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INTEGRATED BIODIESEL PRODUCTION IN BARRALCOOL SUGAR AND ALCOHOL MILL[1]

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INTRODUCTION

In Brazil in 1975, the National Alcohol Program – Proálcool – started, to represent the beginning of a new concept in the sugarcane sector: the production of renewable energy from sugarcane.

Ethanol production has brought on a huge growth of the industry, while mills experienced important evolution in capacity, overall yields, and optimum use of sugarcane energy, products and by-products (OLIVÉRIO, 2002).

At the end of the Program, some industry entrepreneurs enhanced the vision of the business by understanding that the mill, in its agricultural (+) industrial integration, is not a sugar and alcohol producing unit only, but an energy-and-food producing centre (OLIVÉRIO, 2002, 2006), as shown in Figure 1. It must be emphasized that the representation is simplified, since today the number of products derived from agricultural and industrial activities is much higher.

Ethanol, or bioethanol, as it is also called, was focused almost completely on the partial or total replacement of gasoline in vehicles. In the 1980s, a parallel program to Proalcohol was Pro Oil, which had as the main purpose the production of fuel as an alternative for diesel oil. Pro Oil did not prosper, but the remembrance of the alternative fuel remained.

With such background, and mainly taking the expressive European biodiesel program as reference, on December 4, 2004, the National Program of Biodiesel Production and Use was launched in Brazil, introduced by Law n. 11 097/2005, which establishes the minimum percentage of blending biodiesel to diesel and the monitoring of the introduction of the new fuel into the marketplace.

And what is biodiesel? In a simple explanation, it is the natural substitute for diesel oil, which is produced from renewable sources, such as vegetable oils, animal fats, as well as used fried oil (OLIVÉRIO, 2004). Chemically, it is defined as a monoalkylate ester of fatty acids (methyl-ester or ethyl-ester), derived from lipids (or fatty acids) of natural occurrence, and is produced, together with glycerin, through the reaction of transesterification (or esterification) of triglycerides (fatty acids) with alcohols – methanol or ethanol – in the presence of an acid or basic catalyst (BARREIRA, 2005).

Figure 2 outlines this definition. The quantities are not accurate and are presented only as a reference.

It is important to emphasize that methanol, or bioethanol, participates in the reaction with an exceeding amount in relation to stoichiometric to maximize the efficiency of transesterification and, when removing process water, it limits the parallel reaction of saponification as much as possible.

By examining Figure 1, one can see that the energy-and-food mill produces the two feedstocks

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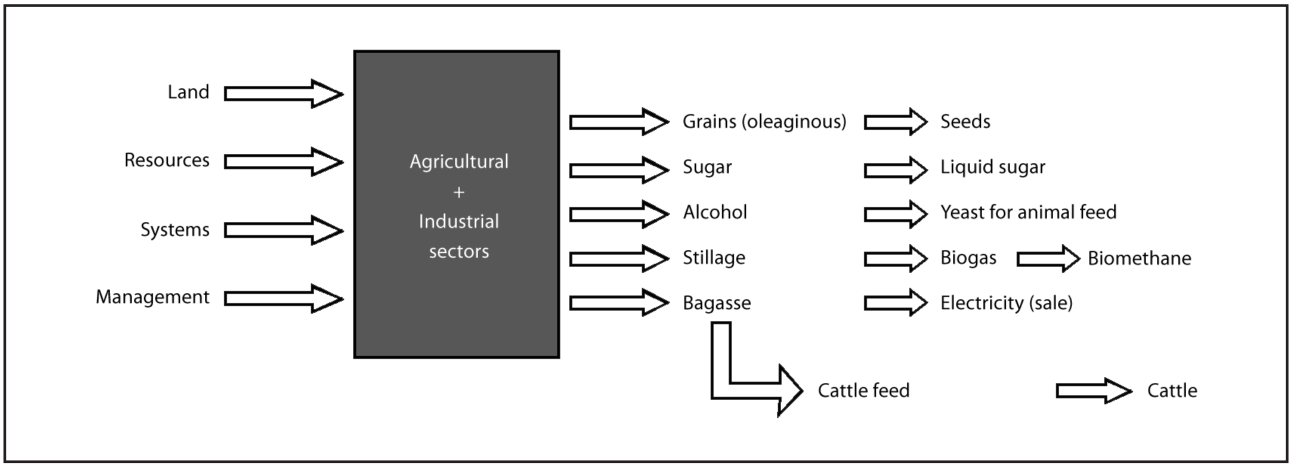

FIGURE 1 The sugar and alcohol mill defined as an energy-and-food producing unit.

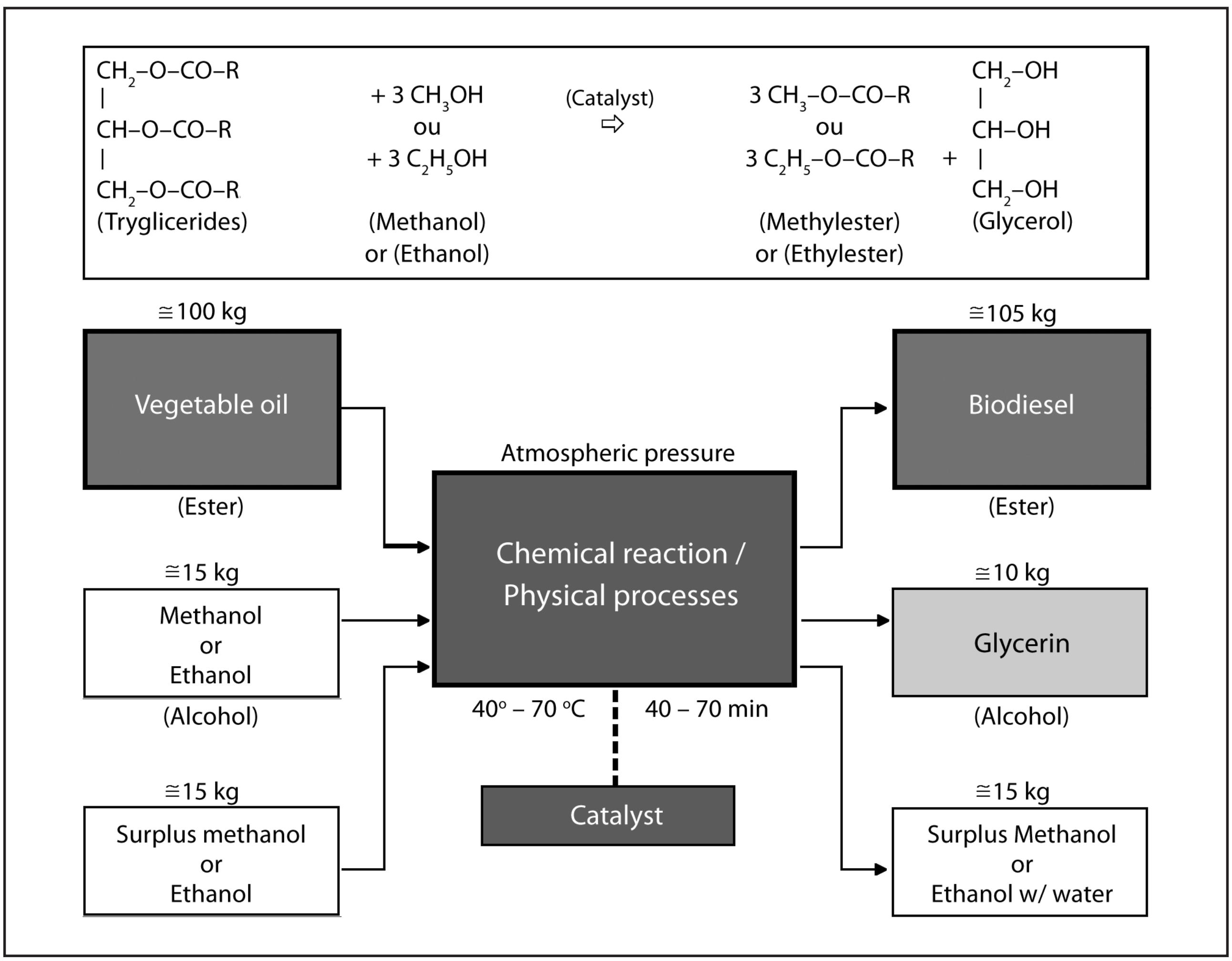

FIGURE 2 The transesterification reaction and the process used in biodiesel production (sketch).

of Figure 2 which are used for biodiesel production: oleaginous grains from which vegetable oil is extracted, and bioethanol.

From bagasse, the mill can also supply energy – thermal and electric – used in the production of biodiesel.

This first conclusion was the starting point for an in-depth investigation, when a great synergy between the production processes and uses of biodiesel and bioethanol was noticed to exist. Thus, a new pioneering concept was developed and introduced into the marketplace in November, 2004, that is, the integrated biodiesel production in sugar and alcohol mills (OLIVÉRIO, 2004).

BIODIESEL – BIOETHANOL SYNERGY, OR THE INTEGRATED PRODUCTION OF BIODIESEL IN SUGAR AND ALCOHOL PLANTS

The existing synergies and the advantages of integrated biodiesel production in the mills can be grouped into 3 classes: agricultural sector, industrial sector, management and businesses (BARREIRA, 2005).

In the agricultural sector, the know-how for oleaginous grains production in rotation to sugarcane crops is already available. It is a traditional practice, for example, the cultivation of soybean in areas of sugarcane renovation, after 4 or 5 cuts. Such practice maximizes land productivity with optimum and profitable use of the land. It also breaks the cycle of plagues and diseases and contributes to recover the soil fertility; from soybean, the oil that is the feedstock for biodiesel can be produced.

Another synergy that benefits the integration is the common use of the structure and agricultural and industrial resources, which allows costs sharing, optimized use of facilities, and minimized investments. It can include tractors, harvesters, trucks, machinery, agricultural implements, steam, co-generated electrical power, water, integrated solutions for wastewaters, agricultural and industrial labour, use of plants, facilities and support services. The surplus bioethanol with water, which derives from the biodiesel production, as could be seen in Figure 2, may be reprocessed in the distillery already available at the mill and, after dehydration, is sent back to the biodiesel process.

The biodiesel produced can be used in the agricultural sector to fuel the vehicles used in the production of sugarcane and the oleaginous grains.

Regarding management and businesses, we can point out the synergies and advantages of: a new market for use of the anhydrous bioethanol, the increase of income/profits from the new products, biodiesel and glycerin, to the production chain, which also helps to dilute market risks.

Biodiesel commercialization will be made by counting on the experience and expertise obtained from the bioethanol business, to be traded with the same clients. Finally, the same structure and management systems can be used.

When using biodiesel in the mill vehicles, the fuel is tax exempt, so it costs less (for being own production), and replaces diesel that is tax liable.

Figure 3 highlights that having as a core the land, the human, physical and financial resources, systems and management, the biodiesel-bioethanol integration takes place in the crop and in the industry, and leads to economic, energetic and process integration (OLIVÉRIO, 2004).

We understand that the integrated production of biodiesel in the sugar and alcohol plant must take place in 3 stages, and initially the synergies already available are used, which evolve to stages of higher integration (OLIVÉRIO, 2004, 2006), as shown in Figure 4.

For stages 1 and 2, technology is already available, and the 3rd is in the initial stage of development and will have a significant future impact in the additional reduction of biodiesel and bioethanol costs. To cite possible examples, bioethanol can be the solvent in the extraction process of oil from grain, replacing hexane, increasing oil production and, at the same time, producing value-added meal with higher protein content. Additionally, some sugars present in soybean may be added to the juice, thus increasing ethanol production at the plant.

At this point, it is important to emphasize that the technology for the continuous process of biodiesel production was available by the methyl

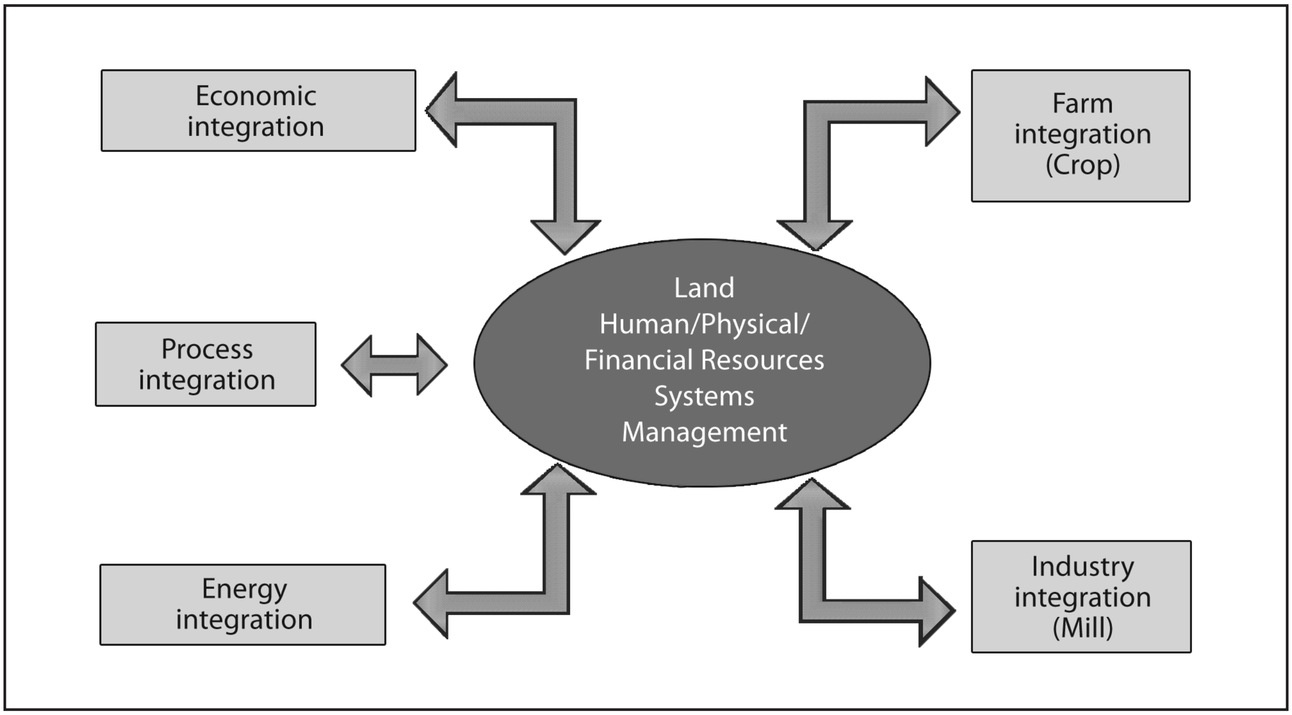

FIGURE 3 Biodiesel-bioethanol integration.

route only, developed mainly in Europe. For the biodiesel-bioethanol integration, it was necessary to develop the ethyl route in a continuous process. The conclusion of such development was presented in July 13, 2004, during the II SIMTEC – International Symposium and Technology Exhibit of the Sugar and Alcohol Agroindustry – held in Piracicaba, when Dedini and DeSmet Ballestra promoted the launching of the pioneer process of continuous production of biodiesel by the ethyl route (OLIVÉRIO *et al*., 2004).

THE BARRALCOOL SOLUTION

What was initially a concept became reality when, in November 2005, the pioneer contract for the supply of a biodiesel plant integrated to the Barralcool Mill was signed, and operations started in November 2006. It must be pointed out that Barralcool mill was the first plant to produce bioethanol in the state of Mato Grosso, and also the first in the state to supply bioelectricity to the grid, thus becoming the first mill in the world producing the 3 BIOs: bioethanol, bioelectricity and biodiesel.

Figure 5 shows Barralcool Mill in a schematic form.

Description of the mill

Barralcool Mill is located in Barra do Bugres, MT, and was built while Proálcool was in force, for production of alcohol exclusively. Its first milling season took place in 1983, processing 58 734 tonnes of cane. From 1993, it was expanded for production of sugar. It began supplying electricity to the grid in 1996, and production of biodiesel in 2006.

Since it was founded, it has undergone expansion which will continue in the next years, according to Tables 1 and 2.

The milling season is from April to November each year.

The average diesel consumption in the crop is 2.5 litres of diesel/t crushed cane.

The sugarcane renovation, on average, occurs at every 6.7 cuts; therefore, the renovation area represents about 15% of the cutting area of sugarcane.

Soybean production is made in rotation with sugarcane, using nearly 70% of the renovation

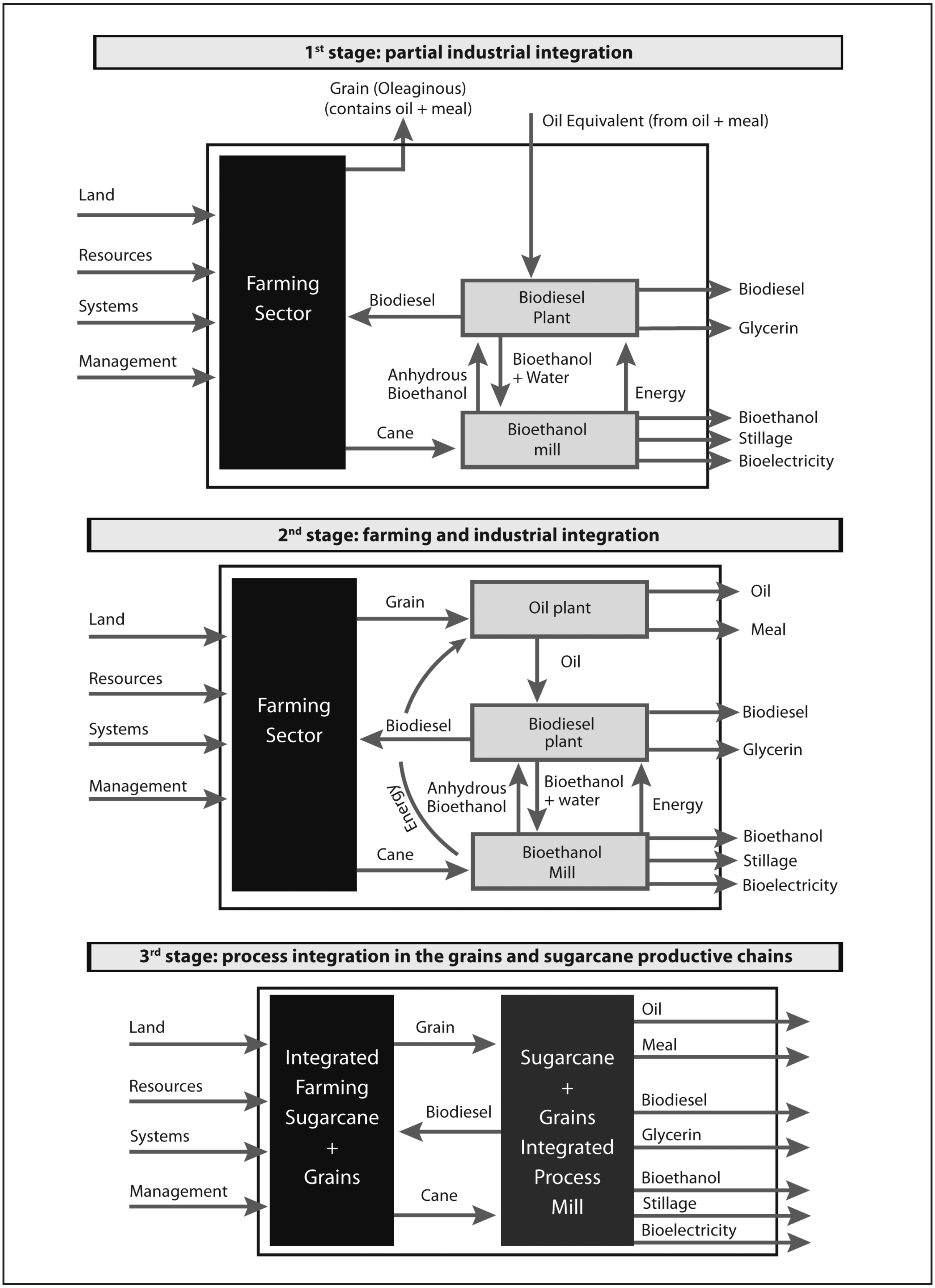

FIGURE 4 The 3 evolution stages of integrated biodiesel production in the sugar and alcohol mill.

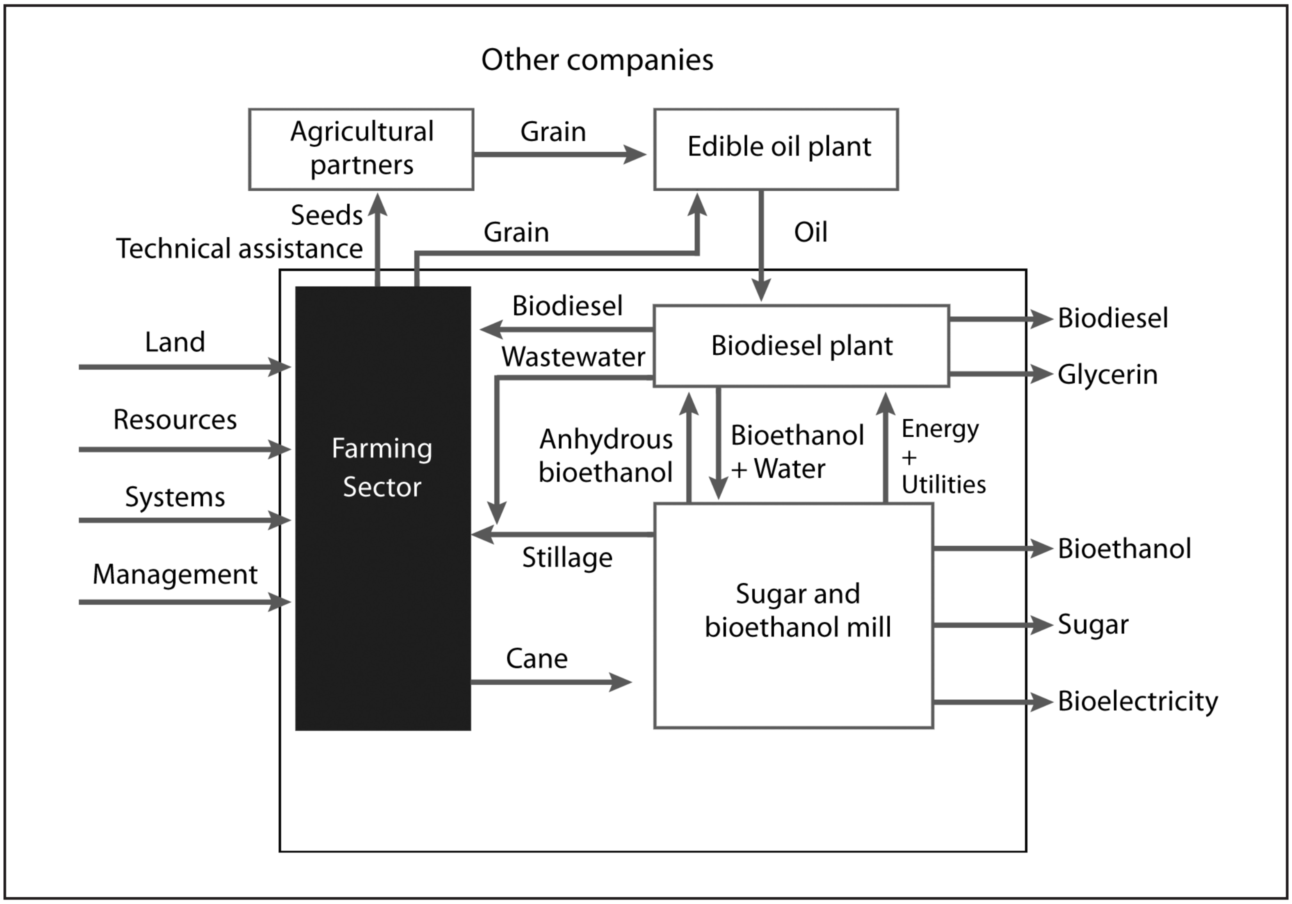

FIGURE 5 Barralcool Mill: operational flow.

TABLE 1 Historical data –2000 to 2006 milling seasons – Barralcool Mill.

Description	Unit	2000	2001	2002	2003	2004	2005	2006
Processed sugarcane	tc/y	1,080,616	1,483,786	1,780,736	1,825,597	2,154,873	1,886,464	2,221,669
Total sugarcane area	ha	20,487	21,464	24,168	26,211	28,015	26,398	32,659
Harvesting area	ha	18,724	20,378	22,769	23,981	25,997	24,811	26,649
Average daily cane	tc/d	7,946	8,243	8,816	9,128	10,615	11,790	10,733
Crushing days	d/y	136	180	202	200	203	160	207
Ethanol production	m^3/y	72,327	95,113	113,511	118,220	151,222	139,382	152,017
Sugar production	t/y	22,171.0	32,957.4	42,647.5	40,021.2	37,571.1	36,986.0	50,130.2
Soya own production*	t/y	–	–	–	1,156	3,090	6,282	6,401

* Soybean own production in sugarcane renovation area.
c = sugarcane; y = year; d = day; t = ton; ha = hectare; tc = ton of sugarcane.

TABLE 2 Forecast – 2007 to 2009 seasons – Barralcool Mill.

Description	Unit	2007	2008	2009
Total cane processed	tonne cane/season	2,400,000	2,600,000	2,800,000
Soya own production	Tonne/year	9,000	9,600	11,500

TABLE 3 Raw materials specifications.

Degummed oil specification (soya/sunflower/rapeseed)		
Parameter	**Unit of measure**	**Value**
Free fatty acid	%	0.1 max.
Moisture content	%	0.1 max.
Impurities	%	0.1 max.
Phosphorus	ppm	20 max.
Unsaponifiables	%	1 máx.
Ethanol specification – ANP 36*, 06.12.2005, except:		
Water content	%w/w	0.20 max.
Methanol specification – technical grade, and:		
Water content	%w/w	0.15 max.

* Brazilian specification.

area. In the conditions of Barralcool Mill, a higher percentage soybean production interferes in the agricultural practices required for sugarcane, which must be avoided.

Let's review the biodiesel-bioethanol integration taking as reference the 2009 milling season of Barralcoool Mill.

Barralcool's new solution will be presented by dividing it into three parts: agricultural sector, industrial sector, and biodiesel plant.

Biodiesel plant

The biodiesel plant has the following characteristics:

- capacity: 50,000 tonnes/year (around 56 million litres/year); 8,000 hours/year;
- continuous process, multi-feedstock;
- flexible route: ethyl or methyl;
- feedstocks: multiple degummed vegetable oils, beef tallow, bioethanol or methanol;
- end products: biodiesel and glycerine.

Figure 6 presents the process flowchart of biodiesel production using vegetable oils. In the Barralcool Biodiesel Plant, an esterification process stage was introduced, that produces additional biodiesel from fatty acids, increasing yields.

The use of beef tallow requires additional stages for treatment of this raw material, which will not be discussed in this paper.

Tables 3 to 8 present the materials and utilities specifications involved in the process, as well

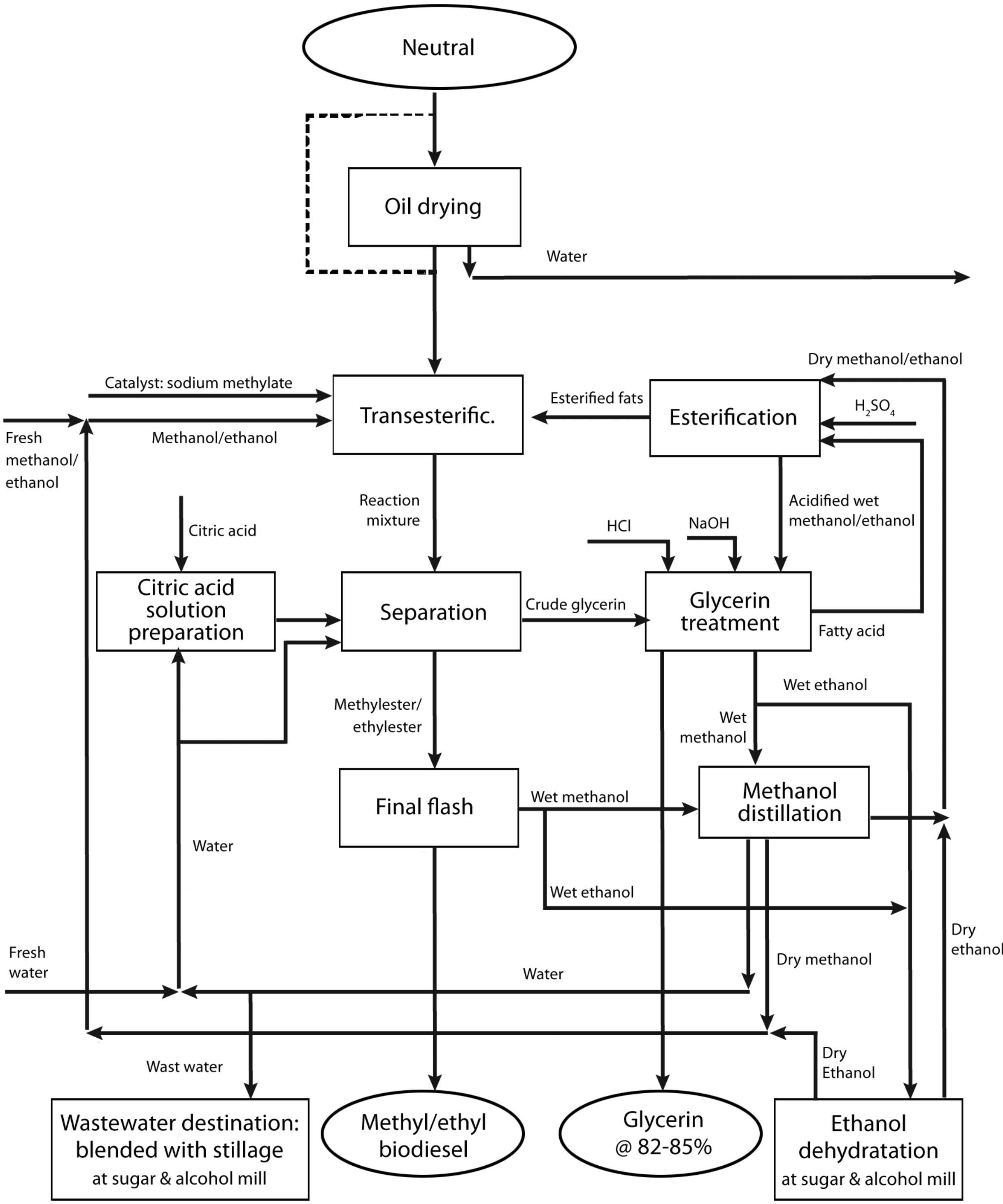

FIGURA 6 Barralcool biodiesel production process flowchart – ethyl/methyl route.

TABLE 4 Chemical inputs specifications.

Hydrochloric acid	36% concentration technical grade
Ester interchange catalyst	Sodium methylate as methanol solution 30% conc.
Caustic soda	50% weight solution
Citric acid	Technical grade mono-hydrate
Process water	Softened water (1°F hardness)
Sulfuric acid	98.5% purity

TABLE 5 Utilities specifications.

Process water	
Type	softned
Pressure	3 bar g min.
Temperature	ambient
Hardness	1ºF max
Iron content	max 5 ppm as Fe
Cooling water	
Pressure	4 bar g min.
Temperature inlet	28 ºC max
Temperature outlet	34 ºC max
Saturated steam	
Pressure	12 bar g min.
Instrument air	
Type	dried and oil free
Pressure	7 bar g min
Dew point	–20 ºC
Nitrogen	
Type	99% purity
Pressão	7 bar g mín.
Electric power	
Driving power	380 V (HOLD) – +/-5% – 60 Hz – 3 + N phases
Control and auxiliary circuit	220 V (HOLD) – 60 Hz – 1 phase
Lamps	24 V (HOLD) – 60 Hz – 1 phase

as the end products, wastewaters and respective consumptions or production.

Agricultural Sector

In 2009, soybean will/was be cultivated on 70% of the sugarcane renovation area, which represents 15% of the harvest area, giving a total of 11,500 tonnes of grains (Table 2).

This amount is not sufficient to meet the capacity of the biodiesel plant. Barralcool solution was to enter into partnership agreements with independent producers (family and small farmers) to whom the mill supplies the seeds and technical support.

Doing that, Barralcool meets the objective of social inclusion contained in the premises of the Brazilian Biodiesel Program, and the biodiesel produced by the mill is entitled to tax reduction in sales.

The soybean grain is sent to an oil industry which, through an operation called "Façon", it exchanges grains, which contain oil and meal, for the equivalent in oil, as shown in Figure 7 (BARBOSA, 2006).

Concluding, agricultural production will provide 5030 tonnes of oil/year, around 10% of capacity, and the remaining 44,970 tonnes/year will be supplied by third parties.

To increase the proportion corresponding to own production, Barralcool mill is developing procedures to produce two crops of grains in the same area and in the same period of sugarcane renovation, using soybean and peanut. Barralcool expects to increase oil production per hectare by about 30%.

A blend of 30% of biodiesel in the mixture with diesel – B30 – will be used as a first step in Barralcool. 7 million litres of fuel will be utilized in 2009 (2,800,000 t cane X 2.5 L/t cane) and the internal utilization of biodiesel will reach 2.1 million litres.

Industrial Sector

The integration of the biodiesel plant into Barralcool mill industrial sector is represented by Figure 5.

TABLE 6 The biodiesel produced meets the Brazilian specifications (ANP 42), USA specifications (ASTM 6751-3) and European specifications (EN 14214).

Characteristic	Unit	Standard		
		ANP 42*	**ASTM 6751-3**	**EN 14214**
Specific mass at 20 ºC	kg/m^3	register	–	0.86-0.90
Kinematic viscosity at 40 ºC	mm^2/s	register	1.9-6	3.50-5.00
Water and sediments, max.	% vol.	0.050	0.050	0.050
Total contamination, max	mg/kg	register	–	24
Flash point, min.	ºC	100	130	120
Ester content, min.	% mass	register	–	96.50
Distillation; 90% vol. Recovered, max.	ºC	360	360	–
Carbon residue of 100% – final distillate, max	% mass	0.10	0.30	0.30
Sulfated ashes, max.	% mass	0.02	0.02	0.02
Total sulfur, max.	% mass	register	15	10
Sodium + potassium, max.	mg/kg	10	5	5
Calcium + magnesium, max.	mg/kg	register	5	–
Phosphorus, max.	mg/kg	register	10	10
Copper corrosion, 3 h to 50 ºC, max.	–	1	3	1
Number of cetanes, min.	–	register	47	51
Cold filter plugging point, max.	ºC	–	–	–
Acidity, max.	mg KOH / g	0.80	0.80	0.50
Free glycerol, max.	% mass	0.02	0.02	0.02
Total glycerol, max.	% mass	0.38	0.24	0.25
Monoglycerides, max.	% mass	register	–	0.80
Diglycerides, max.	% mass	register	–	0.20
Triglycerides, max.	% mass	register	–	0.20
Methanol or ethanol, max.	% mass	0.5	–	0.20
Iodine number	–	register	–	120
Oxidation stability at 110 ºC, min	h	6	–	6

* PROVISIONAL ACTS n.: 214, 13/0904 and 227, 06.12.2004.

TABELA 7 Specification of the glycerin produced.

Resolution n. 42, 24.11.2004

Parameter	Specification – %
Glycerin content by mass	82 ÷ 85
Water by mass	8.0 max.
Methanol/ethanol by mass	0.1 max.
Organics non glycerol, by mass	1.5 max.
Salts by mass	7.0 max.

It must be emphasized that use is made of utilities already available at the mill, surplus bioethanol dehydration in the equipment already used to produce anhydrous bioethanol, optimum use of the existing technical, administrative, and management structure, which allows reduction in costs and investments.

In Figure 8, a picture shows an overall view of the Biodiesel Plant Integrated to Barralcool Mill, and, in Figure 9, the inauguration of Barralcool Biodiesel Plant.

IMPACTS ON INVESTMENTS, COSTS, AND MANAGEMENT

Investments

When Barralcool biodiesel plant was defined, not all existing synergies had been used.

This decision had the purpose of allowing greater flexibility in operations with less possibility of interference among them.

Yet, the investments for a non-integrated, independent biodiesel plant are 22% higher than the integrated solution of Barralcool mill, as can be seen in Table 9 next.

Costs and Management

In order to assess the cost differentials, let us compare integrated and non-integrated production in the ethyl and methyl routes.

TABLE 8 Consumptions and production.

For 1,000 kg of biodiesel (final product)	
Processing: neutral oil	
Raw materials	
Oil-methyl(1)/oil-ethyl(2)	1,000 kg(1)/956 kg(2)
Methanol/ethanol	100 kg(1)/154 kg(2)
Products	
Biodiesel	1,000 kg
Glycerin	117 kg
Chemicals and utilities	
Chemicals	
Sodium methylate (as 30%)	18.3 kg(1)/33.4 kg(2)
Citric acid	0.65 kg
Hydrochloric acid @ 36%	9.5 kg
Caustic soda @ 50%	1.5 kg
Process water	4.0 kg
Sulphuric acid	0.2 kg
Utilities	
Electric power (absorbed)	15 kWh
Steam	300 kg
Cooling water duty (recycling)	145.000 Kcal
Nitrogen	(3)
Instrument air	6 Nm^3
Effluents	
Exhaust air from vent sub cooling	1.6 kg(4)
Waste water from biodiesel	10 kg(5)

(1) methylic route;
(2) ethylic route;
(3) discontinuous;
(4) with 150 ppm methanol/ethanol;
(5) 0.3% max methanol/ ethanol, BOD 7500 ppm, PH 7/9.

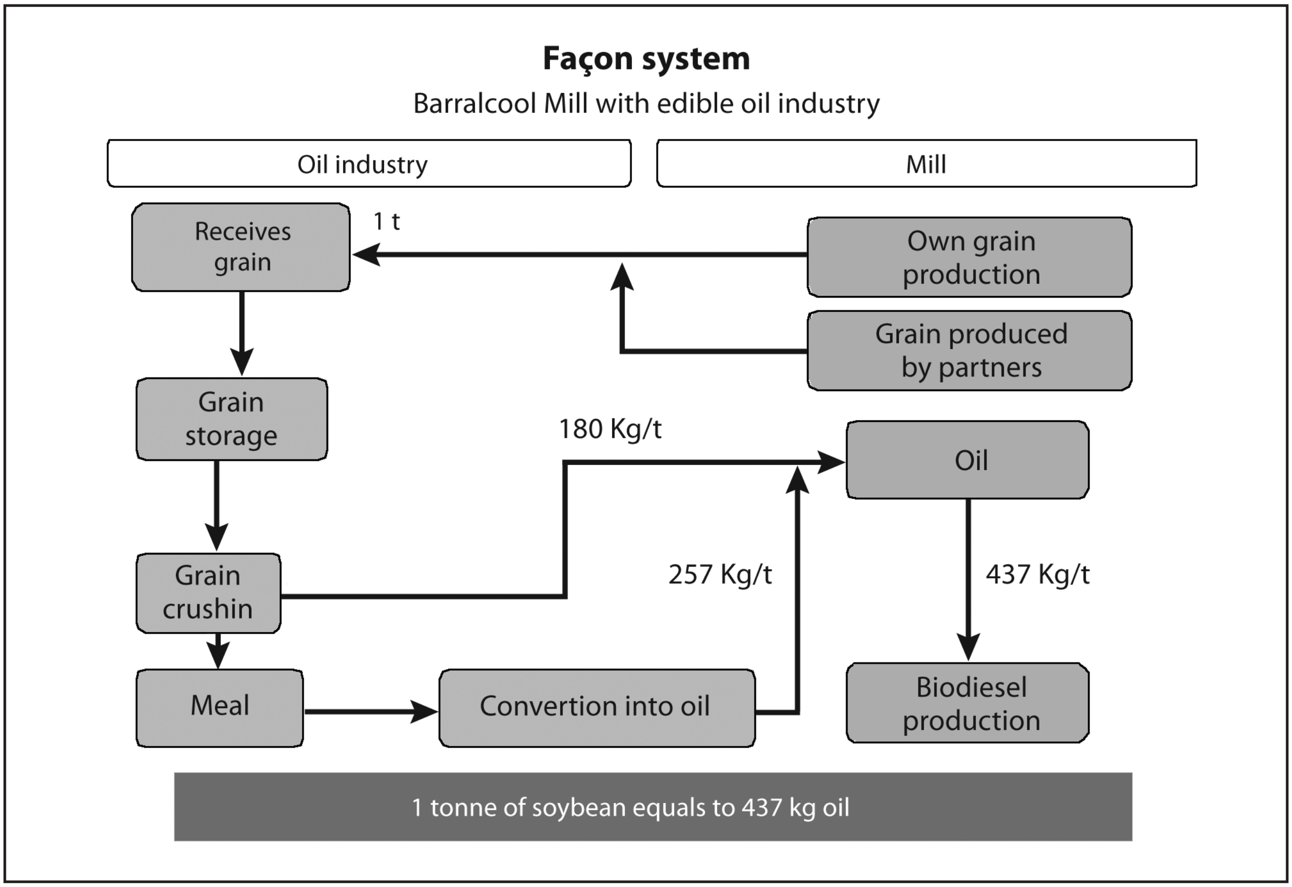

FIGURE 7 Exchange of soybean grain for oil – the Façon system.

The main components in the cost of biodiesel are the raw materials, and the vegetable oil represents around 85% of total cost.

In the integrated solution, the grain production makes available around 5,000 tonnes of oil/year, calculated at cost of production and using the façon system.

For the complementary 45,000 tons of oil, Barralcool makes use of partnership with family farming, obtaining oil at a lower cost than the market price. But to obtain a broader conclusion, let us consider that the complementary oil is acquired at normal market prices.

Table 10 presents the oil cost calculations used for biodiesel production at Barralcool, within these premises, obtaining an average value of US$ 611.56/t, using the conversion rate of US$ 1.00 = R$ 2.20.

As can be seen, own grain production integrated with cane production and conjugated with the façon system enables a significant reduction in the cost of oil, in the order of 40%.

The small quantity, around 10% of the plant capacity, suggests that solutions be developed to increase this participation, such as, for example, planting 2 oleaginous crops in the renewal area in the same harvest season, or installing 1 biodiesel plant supplied by several other mills.

Table 11 presents the total comparative cost of biodiesel production, emphasizing the most significant items and grouping the others. The bioethanol cost used is the internal production cost at the Mill.

When analysing the results, one is able to conclude that the integrated solution presents a lower cost, in which the ethyl route is more advantageous, with a cost of US$ 0.604 per litre of biodiesel. It is pointed out that the cost of diesel to the mill is US$ 0.74 per litre. The comparative reduction of Usina Barralcool's costs when us-

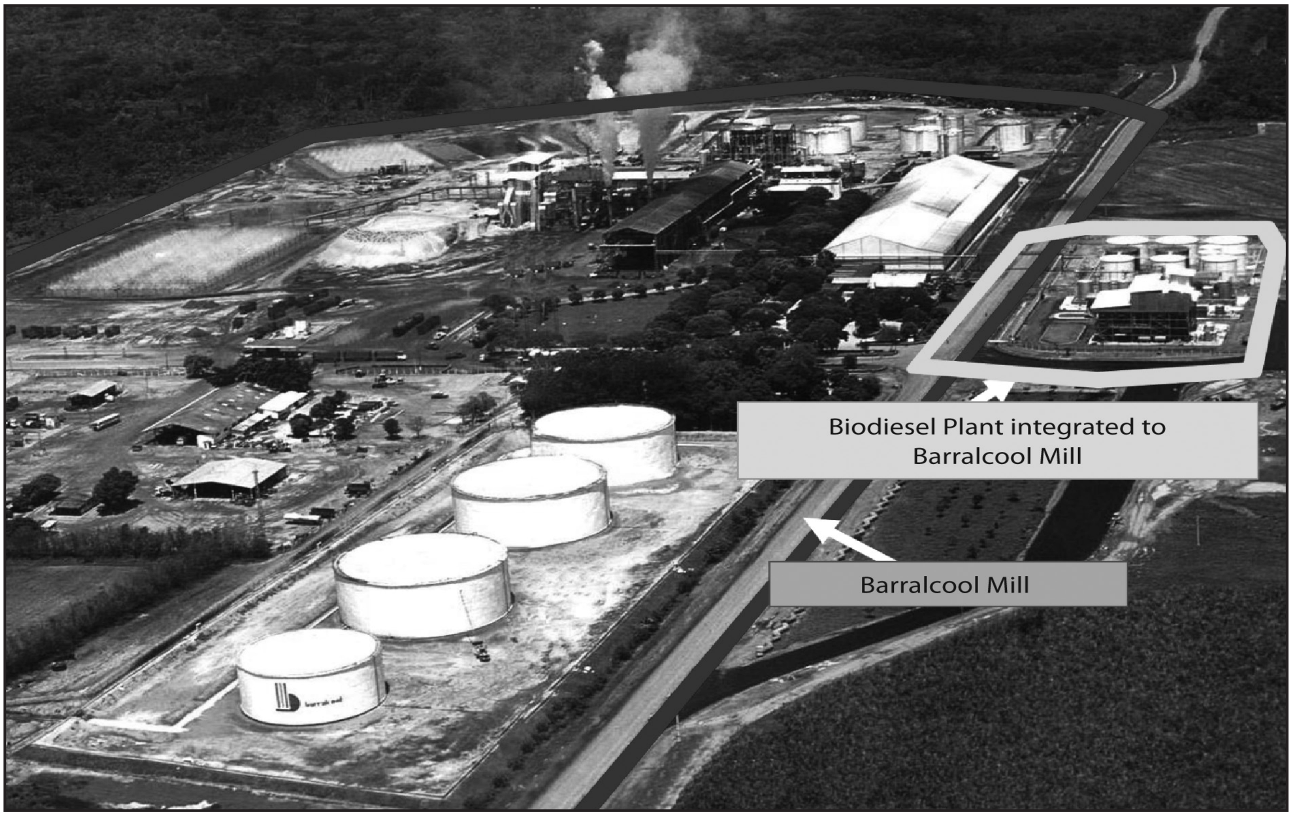

FIGURE 8 Biodiesel Plant Integrated to Barralcool Mill.

FIGURE 9 Barralcool Biodiesel Plant.

TABLE 9 Comparison of investments – Integrated biodiesel plants *versus* non-integrated plants.

Description	Investments – US$ 1,000[(1)]	
	Integrated Barralcool plant	**Non-integrated, independent plant**
Neutralization	1,136	1,136
Biodiesel process	5,909	6,818
Tanks/ Loading and delivery station	1,591	1,818
Pipe rack	455	682
Boiler	–	250
Cooling towers	–	114
Compressed air	23	23
Substation	682	682
N_2 plant	114	114
Cooling plant	68	68
Water treatment plant	–	91
Wastewater treatment plant	–	227
Fire-fighting installation	227	273
Laboratory	455	591
Scale	–	45
Civil works	1,818	2,273
Total	12,478	15,205
Comparative results	100%	122%

[(1)] Values in Real, converted by rate of US$ 1.00 = R$ 2.20.

TABLE 10 Cost of oil for biodiesel production.

Description	Quantity t/year	Cost U$/t	Annual cost 1,000 U$/year
Oil from own grain production	5,000	388.44	1,942.2
Oil acquired on the market	45,000	636.36	28,636.2
Total	50,000		30,578.4

TABLE 11 Comparative costs of 1 t of biodiesel production – integrated *versus* non-integrated production, in the ethyl and methyl routes, and calculation of 50 000 t biodiesel annual costs.

Description	Unit of measure	Integrated production					Non integrated production				
		Unit Costs US$	Methyl route		Ethyl route		Unit costs US$	Methyl route		Ethyl route	
			Consump-tion/t	Cost US$	Consump-tion/t	Cost US$		Consump-tion/t	Cost US$	Consump-tion/t	Cost US$
Degummed oil	t/t	611.47	1	611.47	0.956	584.56	636.36	1	636.36	0.956	608.36
Methanol	kg/t	0.73	100	73	–	–	0.73	100	73	–	–
Bioethanol	kg/t	0.36	–	–	154	55.44	0.64	–	–	154	98.56
Total raw material		–	–	684.47	–	640	–	–	709.36	–	706.92
Catalyzer	kg/t	1.36	18.3	24.89	33.4	45.42	1.36	18.3	24.89	33.4	45.42
Chemicals	kg/t	Various	Various	9.52	Various	9.52	Various	Various	9.52	Various	9.52
Utilities	Several	Various	Various	1.61	Various	1.61	Various	Various	16.75	Various	16.75
Labor	US$/t	–	–	6.82	–	6.82	–	–	10.23	–	10.23
Total per t biodiesel		–	–	727.31	–	703.37	–	–	770.75	–	788.84
Credit glycerin sale	kg/t	(0.136)	(0.117)	(15.91)	(0.117)	(15.91)	(0.136)	(0.117)	(15.91)	(0.117)	(15.91)
Cost per t biodiesel		–	–	711.40	–	687.46	–	–	754.84	–	772.93
Cost per m² biodiesel		–	–	626.03	–	604.96	–	–	664.26	–	680.18
Comparative		103.5%			100%		109.8%			112.4%	
50.000 t Biodiesel annual cost		35,570,000			34,373,000		37,742,000			38,646,500	

ing B30 (= 2.1 million litres), attains about US$ 300,000 per year.

The ethylic biodiesel sold by Barralcool will have a lower comparative cost than the biodiesel produced by non-integrated plants. Admitting that both are sold on the market for the same price, the mill will have an additional result of US$ 2.1 million/year and US$ 4.1 million/year, in comparison with the methyl or ethyl based product of the non-integrated production.

FINAL CONSIDERATIONS

The innumerable advantages of integrated biodiesel production in sugar and alcohol mills have been described in this paper.

These advantages occur in the farming and in industry, optimizing the use of land, resources, systems and management. Benefits are presented from the energy, process and economic aspects, in which costs and investments are reduced and income and profit are increased; as a result, biodiesel plants integrated with the sugar and alcohol mill provide a better return on investment than isolated plants.

Other relevant aspects deserve to be pointed out:

- The sugar and alcohol mill completes its full energy independence with the use of bagasse, bioethanol and biodiesel to meet all its energy demands.
- Integrated production makes ethylic biodiesel economically feasible. Thus, op-

portunities open for the use of ecological biodiesel, the ethylic biodiesel, 100% green and renewable, which can replace methyl biodiesel that uses the raw material methanol, of fossil origin.

- There are important environmental advantages with biodiesel replacing diesel derived from petroleum, and from the double use of the agricultural area already occupied by sugarcane, and thereby avoiding the use of new areas to install grain plantations.
- The solution of agricultural partnerships with family farmers, adopted by Barralcool, can also be applied by other mills, with the benefit of promoting social inclusion of the small farmer, and fixing persons in the rural areas.
- The use of the cane plantation renovation land can be maximized with the development of technology, new varieties and agricultural practices, which broaden the possibility of obtaining 2 harvests from the same lands and in the same sugarcane crop period. At present, the combined use of soybean, peanuts or sunflower seeds enables an increase of around 30% in grain production, when compared with the harvest of a single oleaginous crop. The potential gains are higher than 30%.
- A very attractive solution is the implementation of 1 biodiesel plant for various other sugar and alcohol mills, all producing grains in rotation with sugarcane, and using the biodiesel produced in the plantations. The plant would be installed at the sugar and alcohol mill that best benefits the set.

It is important to record that all these advantages refer to only the 1st stage of the integrated plant development.

With the expansion of biodiesel production, and therefore, the quantity of grains, implementation of an oil producing industry integrated with the sugar and alcohol mill becomes advantageous, which is the second stage of Figure 4: agricultural and industrial integration.

With the development of the activity, opportunity will be opened for the 3rd stage: integration of processes in the grain and sugarcane productive chains.

We have no doubt that this development will significantly increase the competitiveness of biofuels. And this is a challenge we understand that the sugarcane agribusiness will face in the future. It is a long road.

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