

Approximation of a R+D+I Program for the Agro-Industry of Stevia Rebaudiana (Bertoni), as a Substitution Alternative of Erythroxylum coca (Lam) for the Post-Conflict in Catatumbo, Colombia

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Abstract– The purpose of this dissertation is to investigate if the cultivation of Stevia rebaudiana (Bertoni) may be an effective alternative to replace Erythroxylum coca (Lam) from the ground; secondly, to design an approximation of a R+D+I program that could provide cognitive and methodological support of the processes of introduction, establishment and substitution in the framework of armed post-conflict in Catatumbo, Colombia. The methodology used consisted of a documentary research, resulting in phases or aspects to be considered for the program, which are: study and zoning of agro-climatic conditions in the region of Catatumbo; Evaluation and introduction of cultivars; Design and validation of the technological pattern of production, such as monoculture and polyculture; Post-harvest handling, Artisanal and Industrial processing; Exploration of medicinal, food and industrial applications; Marketing and national and international trade, and the economic, social, environmental and political aspects of the introduction and establishment of this agro-industrial chain in Catatumbo. It is concluded that planting Stevia rebaudiana (Bertoni), is an effective alternative to replace Erythroxylum coca (Lam) and the presented program can be a cognitive and methodological support to its introduction and sustainable settlement.

Keywords: Colombian Post-Conflict, Stevia rebaudiana (Bertoni), R+D+I Program, Substitution of Erythroxylum coca (Lam)

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I. INTRODUCTION

Rural poverty is a factor that has led to the development of the Colombian armed conflict for more than 50 years. The current demobilization process of the main armed group - aside from the law- the revolutionary armed forces of Colombia (FARC), means a structural shift towards peace, which should be oriented in the inclusion of the vulnerable population in all fields of social, economic, political and productive life of the nation.

Catatumbo is a region with tropical humid forest, located in the northeast of Colombia, bordering with Venezuela and forming part of the binational basin of Maracaibo's Lake. In the Colombian side, it has 167,034 hectares of fertile soils, rich water and biodiversity, making it one of the areas with greater potential production of the country.

However, the absence of the presence and assistance of the State, along to the poverty have generated the peasants to develop illegal productive activities throughout the years, activities such as planting and processing of coca, Erythroxyllum coca (Lam), whose leaf is the raw material for the production of cocaine [1].

The cessation of hostilities between FARC and the Colombian State may contribute to creating peace and prosperity in this important region of the Colombian-Venezuelan border; however, illegal activities -economic, and those related to armed violence- could continue if the population established in these locations do not receive means of life that could provide dignified and legal support to the families.

Therefore, sustainable alternatives should be explored in the economic, social, and environmental issues, that is, legal activities that would allow the eradication to its minimum expression of the cultivation and processing of coca leaf; thus, contributing to the reduction in the national and international offer of cocaine.

One of these alternatives can be represented by the cultivation and agro-industrial development of Stevia rebaudiana (Bertoni), due to its characteristics, properties and potentialities at the national and international market.

Based on the latter, the objectives of this research are:

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1. To explore if the cultivation of *Stevia rebaudiana* (Bertoni), may be an effective alternative to replace *Erythroxylum coca* (LAM.) from the ground.

2. To design an approximation of a R+D+I program that would provide cognitive and methodological support of the processes of introduction, establishment and substitution.

The importance of this manuscript is the contribution to the peace process in the region of Catatumbo, Colombia, and the provision of resources to increase the living standards of peasants and the agro-industrial sector of the region..

II. CONCEPTUAL AND METHODOLOGICAL ASPECTS

Stevia rebaudiana (Bertoni) is a shrub belonging to the compositae (asteraceae) family and one of the 154 members of the genus *Stevia*. It is a plant native from the Eastern Region of Paraguay; its leaves contain specific glycosides that produce a sweet taste but without any caloric value, and stevia is 150 to 300 times sweeter than sucrose.

The leaves contain a complex mixture of natural Glycoside (steviol glycosides): stevioside (4-13%), steviolbioside (traces), rebaudioside A (2-4%), rebaudioside B (traces), rebaudioside C (1-2%), rebaudioside D (traces), rebaudioside E (traces) and dulcoside A (0, 4-0, 7%). The highest content of stevioside is found in leaves, suggesting that leaves serve as the main tissue for the synthesis and primary accumulation of steviol glycosides [2].

On the other hand, Programs of Research, Development and Innovation, hereinafter referred as R+D+I, programs, can be defined as a set of strategies and activities aimed at the creation and application of scientific and technological knowledge in favour of objectives related to the improvement of life conditions of a human conglomerate.

Based on this approach [3], this research (R) can be considered as an original and planned research that seeks to discover new knowledge and greater understanding in the scientific and technological field.

The development (D) consists of the application of the results of the research or any other type of scientific knowledge for the manufacture of new materials or products or for the design of new processes or production systems, as well as for the substantial technological improvement of materials, products, processes or pre-existing systems.

Finally, innovation (I) is a process whose result may be a technological advance for obtaining new products, a production method or substantial improvements of the existing methods.

Considering the latter, it can be inferred that the introduction and establishment in the agro-industry of *Stevia rebaudiana* (Bertoni) can be achieved with high probability of success, if it is run under the guidance of R+D+I program, especially if the complications of the establishment of an agro-industrial complex in any region are also influenced by the replacement of coca cultivation and the appeasement of the irregular and violent groups that work with this illegal economy, all this within the framework of the peace agreement between FARC and the Colombian State.

This without considering that the region of Catatumbo, is a border area between Colombia and Venezuela with great economic and social dynamism, both legal and illegal.

Therefore, it is necessary to design and implement a scientific and technological research, development and innovation program (R+D+I), that would include at least the following phases or aspects:

1. Study and zoning of agro-climatic conditions in Catatumbo.
2. Evaluation and introduction of cultivars.
3. Design and validation of the technological pattern of production, such as monoculture and polyculture.
4. Post-harvest handling, artisanal and industrial processing. It includes the design and validation of processes and equipment.
5. Exploration of medicinal, food and industrial applications.
6. Marketing study and national and international trading.
7. Economic, social, environmental and political aspects of the introduction and establishment of the agro-industry in Catatumbo.

II.1. Study of agroclimatic conditions and zoning in Catatumbo.

The study of the ecological or climatic conditions of a productive region includes the investigation and description of the soil conditions, physiography, climatic characteristics and its combination. The particular parameters used in the definition are focused on edaphic and climatic requirements of the crops, in this case, *Stevia rebaudiana* (Bertoni), as well as the management systems.

Under this concept [4], each area has a similar combination of limitations and potentials for the land-use and serves as a reference point for the recommendations designed to improve

the situation of land use, either by increasing the production or by limiting the degradation of the resources.

When combined with an inventory of land uses, expressed as types of land use and specific ecological requirements, the zoning can be used as the basis of a methodology for evaluating the land resources.

Likewise, it is essential for the agro-industrial development of *Stevia rebaudiana* (Bertoni), in the area of Colombian Catatumbo, to start investigating the agroclimatic conditions and the areas that belong to the region.

This study would serve as a baseline for the development of a system of geographic and cadastral information that contains information about the main aspects of natural type and socio-economic type to provide more chances of success to the program.

In the specific case of *Stevia rebaudiana* (Bertoni), this crop requires high and continuous humidity, it does not tolerate long rain-fed periods; thus, in areas where annual rainfall is less than 1,400 mm and long periods of drought the use of irrigation systems is required. *Stevia* is a species native to the subtropical region, semi-humid with extreme temperatures from -6 to + 43 °C, with an average of 24 °C, however, it grows very well from 24 to 28 °C. The altitude of the optimum land is from 0 to 600 m.a.s.l.

The percentage of relative humidity should be less than 85%, this factor has a direct influence on the temperature of the air and soil, and on the content of water vapour in the atmosphere; it is also a determining factor in the incidence of fungal diseases.

The critical photoperiod for the development of *stevia* is 13 hours, but there is a great genetic variability among ecotypes. The ideal soil is sandy-clayey, loamy and sandy-loamy, with acid pH, but it grows well from 6.5 to 7.5, as long as these soils are not saline [5].

The temperature in the area of Catatumbo comprises an altitude from 1,000 to 2,000 masl, with an annual average of 23 °C, maximum means of 28 °C, absolute maximum of 33°C, minimum annual temperatures of 15 °C and minimum lower to 14 °C [6].

Based on all the information mentioned before, it can be inferred that there are high probabilities of adaptation of *stevia* in the Colombian Catatumbo region.

II.2. Evaluation and introduction of cultivars

Stevia rebaudiana (Bertoni) is a crop that has multiple varieties and cultivars. It reproduces both vegetatively and sexually.

Sexual reproduction (done by flowers, fruits and seeds) of *Stevia rebaudiana* (Bertoni) made by cross fertilisation, that is cross-pollinated, causes great diversity of appearance, height and dissemination, useful life, time of flowering, quantity and quality of glycosides (sweetener substances). Thus, the glycoside content of wild plants can vary from 2% to 12%, while the EIRETE variety cultivated, can reach 19% and can double the yield of leaves compared to other varieties [7].

In this regard, the evaluation of cultivars, should include agronomic and agro-industrial variables, such as granulometry, dry matter, insoluble matter in alcohol (IMA), ashes, pH, fat, titratable acidity, proteins, total polyphenols, total soluble solids (TSS), colour and turbidity in dried leaves as well as the quantification of steviolglycosides (stevioside and rebaudioside A) [8].

The evaluation should also include all the agronomic aspects, properties and characteristics that may have an impact on the development of its supply chain and the consumption of intermediate and final products.

II.3. Design and validation of the technological pattern of production, such as monoculture and polyculture, and integrated production systems

The technological pattern of the crop production consists of a set of agronomic practices and management techniques aimed to maximize yields if the agro-ecological conditions are optimal and to optimize yields if the agro-ecological conditions are the minimum necessary for the development of the crop.

Some of the key elements of the development of the technological cultivation pattern consist in determining the processes and activities related to sowing season, land preparation, selection of cultivars, field work, fertilization, phytosanitary controls, irrigation, cultural management and harvest, among others.

The technological pattern considers the aspects of the production environment related to environmental, social, economic, political and cultural aspects.

Modern agriculture, based on the green revolution of the 20th century, is primarily associated with the establishment of monoculture systems. But in the 21st century, this paradigm has been in conflict with the environmental sustainability, thus leading to emerging new intensive production systems, but based on the biological diversity.

Such is the case of the polyculture (agroforestry, grazing systems and others), as well as the development of integrated and planned systems that mix the plant, animal, forestry and aquaculture production, in which *Stevia rebaudiana* (Bertoni), could be the axis of the system.

In relation to the technological pattern of *Stevia rebaudiana* (Bertoni) production, it should be noted that there are references on the crop management in technical and scientific literature, but this literature must be adapted to the conditions of the Colombian Catatumbo region. The information has reported yields ranging from 3,500 to 4,000 kg.ha⁻¹ of fresh and wet leaves and 1,000 to 1,200 kg.ha⁻¹ of dry leaves, under experimental conditions [9].

II.4. Post-harvest handling, artisanal and Industrial management. It includes design and validation of processes and equipment.

Not all *Stevia* products are equal. The flavour, sweetness and the cost of different powders of *Stevia rebaudiana* (Bertoni) will mainly depend on the refinement and quality of the cultivar used.

Regarding the post-harvest management, it refers to the set of techniques and procedures aiming to maintain the optimal conditions of the product harvested before its fresh consumption or industrial processing.

The quality of any product containing *Stevia* depends on the quantity of steviosides contained and the percentage of rebaudioside-A, which are the result of the type of crop and extraction methods.

The presence of these components during the growing period, harvesting or processing are important factors when determining the final quality of the product. The best leaves of *Stevia* are native to South America (Paraguay, Brazil and Colombia, among others) and Mexico, which contain about 12 to 13 percent of steviosides [10].

In the case of *Stevia rebaudiana* (Bertoni) the post-harvest includes at least the following tasks: cleaning, drying of leaves, separation of the leaves from the stem, packing and storing [5].

In terms of the dry leaf processing, some of the following processes and activities must be done: grinding, extraction, filtration, microfiltration, ultrafiltration, nanofiltration, evaporation and crystallization, drying, spraying, packing and storage [5].

The equipment and machinery for performing the operational processes mentioned above, can be designed and manufactured by its simplicity and rudimentary technology,

being some of the most important the following: grinders, vats, filters of cast polypropylene, evaporator-crystallizer, cauldron, dryer, mill pulveriser, mixer and others of support, such as pumps, scales, gauges and compressors. Many of these can be found in local markets or can be manufactured for the process to be developed [11].

Finally, it should be noted that this process can be done handmade in small rural agro-industries, in a business model similar to the production of coca paste or in large scale, but in the latter case, the process must be designed, patented and validated on the basis of guarantees of sufficient and continuous supply of *Stevia rebaudiana* (Bertoni) [11] leaf.

II.5. Exploration of the medicinal and food uses.

Due to its versatility, *Stevia rebaudiana* (Bertoni), can serve as raw matter and as a complementary product in different industries and sectors of the economy, particularly in the pharmaceutical industry and in the food industry.

Stevia rebaudiana (Bertoni) can be used in different ways, each with a different purpose: as a simple infusion, in liquid or as soluble crystals and each of these will have different properties or applications [12].

The sweetener properties of the sweet grass are ideal to meet the needs of consumers who must control the intake of sugars by having health problems linked to metabolic disorders [12]. From the multiple studies that have been carried out since the 1970s on the effects of *Stevia* in the human health (particularly in Japan, Brazil and Denmark), it is deduced that *stevia* is a plant with different benefits: antacid, oral antibacterial, anti-diabetic, cardiogenic, digestive, diuretic, sweetener, hypoglycemic, hypotensive, improvement of the metabolism and vasodilator [13] [14].

Unrefined *stevia* is used as bactericide by inhibiting the growth of the bacteria, especially those that produce tooth decay and gum problems, as well as to relieve the problem of irritated throat and gum bleeding [15]. It is also a powerful antibiotic against fungi that cause vaginitis in women.

In the case of the I+D+I program to develop, it is necessary to define research lines related to the production of food and medicinal products containing *Stevia rebaudiana* (Bertoni).

II.6. Study of marketing and national and international trade

Since December 2008, when the Food and Drug Administration (FDA) approved the use of rebaudioside A (Reb: the most important active ingredient of *stevia*) in foods and beverages of the United States the market for this crop has been booming. Until the middle of July 2009, sales

reached \$95 million, a substantial increase over the \$21 million achieved in all 2008.

Japan, which represents one of the main markets of the product and the country with more consumption (220 tons of glass per year), especially in the food industry; currently produces 3,000 tons of glass in the world, consumed as a whole [16].

The biggest producer of Stevia rebaudiana (Bertoni) is China which sells 50% of its production in its domestic market. Asia exports to Japan (around 40% of its production) and the remaining 10% is sold in Korea, Indonesia and the United States [17]. Other regions with high potential for consumption are represented by the European Union and South America [16].

Currently, the most important market is the food industry, especially as flavourings and sweeteners. In recent decades, transnational corporations such as Coca-Cola and Nestlé, among other brands, have substantially replaced sugar and chemical sweeteners and incorporated Stevia rebaudiana (Bertoni) in their products to attract their buyers [18].

Artificial sweeteners encompass 12% of the sweetener market; this information gives an idea of the size of the potential market that is opened for Stevia as a substitute for the rest of the sweeteners.

Perhaps the most important quality of Stevia is that it is an ideal sweetener for people with diabetes. This medicinal use also offers enormous possibilities [10], however, food and pharmaceutical products made from the leaf of Stevia rebaudiana (Bertoni), may have legal restrictions to access international markets.

In 2015, the products of Stevia rebaudiana (Bertoni) only accounted approximately 2% of the global market for sweeteners; however, the consumption of the plant in the world increased from 35 tons in 2008 to 916 in 2013, an increment of approximately 16% annually, compared to 1% in the area.

The global market of sweeteners in 2015 was of 70,000 million of Euros, out of which 60,000 correspond to sugar. Stevia only reached 200 million of Euros [19].

At present, the international price of the powder of Stevia rebaudiana (Bertoni) is from 80 to 90 USD.Kg-1 [16], which makes its development attractive as a basis for the local economy in Catatumbo.

Another great part of its potential can be placed in the local economy, through the artisan production of products and sub-products for animals [20].

II.7. Economic, social, environmental and political aspects of the introduction and establishment of the agro-industry of Stevia rebaudiana (Bertoni), in Catatumbo

Catatumbo is a region of peasant colonization and a territory of indigenous communities, whose recent historical process was developed in three direct periods.

The first period corresponded to the coffee and tobacco boom during the decade of 1850, the second period, from 1945 to 1979, consisted of the oil boom and the wave of displacement of the population due to the bipartisan violence that occurred during the 40s and 50s. The third period of colonization, at the end of the 80s until 1999 is characterized by the coca boom and the incursion of paramilitaries in the region [21].

From the first decade of the 21st century, oil palm (*Elaeis guineensis* Jacq.) has had the role as an important crop. The participation of the Colombian State and the industrial producers in the region managed to establish important cropping surfaces and industrialization processes in the extraction of raw oil.

However, with the advent of the peace agreement in Colombia, a new process of occupation and production must be developed for the fertile territories of Colombian Catatumbo, in which Stevia rebaudiana (Bertoni), can play a vital role.

Therefore, it is necessary to develop a research process that will serve as the basis for facing the challenges and impacts on the socio-economic environment of a company of this magnitude and commitment.

III. EXPECTED RESULTS

The progress of each of the phases or aspects of the scientific and technological programme of research, development and innovation (I+D+i), outlined in the previous section, will allow obtaining partial and cumulative results, and if the program is properly structured it will offer integral result, with productive, social, economic, environmental and political benefits for the Colombian Catatumbo region.

Outlined below are the main expected results in each phase or aspect of the program:

- Phase 1. The specific knowledge of the agro-ecological conditions of the region and the existing variants that would allow establishing zones or agro-productive micro-regions for the cultivation of Stevia.
- Phase 2. Introduction and selection of the best cultivars for the region and each agro-ecological zone, based on its agricultural, industrial, medicinal and nutritional benefits.

- Phase 3. Design, development and validation of the technological pattern, in conventional and sustainable production systems of monoculture and polyculture systems.

- Stage 4. Design, development and validation of artisanal, semi-industrial and industrial processes for the transformation of Stevia leaf into intermediate and final products.

- Phase 5. Identification, application and validation of potential food and medicinal uses of intermediate and final products elaborated with Stevia rebaudiana (Bertoni), with the technology levels of the area, to then continue with an improvement strategy based on the innovation of processes and products focused on the demands of the market.

- Phase 6. Exploration, identification and development of specific markets at the national and international level for products and sub-products of Stevia rebaudiana (Bertoni), generated in the region of the Colombian Catatumbo.

- Phase 7. Harmonic Integration of the main economic, political and social factors in the design, implementation and benefit of the R+D+I program for the introduction and establishment of the agro-industry of Stevia rebaudiana (Bertoni), as an alternative to replace Erythroxylum coca (Lam) for the post-conflict in Catatumbo.

Finally, the main achievement of the development of the program will be its contribution to peace in this important region of Colombia, by creating a management model that integrates the scientific knowledge with the purposes of society at an important moment in its history.

IV. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions resulted from the exploration of the conceptual and methodological aspects to be considered for the design of a science and technology programme of research, development and innovation (R+D+I) for the introduction and establishment of the agro-industrial chain of Stevia rebaudiana (Bertoni), as a strategic alternative to replace Erythroxylum coca (Lam) in the framework of the armed post-conflict in the Colombian Catatumbo region.

The cultivation of Stevia rebaudiana (Bertoni), is an effective alternative to replace Erythroxylum coca (Lam) in the fields, due to the similarities observed in relation to its South American origin, adapted to humid tropical conditions, architecture (shrub), agronomic management, identical commercial parts of the plant (leaf), manual and crafted harvest and post-harvest, as well as its great development

potential in the national and international market for its benefits on health and food.

The program presented as means of an approximation in this manuscript can serve as cognitive and methodological support for the introduction, establishment and substitution of Stevia rebaudiana (Bertoni), through a process of technological and institutional negotiations that would follow a specific plan of financing with quantifiable impacts over the time by committed people.

Likewise, it is recommended to create or designate an organizational organism to promote and manage the implementation of this interdisciplinary and trans-disciplinary programme, as well as the participation of researchers, and national and international institutions.

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