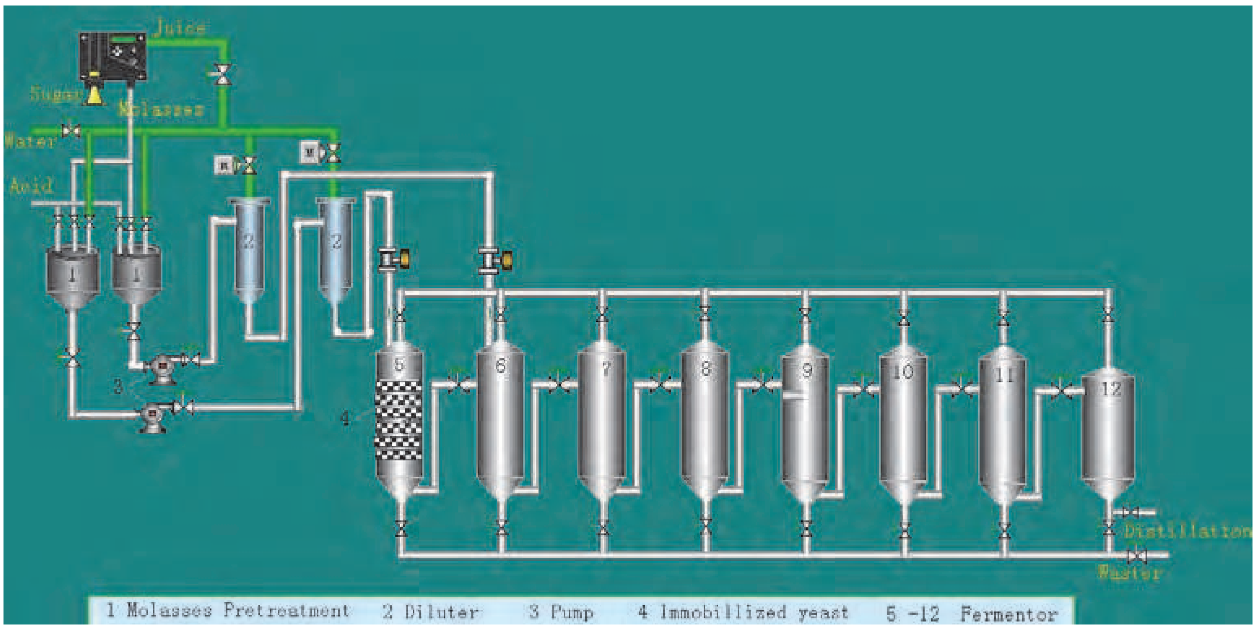

Fig. 9. Continuous fermentation of molasses and sugarcane juice to produce ethanol

5.3.3 Sugarcane pieces as yeast supports for alcohol production from sugarcane juice and molasses

A limitation to continuous fermentation is the difficulty of maintaining high cell concentration in the fermenter. The use of immobilized cells circumvents this difficulty. Immobilization by adhesion to a surface (electrostatic or covalent), entrapment in polymeric matrices or retention by membranes has been successful for ethanol production (Godia et al., 1987). The applications of immobilized cells have made a significant advance in fuel ethanol production technology. Immobilized cells offer rapid fermentation rates with high productivity – that is, large fermenter volumes of mash put through per day, without risk of cell washout. In continuous fermentation, the direct immobilization of intact cells helps to retain cells during transfer of broth into collecting vessel. Moreover, the loss of intracellular enzyme activity can be kept to a minimum level by avoiding the removal of cells from downstream products (Najafpour, 1990). Immobilization of microbial cells for fermentation has been developed to eliminate inhibition caused by high concentration of substrate and product and also to enhance ethanol productivity and yield. Neelakantam (2004) demonstrated that a high yeast inoculation at the start of the sugarcane juice fermentation allows the yeast outgrow the contaminant bacteria and inhibit its growth and metabolism.

Varies immobilization supports for variety of products have been reported such as polyvinyl alcohol (PVA, see Fig10), alginates (Kiran Sree, 2000; Corton et al., 2000), Apple pieces (Kourkoutas et al., 2006), orange peel (S.plessas, 2007), and delignified cellulosic residues (Kopsahelis, 2006; Bardi & Koutinas, 1994). We applied sugarcane pieces as yeast supports for alcohol production from sugarcane juice and molasses(Fig 11).The results(Liang et al.,2008) showed ethanol concentrations (about 77g/l or 89.76g/l in average value) , and ethanol productivities (about 62.76 g/l.d or 59.55g/l .d in average value)were high and stable, and residual sugar concentrations were low in all fermentations(0.3-3.6g/l)with conversions ranging from 97.7-99.8%, showing efficiency(90.2-94.2%) and operational stability of the biocatalyst for ethanol fermentation. the results presented in this paper (see table 3), according to initial concentration of sugars in the must, showed that the

Fig. 10. Yeast immobilized in Polyvinyl Alcohol

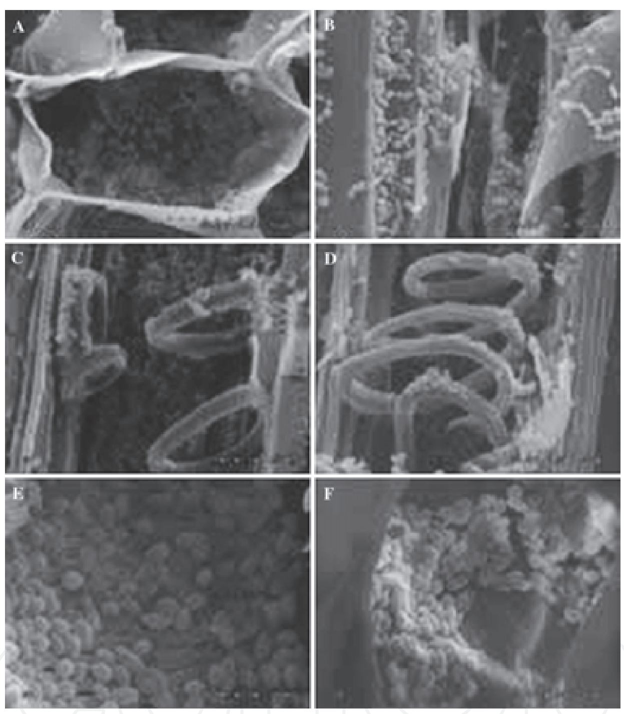

Fig. 11. Scanning electron micrographs of the middle part of the support after yeast immobilization.

sugarcane supported biocatalyst was equally efficient to that described in the literature for ethanol fermentation. Sugarcane pieces were found suitable as support for yeast cell immobilization in fuel ethanol industry. The sugarcane immobilized biocatalysts showed high fermentation activity. The immobilized yeast would dominate in the fermentation broth due to its high populations and lower fermentation time, that in relation with low price of the support and its abundance in nature, reuse availability make this biocatalyst attractive in the ethanol production as well as in wine making and beer production. After a long period of using, spent immobilized supports can be used as protein-enriched(SCP production) animal feeds.

Carrier	Medium	Initial sugar (g/l)	Ferm.time (h)	Residual sugar (g/l)	Ethanol (g/l)	Ethanol productivity (g/l.d)	Conversion (%)
Apple pieces (Y. Kourkoutas et al.,2001)	Grape must	206	80	30.8	85	26	85
Dried figs（Bekatorou et al., 2002）	Glucose	120	45	1.4	45.0	24.0	98
Spent grains (Kopsahelis et al.,2006)	molasses	187	30	8.8	51.4	42.7	95.3
Orange peel (S.plessas et al.,2007)	Glucose	125	9	4	51.4	128.3	96.8
	molasses	128	14	2	58.9	100.1	98.4
	Raisin extract	124	12	2.3	55.3	110.4	98.1
Sugarcane pieces present study	Molasses	154	27	2.3	77.12	62.76	98.5
	Sugarcane juice	176	32	0.85	89.76	59.55	99.5

Table 3. Fermentation parameters（average value）obtained in batch fermentation with *Saccharomyces cerevisiae,* immobilized on various carriers, at 30℃

5.3.4 Ethanol purification and water recovery

Distillation and molecular - sieve absorption are used to recover ethanol from the raw fermentation beer. The flow sheet of this section is presented in Figure 12 and figure 13. Distillation itself is a two-way progress include heating and cooling. That could be possible to save much steam and cooling water if we take good advantage of the heat exchange in the system. Due to its energy-saving, so far negative pressure distillation system has been popular in China. Take molasses alcohol as an example, compare to air distillation system, negative pressure distillation system could save approximately 2t steam per ton 95% (v/v) alcohol. The system showed in figure contains 3 columns, which is .fractioning column 1, fractioning column 2, and separating methanol column respectively. Making use of the different boiling points the alcohol in the fermented wine is separated from the main resting solid components. The remaining product is hydrated ethanol with a concentration of 95% (v/v). Further dehydration is normally done by molecular-sieve absorption, up to the specified 99.7°GL in order to produce anhydrous ethanol which is used for blending with pure gasoline to obtain the country's E10 mandatory blend. The fermented mash which contains 10~13 %(v/v) alcohol is preheated by the alcohol gas from the top of the first column and gas is cooled simultaneously. Then the gas stream is cooled by 3 heat exchangers, the cooler is water. Subsequently the liquid distillate which contains 30% (v/v) alcohol is feeding on the middle tray of column 2. Wastewater of column 1 is heated by the alcohol gas from the top of column 2 in the reboiler, meanwhile the steam flash evaporated in the vacuum bottom. The waste goes to anaerobic jar and then aeration tank. Cooled alcohol is pumped back to the top trays of column 2. Fusel oil is extracted from the middle trays of the column 2. Liquid distillate contains 95 %(v/v) alcohol and exceeded methanol amount. In order to decrease the concentration of aldehyde and methanol, one more column is needed. The 96%v/v alcohol with 4% water is feeding on the molecular-sieve absorption system.Finally 99.5%v/v ethanol which could be added to the gas to make gasohol is achieved.

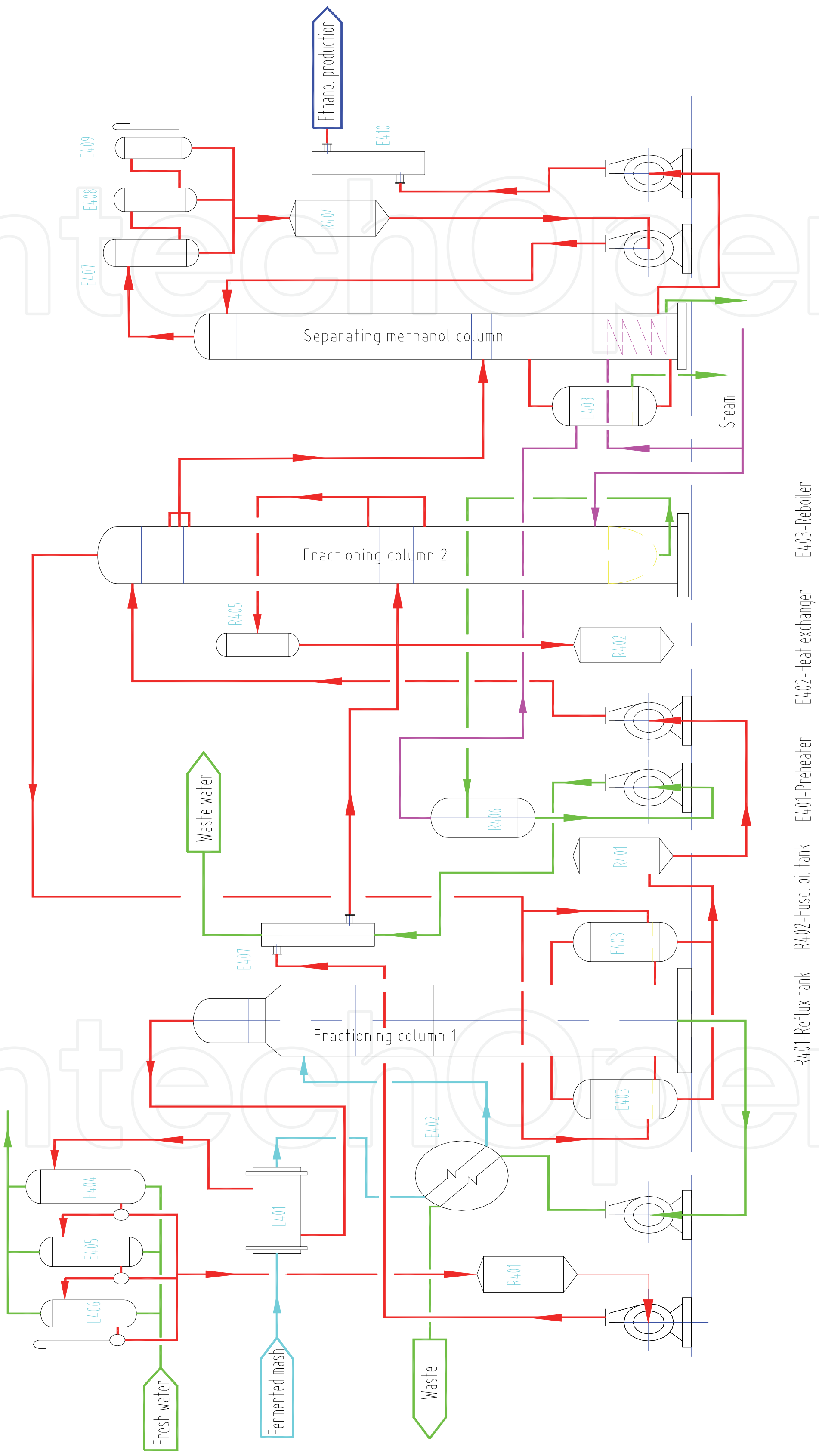

Fig. 12. Ethanol separation and dehydration.

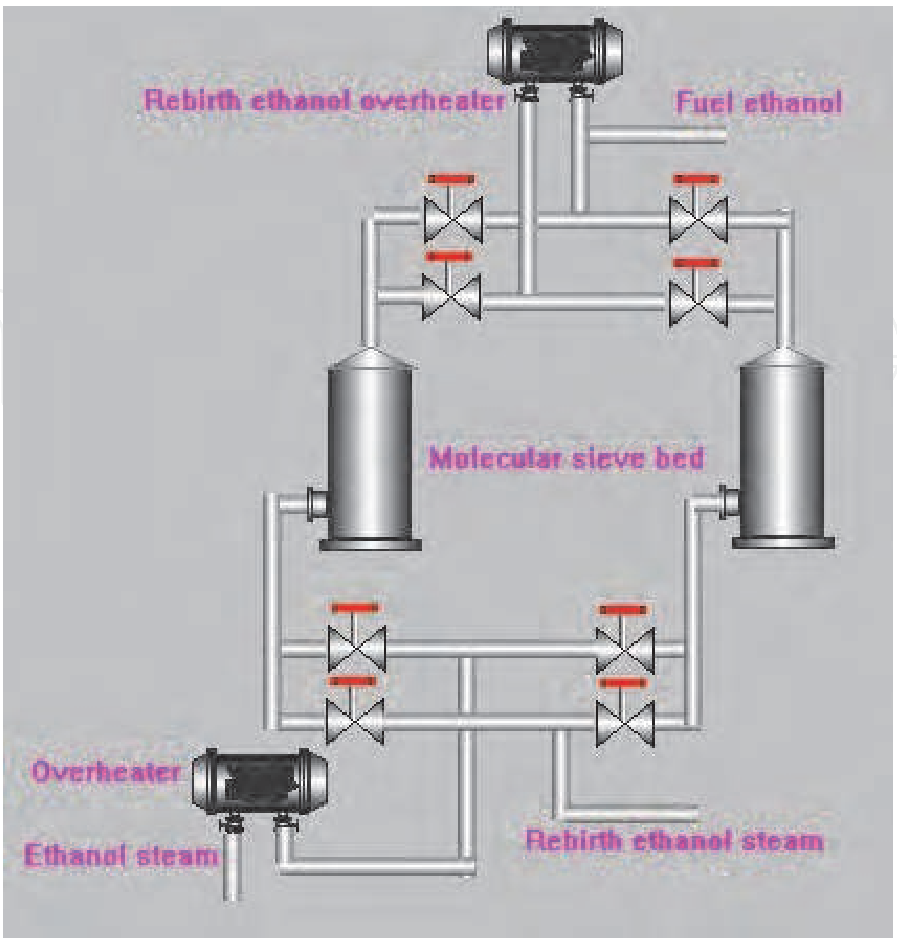

Fig. 13. Ethanol dehydration with molecular sieve bed

5.4 Economic analysis for simultaneous production of sugar and ethanol from sugarcane

Based on the economic analysis, the profits of the three different modes in 5,000 tons sugarcane pressed plants are showed in table 4. There are high costs of fermentation and distillation for sugarcane directly for ethanol fermentation due to low concentration of sugarcane juice, and about 15 tons waste water need treatment. It is also uneconomic to produce fuel ethanol using concentrated juice because of high energy costs. Therefore, that sugarcane is used directly for fuel ethanol production does not reflect its best economic benefits and flexible market response capacity.

In traditional opinion, people prefer to produce sugar as possible as they can rather than use more molasses to produce ethanol. They think that it is uneconomic to produce 1 ton ethanol with nearly 2 tons sugar consumption. In fact, we can achieve the maximized economic benefits applying "the simultaneous production of sugar and ethanol " mode, in which we boil the A-syrup that have the good characteristic of low energy consumption, to produce the top-grade white sugar production. B-green syrup and second pressed juice are mixed to produce the fuel ethanol. Costs of the ethanol production can be greatly reduced.

According to the calculations, it will bring more economic benefits while employ "the simultaneous production of sugar and ethanol" mode.

Project	Sugar product only	sugar combined fuel ethanol	Ethanol product only
Sugarcane milled（t/d）	100	100	100
Fuel ethanol (t)	-	1	7
Sugar (t)	12	11.5	-
Molasses (t)	3	-	-
Sugar product costs（RMB/t sugar）	4000	3970	-
Fuel ethanol product costs （RMB）	-	1000	5500
Total costs (RMB)	48000	46655	38500
Fuel ethanol product incomes (RMB)	-	8000	56000
Sugar product incomes (RMB)	72000	69000	-
Molasses incomes (RMB)	2700	-	-
Total incomes (RMB)	74700	77000	56000
profits (RMB)	26700	30345	17500

Table 4. The profits of the three different modes

6. Conclusions

Various technologies have been identified for immediate increases in the efficiency and sustainability of current and future sugarcane ethanol. In conclusion, recycle utilization design are seems to be suitable for sugarcane bioethanol development, for example, recycling of byproducts of sugarcane in the fields reduces chemical fertilizers application rates, reducing water consumption with closure of water-processing circuits and the use of bagasse to generate electricity or to manufacture bagasse polymer composites (Xu et al., 2010), improving the energy balance of ethanol production; as well as in production and

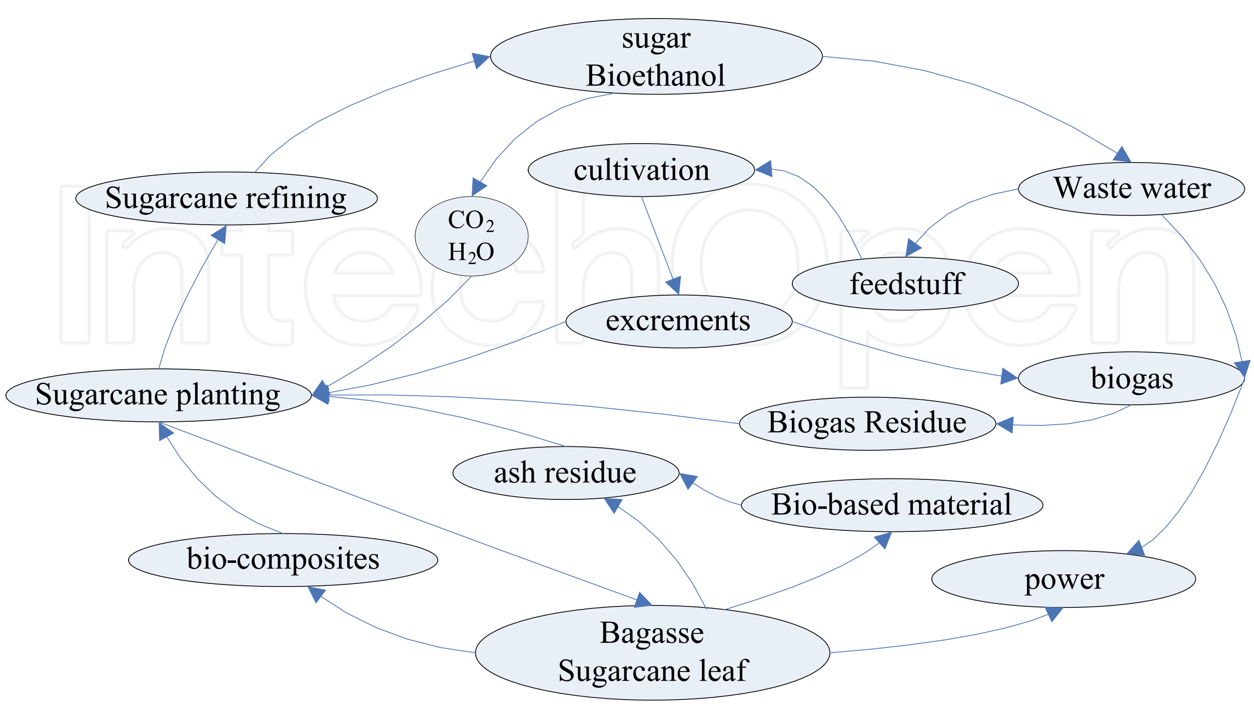

Fig. 14. Recycle utilization design for sugarcane bioethanol development

harvesting processes. At present, we think bagasse is not preferable for directly bioethanol production due to their high bioconversion costs. Adequate developed technology is available to achieve sustainable sugarcane production and bioethanol. However, the adoption of new technologies requires a favorable economic and political environment that facilitates investments in clean technologies. Pollution problems require strict enforcement of legislation and inspection of agricultural and industrial activities.

Developing the sugarcane ethanol provides a novel option for utilization of the sugar industry, and it will be also helpful to the fuel ethanol development in China.

7. Acknowledgements

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8. References

Alexander, A.G. (1984). Energy cane as a multiple products alternative. Proceedings Pacific Basin Biofuels Workshop, Honolulu

Alexander, A.G. (1997). Production of energy sugarcane. *Sugar Journal*, 1, 5-79

Aquarone, E. (1960). Penicillin and tetracycline as contamination control agents in alcoholic fermentation of sugarcane molasses. *Appl Microbiol*, 8, 263–268

Bardi, E. P. & Koutinas, A. A. (1994). Immobilization of yeast on delignified cellulosic material for room and low-temperature wine making. *Journal of Agricultural and Food Chemistry*, 42, 221–226.

BNDES. Banco Nacional de Desenvolvimento Econômico e Social: Sugarcane-based bioethanol: energy for sustainable development / coordination BNDES and CGEE – Rio de Janeiro: BNDES, 2008304 p.

BNDES; CGEE (Orgs.). (2008). Sugarcane-based bioethanol: energy for sustainable development. Rio de Janeiro: BNDES, 316 p.

Cakar, Z. P., Seker, U. O., Tamerler, C. et al. (2005). Evolutionary engineering of multiple-stress resistant *Saccharomyces cerevisiae*. *FEMS Yeast Research*, 5, 569–578

Cerri, C.C., Maia, S.M.F., Galdos, M.V., Cerri, C.E.P., Feigl, B.J. & Bernoux, M.k. (2009) Brazilian greenhouse gas emissions: the importance of agriculture and livestoc. *Scientia Agricola*. 66, 6,831–843.

Chandel, A. K., Chan E.S., Rudravaram, R. et al. (2007). Economics and environmental impact of bioethanol production technologies: an appraisal. *Biotechnology and Molecular Biology Review*. 2, 1, 14-32

Cheng, J.F., Liu, J.H., Shao, H.B. & Qiu, Y.M. (2007). Continuous secondary fermentation of beer by yeast immobilized on the foam ceramic. *Research journal of biotechnology*, 2, 3, 40

Corton, E., Piuri, M., Battaglini, F. & Ruzal, S.M. (2000). Characterization of *Lactobacillus* carbohydrate fermentation activity using immobilized cells technique. *Biotechnology Progress*,16,1,59-63

Day, W.H., Serjak, W.C., Stratton, J.R. & Stone, L. (1954). Antibiotics as contamination control agents in grain alcohol fermentations. *J Agric Food Chem*, 2, 252–258

Dien, B.S., Jung, H.J.G., Vogel, K.P., Casler, M.D., Lamb, J.A.F.S., Iten, L., Mitchell, R.B. & Sarath, G. (2006). Chemical composition and response to dilute acid pretreatment and enzymatic saccharification of alfalfa, reed canary grass and switch grass. *Biomass and Bioenergy*, 30, 10, 880-891

Gasch, A. P., Spellman, P. T., Kao, C.M. et al. (2000) Genomic expression programs in the response of yeast cells to environmental changes. *Mol Biol Cell*, 11, 4241-4257

Goldemberg, J., Coelho, S.T. & Guardabassi, P. (2008). The sustainability of ethanol production from sugarcane. *Energy Policy*, 36, 2086– 2097

Godia, F., Casas, C. & Sola, C. (1987). A survey of continuous ethanol fermentation systems using immobilized cells. *Process Biochem*, 22, 43–48

Hamdy, M.K., Toledo, R.T., Shieh, C.J., Pfannenstiel, M.A. & Wang, R. (1996). Effects of virginiamycin on fermentation rate by yeast. *Biomass Bioenerg*,11,1–9

Herrera, S. (2004). Industrial biotechnology- a chance at redemption. *Nature Biotechnol*. 22, 671-675

Hynes, S.H., Kjarsgaard, D.M., Thomas, K.C. & Ingledew, W.M. (1997). Use of virginiamycin to control the growth of lactic acid bacteria during alcoholic fermentation. *J Ind Microbiol Biotechnol*, 18, 284–291

Giamalva, M. J., Clarke S. J. & Stein, J.M. (1984). Sugarcane hybrids of biomass. Biomass, 6, 61-68

Giudici, P., Solieri, L., Andrea, M., Pulvirenti et al. (2005). Strategies and perspectives for genetic improvement of wine yeasts. *Appl Microbiol Biotechnol*, 66, 622–628

International Energy Agency. (2004). Biofuels for transport—an international perspective. Paris: International Energy Agency.

Islam, M., Toledo, R. & Hamdy, M.K. (1999). Stability of virginiamycin and penicillin during alcohol fermentation. *Biomass Bioenergy*, 17, 369–376

Kiran Sree, N., Sridhar, M. & Venkateswar Rao, L.(2000). High alcohol production by repeated batch fermentation using an immobilized osmotolerant Saccharomyces cerevisiae. *Journal of Industrial Microbiology & Biotechnology*, 24, 222–226

Kopsahelis, N. (2006). Comparative study of spent grains and delignified spent grains as yeast supports for alcohol production from molasses. *Bioresour.Technol*, doi:10.1016/j.biortech.2006.03.030

Kourkoutas, Y., Kanellski, M. & Koutinas, A.A. (2006). Apple pieces as immobilization support of various microorganisms. *LWT*, 39, 980-986

Lynd, L.R. & Wang, M.Q. (2004). A product-nonspecific framework for evaluating the potential of biomass-based products to displace fossil fuels. *J. Ind. Ecol*, 7, 17-32

Liang, L., Zhang, Y., Liang S., et al. (2008). Study of sugarcane pieces as yeast supports for ethanol production from sugarcane juice and molasses. *Journal of Industrial Microbiology and Biotechnology*, 35,1605-1613

Macedo, I.C., Seabra, J.E.A. & Silva, J.E.A.R. (2008). Greenhouse gases emissions in the produciton and use of ethanol from sugarcane: the 2005/2006 averages and prediciton for 2020. *Biomass and Bioenergy*, 2008, 32,582–595

Marèlne Cot, M., Loret, M.O., Francois, J. et al. (2007). Physiological behavior of *saccharomyces cerevisiae* in aerated fed-batch fermentation for high level production of bioethanol. *FEMS Yeast Res*, 7,22-32

Najafpour, G.D. (1990). Immobilization of microbial cells for production of organic acids. *J Sci Islam Repub Iran,* 1, 172–176

Neelakantam V. Narendranath Ronan Power. (2004). Effect of yeast inoculation rate on the metabolism of contaminating lactobacilli during fermentation of corn mash. *J Ind Microbiol Biotechnol* ,31, 581–58

Oliveira de, M.E.D., Vaughan, B.E. & Edward. (2005) Ethanol as Fuel: Energy, Carbon Dioxide Balances, and Ecological Footprint. *BioScience,*55, 57

Rothkopf, G. (2007). A Blueprint for Green Energy in the Americas. Inter-American Development Bank Retrieved 2008-08-22. See chapters Introduction (pp. 339–444) and Pillar I: Innovation (pp. 445–482)

Skinner, K.A. & Leathers, T.D. (2004). Bacterial contaminants of fuel ethanol production. *J Ind Microbiol Biotechnol*, 31, 401–408

S.plessas, A. B. (2007). Use of Saccharomyces Cerevisiae Cells Immobilized on Orange Peel as Biocatalyst for Alcoholic Fermentation. *Bioresource Technology,* 98, 860-865

Stroppa, C.T., Andrietta, M.G.S., Andrietta, S.R., Steckelberg, C. & Serra, G.E. (2000). Use of penicillin and monensin to control bacterial contamination of Brazilian alcohol fermentations. *Int Sugar J*, 102,78–82

Tanaka, L. (2006). Ethanol fermentation from biomass resources: Current state and prospects. *Appl. Microbiol. Biotechnol*, 69, 627-642

Walter, A., Dolzan, P., Quilodrán, O. et al. (2008).A sustainability analysis of the brazilian ethanol. Campinas

Watanabe, M. (2009). Ethanol Production in Brazil: Bridging its Economic and Environmental Aspects. International Association for Energy Economics. Brazil

Wheals, E.A., Basso, L.C., Alves, D.M.G. & Amorim, H.V. (1999). Fuel ethanol after 25 years. *Trends Biotechnol*, 17, 482–487

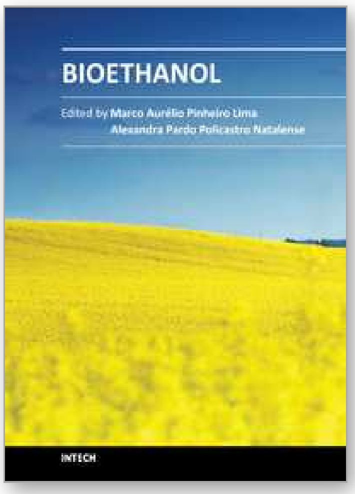
Wyman, C.E. & Hinman, N.D. (1990). Ethanol. Fundamentals of production from renewable feedstocks and use as transportation fuel. *Appl Biochem. Biotechnol*, 24/25, 735-75.

Xu, Y., Wu, Q., Lei, Y. & Yao, F. (2010). Creep behavior of bagasse fiber reinforced polymer composites. *Bioresource Technology*, 101, 3280-3286

Zhang, Y.X., Perry, K., Vinci, V. A. et al. (2002). Genome Shuffling Leads to Rapid Phenotypic Improvement in Bacteria. *Nature*, 415, 644-646

Zhang, M.Q., Chen, R.K., Luo, J, et al. (2000) Analyses for inheritance and combining ability of photochemical activities measured by chlorophyll fluorescence in the segregating generation of sugarcane. *Field Crops Res*, 65, 31-39

Zhong, C., Cao, Y.X., Li, B.Z. & Yuan, Y.J. (2010). Biofuels in China: past, present and future. *Biofuels Bioproducts and Biorefining*, 4, 3, 326–342



Bioethanol

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Recent studies have shown strong evidence of human activity impact on the climate of the planet. Higher temperatures and intensification of extreme weather events such as hurricanes are among the consequences. This scenario opens up several possibilities for what is now called "green" or low carbon economy. We are talking about creating new businesses and industries geared to develop products and services with low consumption of natural resources and reduced greenhouse gases emission. Within this category of business, biofuels is a highlight and the central theme of this book. The first section presents some research results for first generation ethanol production from starch and sugar raw materials. Chapters in the second section present results on some efforts around the world to develop an efficient technology for producing second-generation ethanol from different types of lignocellulosic materials. While these production technologies are being developed, different uses for ethanol could also be studied. The chapter in the third section points to the use of hydrogen in fuel cells, where this hydrogen could be produced from ethanol.

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