INTEGRATED PRODUCTION OF ORGANOMINERAL BIOFERTILISER (BIOFOM®) USING BY-PRODUCTS FROM THE SUGAR AND ETHANOL AGRO-INDUSTRY, ASSOCIATED WITH THE COGENERATION OF ENERGY

By

JOSÉ LUIZ OLIVÉRIO, FERNANDO C. BOSCARIOL, PAULO E. MANTELATTO, ANTÔNIO ROGÉRIO P. CÉSAR, JOÃO RAFAEL PERRONI CIAMBELLI, MARCÍLIO N. DO AMARAL GURGEL and RENATA TORRES GOMES DE SOUZA

DEDINI S/A Indústrias de Base

Rod. Rio Claro-Piracicaba, km 26,3, CEP 13412-900, Piracicaba – São Paulo – Brazil

fernando.boscariol@dedini.com.br

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Abstract

BRAZILIAN bioethanol and sugar production generates large amounts of vinasse, filter cake and boiler ashes (originated from biomass combustion). On the other hand, the distribution of these by-products in the field is usually inadequate, considering the environmental aspects and the best use of nutrients and organic material present in these by-products. This work presents a study for reprocessing of these by-products into a solid and granular organomineral biofertiliser developed by Dedini S/A Ind. Base (BIOFOM®), which can be formulated according to the soil and vegetable specific needs. This article shows the process of an integrated BIOFOM, ethanol and electricity from biomass production system for an industrial unit of large capacity. The results of BIOFOM preliminary agronomic greenhouse tests and analysis of process profitability are also shown. These results indicate an excellent internal rate of return (IRR) and attractive payback time as well, resulting from surplus power sales, reduction of chemical fertiliser and fuel consumption, reduction of by-products distribution infrastructure, and decrease (elimination) of the mill's water withdrawal. Moreover, BIOFOM gave a good agronomic performance in greenhouse experiments, and it will provide an appropriate reuse of the by-products, in accordance with green technologies. Therefore, the studies show that BIOFOM will lead to the existence of a more profitable and sustainable agro-industry that adopts rational and friendly practices for the environment.

Introduction

According to UNICA((União da Indústria de Cana-de-Açúcar, 2008), 495.7 million tonnes of sugarcane were processed in the Brazilian 2007–2008 milling season, producing 2.5 million m³ of ethanol (anhydrous and hydrated) and 30.9 million tonnes of sugar.

The volume of vinasse generated is about 10 times the volume of ethanol produced, 28 kg to 40 kg/t cane of filter cake, and 6.25 kg/t cane of ash and soot resulting from bagasse burning. These by-products are reused in the cane field, but sometimes the disposal of such materials is not made appropriately, with losses in nutrients, N, P, K and organic matter contained in the by-products.

This paper proposes a profitable production system of a solid and granular organomineral fertiliser from these by-products for any mill producing ethanol and cogenerating electricity. The system permits a significant reduction in the use of chemical fertilisers and diesel oil, thus reducing the greenhouse gas emissions (GGE) and allowing the recovery of water contained in vinasse for reuse in the industry or in the crop (ESALQ, 2007 and 2008; Gurgel, 2009).

Materials and methods

For a technical-economic evaluation of the proposed solution, a case study was carried out for an ethanol producing mill equipped to produce power by cogeneration, with capacity to process 20 000 tonnes of cane per day (Table 1A).

For the purposes of the study, an industrial plant to meet this capacity was dimensioned and price quotations were duly requested. The costs of handling and distribution of the by-products in the cane field (vinasse, filter cake, ash, soot and chemical fertilisers) were calculated, and these costs were compared with those involved in the production and distribution of the organomineral biofertiliser, called BIOFOM® (Gurgel, 2009; Kiel, 1985; Mantelatto *et al.,* 2007).

To evaluate BIOFOM's agronomic potential, batches of this fertiliser were produced (see Figure 1) from vinasse, filter cake, ash and soot and complemented with chemical fertilisers, which were granulated and dried (Carmello *et al.,* 2009). The biofertiliser granulation was made in a plate granulator with 35 r/m disc rotation. The experiment (ESALQ, 2009, Carmello *et al.,* 2009) was conducted in the greenhouse of the Department of Soil Sciences of 'Luís de Queiroz' College – ESALQ (University of São Paulo, 2009) in Piracicaba, SP.

The experiment was designed for 25 treatments: Control sample, mineral fertiliser 100%, 75% and 50% of 50 kg of N, 100 kg of P_2O_5 and 100 kg of K_2O; BIOFOM from vinasse (resulting from ethanol production), concentrated, 30% and 45% total dolids with 100%, 75% and 50% of the N, P and K doses of the treatment with mineral fertiliser; BIOFOM from vinasse plus sugar, concentrated, 30% and 45% total dolids with 100%, 75% and 50% of the N, P and K doses in the treatment with mineral fertiliser; BIOFOM from vinasse (resulting from sugar production), concentrated, 30% and 45% total solids with 100%, 75% and 50% of the N, P and K doses of the treatment with mineral fertiliser; concentrated vinasse (30% total solids) from ethanol production with mineral complementation for 100% of 50 kg of N, 100 kg of P_2O_5 and 100 kg of K_2O; concentrated vinasse (30% total solids) from ethanol and sugar production with mineral complementation for 100% of 50 kg of N, 100 kg of P_2O_5 and 100 kg of K_2O; concentrated vinasse (30% total solids) from sugar production with mineral complementation for 100% of 50 kg of N, 100 kg of P_2O_5 and 100 kg of K_2O, with four replications each, resulting in 100 plots. All treatments received limestone, including the control sample. Each plot was represented by a 2.5 L capacity pot, wherein 2 kg of earth, 0.625 g of $CaCO_3$ and 0.625 g of MgO were added.

Two corn seeds were planted in each pot, and the seedlings were then thinned out to one plant per pot on the 5th day of the experiment. The results were evaluated with respect to the foliar area, dry matter of the aerial portions and roots, amount of nutrients in the plant's aerial portions and roots, and remaining BIOFOM after harvest.

Results

Technical-economic evaluation of the BIOFOM producing unit

Figure 1 shows the organomineral fertiliser made from cake, ash, soot and concentrated vinasse and complemented with chemical fertiliser, called BIOFOM (Gurgel, 2009; Kiel, 1985; Mantelatto *et al.,* 2007).

Figure 2 presents a chart of the unit operations, feedstock and utilities for BIOFOM production for a basic formulation of the end fertiliser. In this process, filter cake, boiler ashes and soot are mixed and dried. The vinasse generated by the distillation of ethanol is concentrated up to 50% dry substance (DS) in multi-effect vacuum evaporators and is further mixed with a mineral source of N, P and K and sent to be mixed with cake, ashes, and soot previously dried. The mixture is granulated and dried, resulting in a solid organomineral fertiliser (Figure 1) according to the planned formulation. The energy required for the vinasse concentration is obtained from the integration of energy with distillery, and the dried mixtures result from the combustion in the furnace of bagasse and/or trash ('straw') and/or optionally concentrated vinasse.

Fig. 1—BIOFOM.

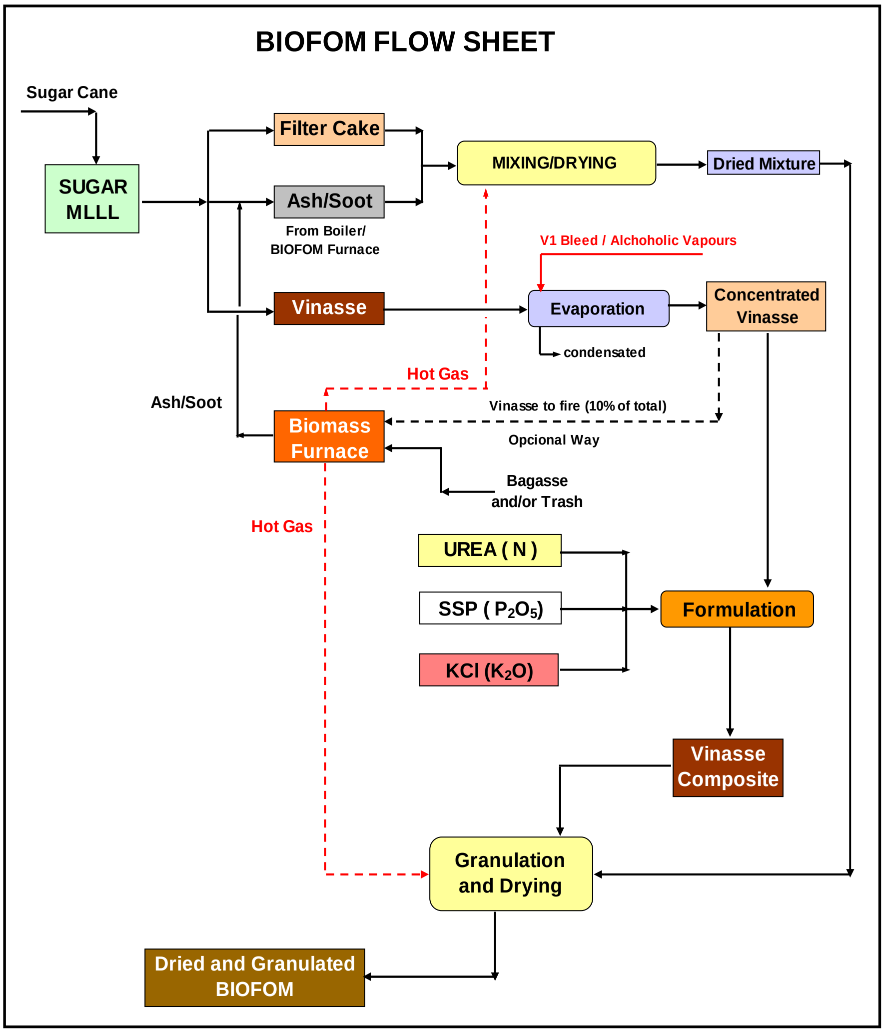

Fig. 2—BIOFOM flow sheet.

Fertiliser savings with the use of BIOFOM

Table 1 (A) is a summary of the case study of a mill producing ethanol, power and BIOFOM. According to the data presented, a unit processing 3 600 000 tonnes of cane/season (20 000 tonnes of cane/day), equipped with a 67 kgf/cm² boiler that consumes some 430 kg of steam/tonne of processed cane, it is possible to process 1 500 000 L of ethanol/day, cogenerate 65 kWh/tonne of cane, and produce 180 955 tonnes of biofertiliser/season with a formulation (3, 3, 4).

Table 1(A)—Summary of integrated production of ethanol, energy and BIOFOM®.

Integrated production of BIOFOM in sugar milling		
Milling of cane (742 tc/h)	t/season	3 600 000
Cane area (harvest base: 86 t/ha)	ha	41 860
Cogeneration	kWh/tc	65
Specific steam consumption	kg/tc	430
Boiler pressure (abs)	kgf/cm^2	67
Vinasse		
Mass flow (3% DS)	t/season	2 387 664
Mass flow (60% DS)	t/season	115 350
Recovery water	t/season	2 272 314
Volume reduction	#	20.7
Filter cake		
Mass flow (40%DS)	t/season	104 818
Ash from boiler		
Ash from boiler/furnace	t/season	40 680
Chemical fertiliser complementary		
Urea (45**%** of N)	t/season	6265
SSP (21% P205)	t/season	1322
Potassium cloride (KCl)	t/season	196
Biofertiliser—BIOFOM		
Total production (85% DS)	t/season	180 995
Specific production of BIOFOM	kg/tc	50
Specific rate of application on land	t/ha/year	4.3

In this case, the power used to concentrate vinasse comes from the vegetal steam generated by juice evaporation and the alcoholic vapours of the distillery.

Table 1 (B) shows the savings obtained with BIOFOM fertiliser. According to these data, 35% of nitrogen, 62% of phosphorus and 98% of potassium can be recycled, which reduces dramatically the amount of fertiliser to be purchased.

In the overall picture, about 67% of the fertiliser to be used in the milling season can be optimally recycled and distributed in the field.

In addition, 2 272 314 m³ of water via recovered condensates by vinasse concentration can be used in the industry or in the field.

Table 1(B)—Chemical fertiliser saved by use of BIOFOM.

Fertiliser saved by BIOFOM use		
Consumption of fertiliser		
Urea (45% of N)	t/season	9648
SSP (21% P205)	t/season	4179
Potassium chloride (kCl)	t/season	10 287
Total	t/season	24 115
Fertiliser recycled by BIOFOM		
Urea (45% of N)	t/season	3383 (35.1%)
SSP (21% P_20_5)	t/season	2848 (68.1%)
Potassium chloride (KCl)	t/season	10 091 (98.1%)
Total recycled	t/season	16 322 (67.6%)
Other compounds recycled by BIOFON		
Organic material	t/season	86 882
CaO	t/season	3665
MgO	t/season	1108
SO_4	t/season	4023
Cu	t/season	21.2
Zn	t/season	9.3
Mn	t/season	46.8
Fe	t/season	187.0
Bo	t/season	2.8

Economic evaluation

To evaluate the economic impact of BIOFOM production and use in the ethanol and energy producing complex, a study considering all investments and the fixed and variable costs for the production of this fertiliser in industrial and agricultural operations was carried out.

The study points out that the main advantage of BIOFOM lies in the reduced expenses with acquisition of fertilisers and the reduction in the investment and operational costs regarding agricultural operations. Vinasse distribution is no longer required, eliminating the need for trucks to transport such huge volumes.

In the case studied, it was assumed that vinasse would be concentrated up to 50% DS before mixing with the filter cake and ashes. A BIOFOM plant was designed for such a system, taking into consideration N, P and K complements to meet exactly the total sugarcane plantation needs.

Fertiliser expenses, which in the BIOFOM process refer to the N, P and K complements, reduced 70% when compared to the use of mineral fertilisers. Investments in trucks and distribution systems showed a reduction about 67% for the worst case (ethanol mill very close to the plantation).

Even when taking into account the extra labour required for the BIOFOM plant, the steam, electricity and bagasse consumption by the BIOFOM process, the net result is very positive.

Considering a capital cost of 12% per year and typical equipment costs, it can be shown that the discounted payback time of such a project ranges from 2 to 3.5 years, depending on the distance between the ethanol mill and the sugarcane plantation.

Another study shows that a water-exporting ethanol mill, based only on vinasse concentration but not producing BIOFOM, is not profitable, due to the low incomes and high investment. Since the BIOFOM process is a step further in that process, including the benefit of water exportation (Gurgel, 2009; Mantelatto *et al.,* 2007), and was demonstrated to be profitable, it can be concluded that BIOFOM is a solution that makes water-exporting mills not only environmentally beneficial but also profitable.

Greenhouse results

Table 2 presents a summary of the comparative results (100% of the formula to sugar-cane) of the samples that were treated with BIOFOM (by using vinasse with 45% DS), conventional fertiliser and those that did not receive fertiliser (control sample). Both those pots fertilised with BIOFOM and those fertilised with a formulation prepared with chemical fertiliser only were prepared to meet 45%, 75% and 100% of the amount of N, P and K required for sugarcane culture. The BIOFOM samples were prepared with three different types of vinasse, obtained from fermentation of mixed juice (J), or molasses (M) or mixtures of molasses and mixed juice (MJ).

After harvesting, 50 days after planting, all samples were evaluated with regards to foliar area, dry mass and nutrients present in the aerial portion of the plants and in the root system, residual N, P and K in soil, and the remaining BIOFOM in the granule after harvest

As the results presented in Table 2 show, all treatments had significantly better performance than the control sample. Also, there were no significant differences between the treatments with BIOFOM using different vinasses (MJ, M and J).

Table 2—Summary of the greenhouse tests of BIOFOM.

Parameter	Part analysed	Mineral fertiliser	BIOFOM (complemented of 100% of formula of cane plantation)			Control sample
			MJ	M	J	
Leaf area (cm^2)		3 771	2 361	2 903	2 870	546
Dry substance (g)	Aerial part	20.42	9.55	13.26	14.94	3.27
	Root	9.14	8.5	8.33	9.07	8.25
Nitrogen (mg/dm^3)	Aerial part	490.73	222.01	231.01	255.2	35.44
	Root	128.24	107.31	96.83	88.93	52.01
	Soil	nd	nd	nd	nd	nd
Phosphorus (mg/dm^3)	Aerial part	71.43	23.37	27.18	29.24	2.82
	Root	16.68	9.21	8.15	9.44	
	Soil	166.75	47.5	35.5	44	5.75
Potassium (mg/dm^3)	Aerial part	702.8	362.87	418.67	468.91	33.56
	Root	125.09	72.45	89.87	77.73	5.27
	Soil	1.88	7.48	6.05	3.8	0.35
Granules remaining (%) after harvest (50 days after plantation)	DS	nd	51.11	53.16	53.58	
	N	nd	49.56	45.37	53.23	
	P	nd	81.87	100.00	90.41	
	K	nd	10.74	19.78	8.16	

Note: MJ : vinasse from molasse and juice, M: vinasse from molasses, J: vinasse from juice, nd: not detected

The mineral fertiliser produced a bigger mass of dry matter in the aerial portion of the plant, which shows that some of the nutrients present in BIOFOM were not available 50 days after application, which is an advantage in an open system environment where leaching of the mobile nutrients in the soil occurs. In fact, it should be noted that more than 50% of the nutrients in

BIOFOM initially applied remained in the soil after 50 days. It should also be taken into account that, in this experiment, being a closed system, no losses occurred, resulting in a slightly higher efficiency in the treatments where chemical fertiliser was applied.

For sugarcane, whose cycle is 12 to 18 months, there is enough time for the remaining BIOFOM nutrients to be available and, therefore, it can be expected that it responds similarly or even better than the treatments with mineral fertilisers (Carmello *et al.*, 2009).. Kiel (1985) reported the benefits of the application of organic matter in soil, which promotes the improvement of the soil physical-chemical properties, the CEC –Cation Exchange Capacity, and porosity, which facilitates the absorption of nutrients and reduces the losses caused by leaching. By using BIOFOM in soil, the same benefits reached with organic matter can be expected, given that BIOFOM is composed of about 40 to 70% of organic matter, depending on the formulation used.

Conclusions

According to the results obtained, we can conclude that:

- It is evident that BIOFOM is a competitive and sustainable organomineral fertiliser;
- BIOFOM permits an optimum and profitable distribution of sugar, ethanol and energy by-products, which enables recycling of more than 50% of the fertiliser required in sugarcane plantation;
- BIOFOM can be formulated according to the specific needs of the soil, permitting optimum use of chemical fertilisers;
- Additional gains with the use of BIOFOM, because of its high content of organic matter, will be obtained with the improvement of the soil physical-chemical properties, the CEC –Cation Exchange Capacity, and porosity, which facilitates the absorption of nutrients and reduces the losses caused by leaching;
- The economic study showed the feasibility of the project implementation for BIOFOM production: excellent internal rate of return (IRR) and payback time of 2 or 3 years;
- The use of BIOFOM in the crop land allows a significant reduction of the infrastructure required to distribute fertiliser, vinasse, filter cake and ashes;
- With implementation of BIOFOM, it is possible to reduce or even eliminate water withdrawal by the mills by using only the water contained in sugarcane: a portion of the recovered water in vinasse concentration can be reused in the industry or in the field.
- Optimisation of power consumption in the mill in connection with the implementation of a BIOFOM plant will certainly increase the profitability of the sugar and ethanol complex, due to the integrated production of biofertiliser, ethanol, sugar, surplus power generation and water recovery.

REFERENCES

Carmello, Q.A.C., Anti, G., Gurgel, M.N.A. and Mantelatto, P.E. (2009). Avaliação Agronômica do BIOFOM em casa de vegetação, com milho como planta teste, Internal Report of Dedini, 2009.

ESALQ (2009)**.** Escola Superior de Agricultura Luis de Queiroz, www.esalq.usp.br.

Gurgel, M.N.A.(2009). A Usina Dedini para Produção de BIOFOM-Biofertilizante Organomineral, SIMTEC-Piracicaba, São Paulo.

Kiel, E.J. (1985). Fertilizantes Orgânicos, Ed. Agronômica Ceres Ltda, São Paulo.

Mantelatto, P.E, Oliverio, J.A, Boscariol, F.C, Ciambelli, J.R., Pereira Cesar, A.R. and Gurgel, M.N.A. (2007) Dedini patent request in Brazil, 'Processo para Produção de Fertilizante Orgâno-Mineral'- PI-0801794-8.

UNICA (2008). União da Indústria de Cana-de-açúcar, www.unica.com.br.

PRODUCTION INTÉGRÉE DE BIOENGRAIS ORGANOMINERAL (BIOFOM ®) À L'AIDE DES SOUS-PRODUITS DU SUCRE ET DE L'AGRO-INDUSTRIE D'ÉTHANOL, ASSOCIÉE À LA COGÉNÉRATION D'ÉNERGIE

Par

JOSÉ LUIZ OLIVÉRIO, FERNANDO C. BOSCARIO, PAULO E. MANTELATTO,
ANTÔNIO ROGÉRIO P. CÉSAR, JOÃO RAFAEL PERRONI CIAMBELLI,
MARCÍLIO N. DO AMARAL GURGEL et RENATA TORRES GOMES DE SOUZA
DEDINI S/A Indústrias de Base
Rod. Rio Claro-Piracicaba, km 26,3, CEP 13412-900, Piracicaba – São Paulo – Brazil
fernando.boscariol@dedini.com.br

MOTS-CLÉS: Bioengrais Organomineral, Vinasse, Éthanol.

Résumé

LA PRODUCTION de bioéthanol et de sucre au Brésil génère de grandes quantités de vinasse, des tourteaux et des cendres des chaudières (provenant de la combustion de la biomasse). D'autre part, la distribution de ces sous-produits dans le champ est généralement pas satisfaisante, quand l'on considère les aspects environnementaux et la possibilité d'un meilleur usage des éléments nutritifs et des matières organiques présents dans ces sous-produits. Cette communication présente une étude de retraitement de ces sous-produits afin de produire un bioengrais organomineral solide et granulaire développé par Dedini S/A Indiana Base (BIOFOM ®), qui peut être formulé conformément aux caractéristiques du sol et aux besoins spécifiques des plantes. Le procédé d'un système de production intégré de BIOFOM, d'éthanol et d' électricité à partir de la biomasse pour une unité industrielle de grande capacité et décrit. Les résultats des tests préliminaires agronomiques effectués en serre avec le BIOFOM et de l' analyse de rentabilité du procédé sont également présentés. Ces résultats indiquent un excellent taux de retour interne sur l'investissement et le temps de recouvrement est aussi attrayant, étant issu de la vente du surplus d' énergie, de la réduction de la consommation de carburant et des engrais chimiques, de la réduction de l'infrastructure de distribution des sous-produits et de la diminution (élimination) du retrait de l' eau de l' usine. En outre, BIOFOM a donné une bonne performance agronomique dans des essais en serre, et il fournira une réutilisation appropriée des sous-produits, en conformité avec les technologies vertes. Par conséquent, les études montrent que BIOFOM conduira à l'existence d'une agro-industrie plus rentable et durable qui adopte des pratiques rationnelles et favorables à l'environnement.

PRODUCCIÓN INTEGRADA DE FERTILIZANTES ORGANOMINERALES (BIOFOM*) EMPLEANDO SUBPRODUCTOS DE LA AGROINDUSTRIA AZUCARERA Y ALCOHOLERA, ASOCIADA CON LA PRODUCCIÓN DE ENERGÍA.

Por

JOSÉ LUIZ OLIVÉRIO, FERNANDO C. BOSCARIO, PAULO E. MANTELATTO, ANTÔNIO ROGÉRIO P. CÉSAR, JOÃO RAFAEL PERRONI CIAMBELLI, MARCÍLIO N. DO AMARAL GURGEL y RENATA TORRES GOMES DE SOUZA

DEDINI S/A Indústrias de Base

Rod. Rio Claro-Piracicaba, km 26,3, CEP 13412-900, Piracicaba – São Paulo – Brazil

fernando.boscariol@dedini.com.br

PALABRAS CLAVE: **Biofertilizantes Organometálicos, Vinazas, Etanol.**

Resumen

LA PRODUCCIÓN de bioetanol y azúcar generan grandes cantidades de vinazas, tortas de los filtros y cenizas de las calderas (originadas de la combustión de la biomasa). Por otra parte, la distribución de estos subproductos en el campo es usualmente inadecuada, considerando los aspectos ambientales y los usos más efectivos de los nutrientes y los productos orgánicos en estos subproductos. Este trabajo presenta un estudio para el reprocesamiento de éstos en un organobiofertilizante sólido y granular, desarrollado por DEDINI S/A ind. Base (BIOFOM*), el cual puede formularse en correspondencia con las necesidades de los suelos y los vegetales. Este artículo muestra el proceso de un sistema integrado, BIOFOM*, etanol, energía a partir de biomasa, para una unidad de producción industrial de gran capacidad. Se muestran también los resultados preliminares, de las experiencias agronómicas en invernadero, del BIOFOM*, así como un análisis de los beneficios económicos. Los resultados indican excelentes rates internos de retorno (IRR) y atractivos tiempos de recuperación de la inversión, resultado de las ventas de energía sobrante, reducción de fertilizantes químicos, y consumo de combustible y en la infraestructura de la distribución de subproductos, junto al decrecimiento (eliminación) de la extracción del agua en el Central. Adicionalmente, BIOFOM* ofrece un buen comportamiento agronómico en los experimentos en invernadero y brindará un reuso apropiado de los subproductos en correspondencia con tecnologías verdes. Por tanto, los estudios muestran que BIOFOM* conducirá a la existencia de una agroindustria más rentable y sostenible, que adopta prácticas racionales y amigables con el entorno.