Scientific Paper

Innovative intensity, technological capacity and excellence level of the biogas technical team in the BIOMAS-CUBA project

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ABSTRACT: The technologies associated to biogas are the most widely used at present due to their compatibility with the environment, because, besides utilizing the biofuel, they allow to treat wastes of high organic load. This study was conducted at the Pastures and Forages Research Station Indio Hatuey in order to evaluate some key indicators, such as innovative intensity (IIT), technological capacity (TCT) and excellence level (ELT) of the technical team linked to the biodigester construction and starting up technologies. An IIT of 70 %, a TCT of 68 %, and an ELT of 78 % were obtained. All the evaluations coincided on the fact that the most limiting aspects were: the generation and protection of the innovations, the quality management system used and, to a lesser extent, the formulation of business strategies. It was concluded that the technical team should focus on conceiving an intellectual property strategy that regulates the procedures for the protection of the results, besides creating a stimulation system for innovators. It is recommended to implement a quality management system, as regulated by the International Standard Organization (ISO). The evaluation of these indicators is considered pertinent, because it allows to detect the limitations and to propose actions for their solution.

Keywords: biofuel, innovation, technology

INTRODUCTION

The indiscriminate contamination of the environment, main cause of the climate change, has caused a marked interest in the development of waste treatment systems. Among the most damaging wastes are the organic ones, which, because of the large contaminating load they have, hinder the innocuousness of the medium where they are poured (Kelleher Environmental, 2013; Persson *et al*., 2014; Suárez *et al*., 2014). That is why at present works are being conducted on the search for efficient systems that can decrease this load.

An alternative has been the design, construction and advice on the adequate management of anaerobic digestion systems (fixed-dome biodigesters, polyethylene tubes, etc.), in order to decrease the organic matter content in wastes (Aremu and Agarry, 2013; Leite *et al*., 2014; Sosa *et al*., 2014; Nasir *et al*., 2015).

Besides the advantages of treating wastes, these systems offer the possibility of utilizing the biogas and effluents, resulting products from the anaerobic digestion process, which has propitiated the technology to be in constant development and, thus, the innovations to be increased. Likewise, the prominent advance of these technologies makes it necessary that the provided products and services are competitive in the market.

In this sense, one of the research and technological innovation processes that are developed within the framework of the international project BIOMAS-CUBA, coordinated by the Pastures and Forages Research Station Indio Hatuey, is related to the production of biogas and biofertilizer in the context of agroenergetic farms; in which food and energy is produced in an integrated way (Suárez *et al*., 2014; Suárez, 2015). This process is accompanied and directed by a specialized technical team; nevertheless, the evaluation from the point of view of its innovative intensity (Suárez *et al*., 2014; Suárez, 2015), technological capacity and excellence level is necessary, which would allow to identify the strengths and weaknesses of this team, as well as solving the latter to achieve a competitive product.

Taking the above-explained facts into consideration, the objective of the study was to evaluate the technical team related to the technologies of construction and starting up of biodigesters, developed in the BIOMAS-CUBA project.

METHODOLOGY

For the evaluation, adaptations were made of the methodological proposals by Suárez (2003) and Hernández (2010), Cuban researchers who have

worked together in the development of the specific procedures to implement the evaluation of the three indicators which are described below.

Procedure for the evaluation of the innovative intensity of the biogas technical team (IIT)

To evaluate the innovative intensity[1], measured through the homonymous indicator IIT, an adaptation was made of the method proposed by Suárez (2003), which consisted in the modification of the variables, their assessment and their weight (*Wi*), as well as their scoring scale (*Pi*), because they were developed for livestock production enterprises.

The Delphi expert method was used to achieve the adaptation of the variables and their weight to the new context. Once the criteria were processed, specific weight (*Wi*) was assigned to each variable from the Füller triangle, as well as a scoring scale.

Among the variables to be evaluated and managed for the team to have high innovative intensity, the following can be included: generation of innovations, patents and records; the training of the human capital; the quality management system; the links with providers and clients; the surveillance of the environment; the environmental protection; the financial capacity; and the role of the top management in the R+D+i process, among others. All of them are integrated in the above-mentioned indicator IIT in a scale of five (5) points, and it is calculated through the expression (1):

$$IIT = \frac{\sum(PixWi)}{5\sum Wi} * 100 \quad [\%] \quad (1)$$

Where:

IIT: Innovative intensity of the biogas technical team.
Pi: score assigned to the variable *i*; *Pi* = 1, 2, 3, 4, 5.
Wi: specific weight of variable *i* according to its importance degree; $1 > Wi > 0$.

The IIT is integrating and indicates how far or close the team is to another one which is called "highly innovative" and which has the maximum score (5 points) in all the variables; that is, its IIT reaches the value 1,0 or 100 %. Once this indicator is determined, the least valued variables are selected, on which incidence is exerted through an improvement process.

Procedure for the evaluation of the technological capacity of the biogas technical team (TCT)

For the evaluation of the technological capacity of the team the variables of the method recommended by Hernández (2010), which differ from the ones proposed by Brito (2000) and Suárez (2003), aimed at manufacturing and livestock production enterprises, respectively, were modified. The evaluation was carried out, through a panel of experts, from a weighing method, which evaluates a set of items from a Likert scale of 5 points; among these items the training of the human capital, the existence of the team's own technologies, intellectual property, surveillance of the environment, existence of a technological strategy, links with the Cuban Science and Innovation System (SIS) and the R+D+i capacity.

Such method considers the essential competences of the team, associated to its resources and technological capacities. The maximum value reached by this indicator is 50 points (table 1), and its calculation is made through the expression (2):

$$TCTi = \frac{(\sum RTCi)}{(\sum PTC)} * 100 \quad [\%] \quad (2)$$

Where:

TCT*i*: technological capacity of the biogas technical team.
RTC*i*: real technological capacity.
PTC: potential technological capacity (max PTC = 50)

Procedure for the evaluation of the excellence level of the biogas technical team (ELT)

To evaluate the excellence level of the team modifications were made on the method recommended by Hernández (2010) regarding the variables, their assessment and their weight (*Wi*), from an adaptation of the proposal made by Suárez Mella (1996) and Suárez (2003) for the industrial and livestock production sectors, respectively, and whose procedure has the following steps:

1. Establishment of the variables of the organizational excellence level of the team (ELT)

The same procedure applied in the determination of the IIT was used. The chosen variables included the utilization of the operation capacity; the width

[1]Level of execution of the innovation activities that exists in a certain business (Hernández, 2010)

Table 1. Technological capacity of the team.

Degree	Scale (maximum 50 points)
High technological capacity	≥ 40 points
Moderate technological capacity	30-39 points
Low technological capacity	20-29 points
Very scarce technological capacity	< 20 points

Source: Suárez (2003).

and differentiation of the products and services portfolio; their quality; production costs and sale prices; training of the personnel; and generation, adoption and improvement of technologies, innovation and knowledge among others.

2. Determination of the specific weight (*Wi*) according to the degree of importance of the variables

The degree of importance granted to each variable by the experts was used as starting information for applying Füller triangle, in order to determine the relative weight of each variable, whose sum should total the unit.

3. Qualification of the variables under the real conditions of the team

The evaluating group, constituted by the members mainly involved in its management, with all the possible quantitative information and with the corresponding qualitative valuations, qualifies the performance shown at that moment by each analyzed variable, considering five evaluation levels or stages (table 2) with their corresponding score (*Pi*) from the method proposed by Suárez Mella (1996).

4. Determination of the ELT

For its calculation a weighed measurer was used which relates the score assigned by the experts to each variable, according to the real performance of the team with regards to the maximum qualification that would be in correspondence with the Excellence status; that is, the maximum value of each variable involved (10 points), with the respective weights according to their importance (expression 3).

$$ELT = \frac{\sum_{i=1}^{n}(PixWi)}{10\sum_{i=1}^{n}Wi} * 100 \qquad [\%] \qquad (3)$$

Where:

ELT: excellence level of the biogas technical team.
Wi: relative weight or weighing of variable *i*.
Pi: score assigned to variable *i*.
n: quantity of variables

The ELT also allows to identify the gap between the excellence level an organization can aspire to have and the one it really has, as well as to determine the existing limitations in order to work on their solution through a process of continuous improvement or radical change (in the cases in which it is necessary).

RESULTS AND DISCUSSION

For the evaluation of the IIT a degree of importance or specific weight (*Wi*) was assigned to each variable, through the utilization of the Füller triangle, and a scoring scale (*Pi*) on each one of them (table 3).

An IIT of 70 % was reached (table 4), level higher than the one obtained by Guevara *et al*. (2008) in 2001 (50,3 %) and 2003 (59,4 %), in a livestock production enterprise; nevertheless, the results coincide in some critical variables, such as: generation of innovations, patents or records per worker and the quality management system used, although in this study the organization strategy was also affected. This value coincides with the one reached by Hernández *et al*. (2009) in an evaluation made of the technology-based socialist organization (TBSO) CespIH® in the years between 2000 and 2009 (range between 68,5 and 96,4 %).

On the other hand, the technological capacity (TCT) reached 68 %, which represents a moderate level (34 points); this value is higher than the one

Table 2. Scoring to qualify the performance of the variables.

Degree	Very good	Good	Regular	Bad	Very bad
Score (*Pi*)	10	8	6	2	1

Source: Suárez Mella (1996).

Table 3. Method to evaluate the innovative intensity of the biogas technical team

Variable	Assessment of the variable	Weight (Wi)	Scoring scale (Pi)
Generation rate of patents, innovations or records (PIR)	PIR / Number of workers Where, PIR: Quantity of patents, innovations and records	0,008	PIR > 2; 5 2 ≥ PIR ≥ 1; 4 1 > PIR ≥ 0,5; 3 0,5 > PIR ≥ 0,2; 2 0,2 > PIR > 0; 1
Products and/or services (P+S) with competitive designs (IPSDC)	IPSDC / P+S	0,041	IPSDC > 50%; 5 50 % ≥ IPSDC > 40 %; 4 40 % ≥ IPSDC > 30 %; 3 30 % ≥ IPSDC > 20 %; 2 20 %≥ IPSDC = 0; 1
Position in the national or international market, according to the case	1st 2nd 3rd 4th 5th Undetermined	0,075	5 4 3 2 1 0
Training of the personnel (TP)	TP > 75 % 75 % ≥ TP ≥ 60 % 60 % > TP ≥ 40 % 40 % > TP > 20 % 20 %> TP > 0	0,066	5 4 3 2 1
Strategy of the organization	Adequate, efficacious implementation Should be improved It exists, but its implementation shows difficulties In the process of being formulated Short-term plans	0,125	5 4 3 2 1
Proportion of polyvalent workers (PPW)	PPW > 65 % 65 % ≥PPW ≥ 40 % 40 % > PPW ≥ 30 % 30 % > PPW > 20 % 20 %> PPW > 0	0,008	5 4 3 2 1
Quality management system	Implantation of more than one of the families of the ISO Regulations. Implantation of one of the families of the ISO Regulations. ISO under process of introduction. Quality system that ensures it. Another non-normalized system.	0,091	5 4 3 2 1
Technological change capacity	High generation of technologies and innovations to the point that there are more than five (5) of the team's own technologies. Frequent assimilation of external or cooperation-developed technologies and innovations. High generation of technologies, to the point that it has 4-5 technologies of its own. Frequent assimilation of external or cooperation-developed technologies and innovations. Moderate generation of technologies and innovations (2-3 technologies of their own). Moderate degree of adoption of external technologies and innovations. Certain generation of technologies and innovations, one (1) technology of its own. It does not have its own technologies. Scarce generation of innovations, incipient adoption of external technologies and innovations.	0,041	5 4 3 2 1

Table 1. (*Continuation*)

Variable	Assessment of the variable	Weight (Wi)	Scoring scale (Pi)
Long-term contracts and close link with providers and clients.	Usual practice Regularly They increase, but regularly Sporadically Very scarce	0,066	5 4 3 2 1
Flexibility of the organization	Excellent (E) Good (G) Regular (R) Insufficient (I) Bad (B)	0,116	5 4 3 2 1
Surveillance level of the organization	Excellent (E) Good (G) Regular (R) Insufficient (I) Bad (B)	0,100	5 4 3 2 1
Environmental protection in the organization	• Clean operation technologies are usually developed and/or used; only organic inputs are used for plant nutrition and health, and wastes are recycled. Existence of an environmental strategy. Implantation of the Regulations ISO 14000. • Clean operation technologies are usually developed and/or used; only organic inputs are used for plant nutrition and health, and wastes are recycled. There is not an explicit environmental strategy. • Clean operation technologies start to be developed and/or used; in general a combination of organic and chemical inputs is used for plant nutrition and health, with predominance of the chemical ones, and wastes are recycled. • Although it can be developing and/or using clean operation technologies, the ones supported on conventional practices prevail; the utilization of chemical inputs for plant nutrition and health is common. • Operation system supported on environment-degrading conventional practices and chemical inputs	0,033	5 4 3 2 1
Aim of the organization	• Focused on the satisfaction of socioeconomic priorities. • At market segments, but the satisfaction of the society's needs is not neglected. • At the clients, but the satisfaction of the society's needs is not neglected. • At the product and sales. • At sales.	0,033	5 4 3 2 1
Financial capacity of the organization	Assessment of solvency and liquidity ratios, as well as profitability, in E, G, R, I y B	0,091	E = 5, G = 4, R = 3, I =2, B = 1
Internal and external informational flow	Assessment of the horizontality of the management with autonomous teams, with a stable internal and external communication, in E, G, R, B and VB.	0,033	E = 5, G = 4, R = 3, B = 2, VB = 1

Table 1. (*Continuation*)

Variable	Assessment of the variable	Weight (Wi)	Scoring scale (Pi)
Innovation culture	Assessment on whether the Top Management takes risks and implicates and stimulates everyone: Always One of the two aspects is always fulfilled, the other one, sometimes One of the two aspects is fulfilled, the other one, never One of the two aspects is sometimes fulfilled, the other one, never None of them is fulfilled None of them is fulfilled; besides the Top Management forbids taking chances.	0,050	5 4 3 2 1 0

obtained by Hernández *et al*. (2009) in the evaluation made in 2005. In this case, the main limitations detected were: inexistence of protection actions of the technologies and innovations, as well as of the other forms of intellectual property; and, to a lesser extent, that the technological strategy and the technological development plan are still under formulation. Table 5 shows the scoring of the variables.

Regarding the organizational excellence level (table 6) 78,0 % (very high) was obtained, higher than the one reached by Delgado (2011) in a study with five Cuban livestock production enterprises (between 28,1 and 52,8 %), although it is below than the one referred by Hernández *et al*. (2009), who obtained a value of 92,2 %. This indicates that there are still gaps to be improved, for which it is necessary to continue paying attention, with emphasis, to the protection of intellectual property, because the other variables were evaluated as Good and Very Good.

Integrally, there was coincidence regarding the fact that the results of innovation were not being protected, which could be due to deficiencies in the strategy of the organization and the technological innovation, as well as in the plan of technological development; besides there is not an adequate quality management system.

Likewise, the main improvement actions are aimed at the conception of a strategy of intellectual property that regulates the procedures for the protection of results in innovation, to the creation of a stimulation system for innovators and to the training of the personnel on quality topics, in order to implement a Quality Management System, as regulated by the International Standard Organization (ISO); all these actions would be implemented in the technical team as well as in the project.

CONCLUSIONS

The innovative intensity, technological capacity and excellence level of the biogas technical team reached favorable values, although some variables were identified that constitute limitations, such as the protection of the generated innovations and technologies and the quality management. Likewise, the evaluations of these indicators, according to the adaptations of the methodologies, is considered pertinent because it allows to determine the limitations and propose actions for their solution.

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Table 4. Innovative intensity of the biogas technical team.

Variable	Assessment of the variable	Weight (*Wi*)	Score (*Pi*)	*Pi* · *Wi*
Generation rate of patents, innovations or records (PIR)	0,45	0,008	1	0,008
Products and/or services with competitive designs	72 %	0,041	4	0,164
Position in the national or international market, according to the case	National leader	0,075	4	0,3
Training of the personnel	26 %	0,066	5	0,33
Strategy of the organization	Adequate, with efficacious implementation	0,125	2	0,25
Proportion of polyvalent workers	23 %	0,008	5	0,04
Quality management system	Although there is not a formalized quality system, it is ensured through phytosanitary and physical quality inspections	0,091	1	0,091
Technological change capacity	Moderate generation of technologies and innovations, with three (3) technologies of its own; moderate degree of adoption of external technologies and innovations	0,041	5	0,205
Long-term contracts and close link with providers and clients	Regularly	0,066	4	0,264
Flexibility of the organization	Good	0,116	4	0,464
Surveillance level of the organization	Certain competitive, technological and environment surveillance is performed, but without a strategy or formal structure	0,100	4	0,400
Environmental protection in the organization	System of operations supported on environment-degrading conventional practices and chemical inputs	0,033	4	0,132
Aim of the organization	At the product and the sales	0,033	5	0,165
Financial capacity of the organization	Adequate solvency, liquidity and profitability; certain investment capacity	0,091	4	0,364
Internal and external information flow	Incipient management with autonomous teams and stable internal communication; the external communication with clients and providers increases	0,033	4	0,132
Innovation culture	Permanently the Top Management takes risks, but it does not always implicate and stimulate all the members of the organization	0,050	4	0,2
Total		1,000		3,50

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Table 5. Evaluation of the technological capacity of the biogas technical team.

Variable	1	2	3	4	5
Attention to the continuous training of the personnel in charge of developing and/or exploiting technologies and innovations	Attention is not given to it	Casual attention	Moderate attention	Good attention (X)	Systematic and stable attention
Existence of the group's own technologies, although they are still in incipient status	They do not have them	They only have a technology of their own	They have 2-3 technologies of their own	They have 4-5 technologies of their own	They have more than 5 technologies of their own (X)
Duration of the learning period of the business when adopting new technologies and innovations	Very long	Long	Moderate (X)	Short	Very short
Existence of an improvement process in the adopted and internally generated technologies and innovations	It does not exist	It is a projection of the Top Management	It exists only in the productive function of the business	It exists in several functions of the business	It exists throughout the business (X)
Protection of the technologies and innovations, as well as of other forms of intellectual property	They are not protected (X)	The initial protection actions have been carried out	Only a part of the innovations and technologies are protected	Most of the innovations and technologies are protected	All the technology and knowledge are protected
Application of a permanent surveillance system of the environment	The technological and competitive environment (TCE) is not monitored	The TCE is sporadically monitored, but information to make decisions is not generated	The TCE is sporadically monitored and information is generated (X)	The TCE is permanently monitored, but information is not always generated	The TCE is permanently monitored and information is generated
Existence of a Technological Strategy (TS) and a Technological Development Plan (TDP)	It does not exist	A TDP is formulated (X)	There is a TDP implanted, but not a TS	There is a TDP, the TS is being formulated	There is a TS with its TDP
Links with research centers, universities and other enterprises	They do not exist	Very sporadic	Good links with some actor of the NSSTI and sporadic with the others (X)	Excellent links with diverse actors of the NSSTI	Formal alliances have been developed with actors of the NSSTI
Capacity of the business in R+D+i with regards to the main enterprises of the sectors where it acts	Very low	Low	Similar	Superior (X)	Highly superior
Participation in fairs, congresses, workshops and other training actions	Never	Sporadically	Moderately	With certain frequency (X)	Often

Table 6. Excellence level of the biogas technical team.

Nº	Indicator	Wi	VG (10)	G (8)	R (6)	B (2)	VB (1)	Pj
1	Utilization of the operation capacity (%)	0,015		X				0,120
2	Amplitude of the portfolio of products and services	0,051	X					0,510
3	Productivity from the improvement of the operation process	0,030		X				0,240
4	Quality of the services (client's level of satisfaction)	0,068		X				0,544
5	Amplitude of the portfolio of clients or market quota	0,019		X				0,152
6	Degree of differentiation of the services; value addition	0,068		X				0,544
7	Consideration of the clients' needs and criteria	0,070		X				0,560
8	Production cost with regards to international standards	0,015	X					0,150
9	Sale price with regards to international standards	0,010	X					0,100
10	Compatibility of the services with the environment	0,063	X					0,630
11	Benefit/cost ratio of the investment for the farmer	0,041		X				0,328
12	Degree of personnel training	0,102	X					1,020
13	Existence of its own R+D+i area	0,083		X				0,664
14	Degree of generation, adoption and improvement of technologies, innovations and knowledge	0,077		X				0,616
15	Degree of protection of the intellectual property	0,017					X	0,017
16	Innovation culture	0,107		X				0,856
17	Degree of interrelation with the environment (providers, clients, allies)	0,067			X			0,402
18	Labor fluctuation	0,069				X		0,138
19	Intensity of renewal and exploitation of the technological equipment (%)	0,027		X				0,216
	Total	1,000	(5)	(11)	(1)	(1)	(1)	7,807

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