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Artículo de Revisión

BIOMASS OF AGRICULTURAL WASTE FOR AGROINDUSTRIAL PRODUCTS OBTAINING: POTENTIALITIES AND CHALLENGES IN ECUADOR

BIOMASA DE RESIDUOS AGRÍCOLAS PARA LA OBTENCIÓN DE PRODUCTOS AGROINDUSTRIALES: POTENCIALIDADES Y DESAFÍOS EN ECUADOR

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ABSTRACT

Introduction:
Agricultural and agro-industrial residues have great potential to obtain products with high added value, such as biofuels, bioactive compounds, and biopolymers which are used in different industries such as food, cosmetics, industrial and pharmacological. They also contribute to the reduction of environmental pollution since they can be used in effluents treatment, mainly in heavy metals adsorption.

Objective:
To establish the potential of Ecuador agricultural residues to obtain agro-industrial products.

Materials and methods:
The study carried out is approached from a qualitative-documentary and descriptive method, where data on the object of study were collected through a bibliographic and documentary review on the subject, published in databases of known scientific relevance and wide scope quality and timeliness were taken into account.

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Results and Discussion:
Various procedures and methodologies for obtaining agro-industrial products were reviewed, different types of residues were identified for each crop under study. Corresponding assessment was carried out in order to establish the potential agro-industrial products that can be obtained from them, according to their chemical composition.
Conclusions:
Bioactive compounds recovery and biofuels generation from agricultural and agro-industrial waste is an alternative to reduce the effects of global pollution, while generating renewable energy and high added value compounds.

Keywords: bioactive compounds; biopolymers; bioproducts; circular economy; vegetable biomass.

RESUMEN

Introducción:
Los residuos agrícolas y agroindustriales, tienen gran potencial para obtener productos con alto valor agregado, tales como biocombustibles, compuestos bioactivos, y biopolímeros los cuales se emplean en diferentes industrias como la alimentaria, cosmética, industrial, farmacológica y en la disminución de la contaminación ambiental en el tratamiento de efluentes industriales y adsorción de metales pesados.
Objetivo:
Establecer el potencial de los residuos agrícolas de Ecuador para la obtención de productos agroindustriales.
Materiales y Métodos:
El estudio realizado se aborda desde un enfoque cualitativo- documental y descriptivo, donde se recopilaron datos del objeto de estudio mediante una revisión bibliográfica y documental sobre el tema, publicados en bases de datos de connotada relevancia científica y amplio alcance, se tuvo en cuenta la calidad y actualidad.
Resultados y Discusión:
Se revisaron diversos procedimientos y metodologías para la obtención de productos agroindustriales, se identificaron diferentes tipos de residuos por cada cultivo en estudio y se realizó la valoración correspondiente con la finalidad de establecer los potenciales productos agroindustriales que se pueden obtener de ellos, de acuerdo a su composición química.
Conclusiones:
La recuperación de compuestos bioactivos y generación de biocombustibles a partir de residuos agrícolas y agroindustriales es una alternativa para disminuir los efectos de la contaminación global, a la vez que genera energía renovable y compuestos con alto valor agregado que pueden ser útiles en diferentes aplicaciones industriales.

Palabras clave: compuestos bioactivos; biopolímeros; bioproductos; economía circular; biomasa vegetal.

1. INTRODUCTION

The agri-food sector is of vital importance in the economy and sustainability of a nation, mainly those that depend on agriculture to a great extent. Organic waste from crops was used for a long time as compost in the fields, but with the increase in agricultural production, pollution has increased due to the production of higher volumes of effluents and solid waste, these waste are subjected to treatments and during the last decades the applications of biomass in the generation of energy and biomaterials have grown notoriously worldwide (Carvalho et al., 2016; Chávez-Sifontes, 2019). The improvement of the quality of life in rural areas through the optimization of the use of agricultural residues, as well as the reduction of polluting gases are benefits that the efficient use of biomass implies (Junqueira et al., 2017; Mejías-Brizuela et al., 2016), therefore it is essential to change the extractivist approach to natural resources and the agro-export pattern of raw materials, for this to happen the agro-industry must be innovative, competitive and efficient, (Andrade et al., 2017; De Jaramillo, 2018).
To achieve greater competitiveness, more efficient technological processes are required, which is why it is necessary to direct actions to reduce CO_2 emissions and mitigate and adapt to climate change along value chains, be innovative and generate new consumer goods, which come from processes that are more environmentally friendly (Carvalho et al., 2016).
Many products can be derived from the transformation of biomass, agricultural residues are rich in lignin, organic acids, proteins and carbohydrates, so they provide the possibility of obtaining energy, secondary metabolites of interest, such as vitamins, organic acids, aromatic compounds volatiles, concentrates for animals, manures, natural fertilizers, dyes, enzymes and ethanol, among others, which have made it possible to establish a new horizon for these economic “raw materials” (Aggelopoulos et al., 2014). Bioenergy occupies the base of the pyramid of the volume of applications, while bioproducts such as nutraceuticals and medicines, occupy the top of the pyramid since they are needed in less volume, however, their added value is greater.
Through this research, the methods and techniques to obtain industrial products with high added value from agricultural biomass were reviewed in a documentary way in order to establish the potential of the most important agricultural residues in Ecuador. The objective of this work is to establish the potential of agricultural residues from Ecuador to obtain agro-industrial products.

2. MATERIALS AND METHODS

2.1 Vegetable biomass in Ecuador

Many definitions have been made for the term biomass, but the definition of biomass, in a broad sense, refers to any type of organic matter that has origin as a consequence of a biological process.
Among the main sources of biomass are agricultural residues (rejected fruit pulp, fruit and grain peel, dry grain powder, stems, leaves, husks, etc.) and agro-industrial residues mainly made up of fruit peel and pulp and vegetables, vegetable fats and oils, as well as the effluents of the different agro-industrial and livestock activities.
Latin American countries such as Ecuador, Peru, Brazil, Mexico, Panama and Colombia

produce a large amount of waste mainly from agricultural activity; In the latter country, around 71 943 813 MT/year of residues are generated from the processing of coffee, oil palm, sugar cane, corn, rice, banana and plantain mainly.

In Ecuador, the provinces with the highest production of plant biomass from agricultural residues from the field and industries are found in the Costa region, with the provinces of Guayas, Manabí and Los Ríos standing out. During 2019, more than 12.9 million hectares of land were used for agricultural use, with Manabí, Guayas and Esmeraldas being the provinces with the highest land use (ESIN, 2014). Among the crops that have the largest planted area and generate the greatest amount of residues, cocoa, African palm, banana and sugar cane stand out at the national level, as detailed in table 1.

Table 1. Residues generated in banana, cocoa, sugar cane and african palm crops in Ecuador (2014)

Crops	***Sown area (ha)***	***Harvest period***	***Annual production (million ton/year)***	***Type of waste generated***	***Type of waste generated***	***Waste generated (million ton/year)***	***Application technologies***	***Provinces with the highest production***
Banana	221775	Annual	7.01	Field waste	Leaves, pseudo stem	4.92	Combustion, gasification (organic rankine cycle)	Los Rios, El Oro and Guayas
				Processing waste	Rachis, product rejection			
Cocoa	507721	Annual	0.13	Field Waste	Pruning, discarded cob, cob husk	2.01	Combustion	Guayas, Los Rios, Esmeraldas, Manabi
				Processing Waste	Rachis, product rejection			
Sugar Cane	106926	June-December	7.37	Field Waste	Stems and leaves	0.79	Combustion, cogeneration	Guayas (70% of national production)
				Processing Waste	Bagasse			
African Palm	240333	Annual	2.64	Field Waste	Palm leaves and trunks	6.87	Combustion, cogeneration	Los Rios, Esmeraldas and Sucumbios
				Processing Waste	Rachis, fiber, mesocarp, walnut shell			

Adapted from (ESIN, 2014).

As can be seen in the table, so far the greatest application of these residuals has been as biofuels, however, due to their origin, properties and physicochemical characteristics, they can generate products other than biofuels (Mehmet, 2020) as biomaterials and bioproducts.

Some studies have been reported that refer that one of the main bioproducts that are marketed within the biomass-based economy are bioplastics. These biomaterials are manufactured from renewable and/or biodegradable raw materials with a wide range of properties and applications. Several authors have worked on this issue with biomass from different plant residues such as banana peel (Yusuf et al., 2020) potato peel or yucca peel (Muñoz and Riera, 2020).

In Ecuador, studies have been carried out on the potential of reject banana to obtain polyhydroxybutyrate and bioethanol, also with promising results, some investigations reveal that sugar cane molasses turns out to be interesting at a technological level since various chemical products with industrial applications can be obtained, such as lactic acid, methanol and ethanol among others (Rosales-Calderon & Arantes, 2019).

2.2 Products derived from biomass conversion

2.2.1 Biofuels

Worldwide, the literature highlights various countries interested in the energy potential of agricultural residues (Berastegui et al., 2017; Cabrera et al., 2016; Corredor and Pérez, 2018; Diaz-Chávez, 2019; Chávez-Sifontes, 2019) and some have considered and implemented policies towards the economic use of biomass to meet energy demand and reduce CO_2 emissions, (De Jaramillo, 2018), therefore numerous initiatives have emerged in order to obtain energy sources from biomass and reducing the environmental impact (Junqueira et al., 2017), however, the cost of biofuel production is higher than that of fossil fuels. The biofuels that can be obtained from biomass are: bioethanol, biogas, and biodiesel (Andrade et al., 2017; Streitwieser and Cabezas, 2018) through different physical, chemical and biological processes (Hernández-Melchor et al., 2019).

Bioethanol production (Carvalho et al., 2016; Andrade et al., 2017; Bustamante et al., 2016) can be made from by-products with high sucrose content or lignocellulose, in the latter a pretreatment must be carried out to break down the lignin that surrounds the fermentable carbohydrates (Llenque-Díaz et al., 2020), currently being sought optimize the bioconversion process through enzyme recirculation to increase ethanol production using lignin-derived nanoparticles (Prangan et al., 2020). Bioethanol is also produced from corn or glucose syrups derived from orange and pineapple peels (Torres et al., 2017) or mixtures of different agro-industrial residues. Biofuels come from oilseed crops (Llenque-Díaz et al., 2020). By transesterification of vegetable oils, glycerol can be obtained and from this obtain inputs for the elaboration of resins, disinfectants, cosmetics, adhesives, detergents and biopolymers (Cury et al., 2017).

The use of biomass, due to the heterogeneity present in its structure, reduces the efficiency of combustion, because the energy released is to evaporate the water and not for the chemical reduction of the material. (Bustamante et al., 2016), therefore, other physical pretreatment methods have recently emerged such as: high hydrostatic pressure, high pressure homogenization, ultrasound, microwaves, ionizing and non-ionizing radiation, pulsed electric field technology to produce fuels and chemical products from organic fractions derived from biomass (Mehmet, 2020; Lynam et al., 2017).

2.2.2 Bioproducts

Traditionally, many agricultural residues are used as a source of animal feed and compost although approximately 10% of organic chemicals are produced from biomass Various phytochemical compounds can be recovered from biomass residues which include phenolic compounds, flavonoids, phytosterols, carotenoids, tools, terpenoids, tannins, glucosinolates, and essential oils, the latter. That due to their antimicrobial activity are used as preservatives and enhancers of the organoleptic properties of food (Adebo & Medina-Meza, 2020; El Barnossi et al., 2020), and in the formulation of various products such as flavorings, cleaning products and flavorings (Ademosun et al., 2016; Attard et al., 2018; Satari and Karimi, 2018).

Thus, it has been reported that some residues of plant biomass are characterized by their antioxidant content, among these are lycopene and resveratrol obtained from tomato and grape skin, while curcumin and gingerol are isolated from turmeric and ginger respectively and the properties of these compounds have been studied in the pharmacological field (Hedayati et al., 2019). Furthermore, biomass has the potential to extract nutrients such as oligosaccharides.

Some active principles are highly valued in the food industry, and are used as additives (Álvarez, 2017), improving the rheological properties of food products without altering their organoleptic characteristics as well as in the elaboration of functional and nutraceutical products (Redondo-Blanco et al., 2020). In the pharmacological industry, nutraceutical products have been developed for clinical purposes (Williamson et al., 2020) and uses in the treatment of various cardiovascular diseases and other biomedical applications.

Food is susceptible to contamination by microorganisms, mainly fungi and bacteria, which can generate toxins causing great economic losses and affecting the health of consumers, for this reason the way of prevent these effects in both post-harvest stored products and processed foods and reports of the use of bioproducts as antifungal agents in stored foods appear (Munteanu and Vasile, 2020; Powers et al., 2019; Shehata et al., 2017). In this field there has been substantial progress in the biotechnological aspect, developing nanocontrol and decontamination methods (Asghari et al., 2016; Karlovsky et al., 2016).

Green nanotechnology has substantially evolved in the production of nanomaterials and biomaterials (Bhaskar et al., 2021; Kavitha et al., 2020; Ventura-Cruz and Tecante, 2021), based on which novel techniques have been developed to incorporate these principles bioactive either in biodegradable polymeric packaging or as nanoencapsulated additives (Bahrami et al., 2020). Also these bioactive substances can be part of edible and harmless biopolymeric films. Biodegradable films made from different residues such as whey, potato peels, cassava or other agri-food wastes rich in starch or proteins (Arrieta et al., 2017) can incorporate bioactive substances that provide an additional function by complementing the barrier function. That the container meets, in order to extend the shelf life of packaged products (Asghari et al., 2016; Bandyopadhyay et al., 2020).

Biodegradable polymers can be applied as bioencapsulation systems using different nanoencapsulation routes in synergy with phytochemicals to improve bioavailability, stability and solubility (Dhakar et al., 2019; Katarzyna et al., 2021; Redondo-Blanco et al., 2020) protecting bioactive phytochemicals against thermal photodegradation and providing a controlled release of antifungal compounds for the development of active packaging (Bahrami et al., 2020).

Biomass waste can also be used to improve environmental quality (Yusuf et al., 2020) by reducing or mitigating the effects of contamination by heavy metals, (Zambrano-Intriago et al., 2020), (Rodríguez-Díaz et al., 2021), (Andrade et al., 2020), colorants or hydrocarbons (Corredor and Pérez, 2018; Durango et al., 2018; El Barnossi et al., 2020). Biomass residues have been used as biofilters (Martínez et al., 2017) as well as in the treatment of wastewater or soils (Acevedo et al., 2017) For this, various agricultural residues have been used such as rice husk (Páez et al., 2016) cassava husk (Tejada et al., 2016) residual biomass of citrus, pineapple peel (Durango et al., 2018) banana peel (Yusuf et al., 2020). These residuals have also been associated with microorganisms to use them as decontaminants (Fernández et al., 2018); (Martínez et al., 2017).

The agricultural and industrial residues of cocoa (*Theobroma cacao L*), have been used in different applications, the husk has been raw material for infusions, obtaining flour and extraction of pectin and polyphenols, mucilage is used in the preparation of jellies, liqueurs, juices and jams, cheese has been made from its lactic bacteria and extracts that act as natural herbicides have been formulated from it. The chemical composition of the cocoa shell. Allows it to be classified as a material of difficult degradation due to its high content of lignin and cellulose, which makes it feasible to use it in the manufacture of paper and biodegradable materials (Rengifo et al., 2020). Because of their high cellulose and starch content, coffee and banana peels are used in balanced formulations for cattle and poultry and for that reason additives used in the food industry can be obtained as thickeners, texturizers, emulsifiers, gelling agents and stabilizers (El Barnossi et al., 2020).

2.2 Technologies available for the use of agricultural residues

Depending on the properties of biomass according to its content and origin, the type of technology to be used is determined. Among the technological processes, different technologies can be mentioned, among them: biochemical transformation (Anaerobic Digestion, Alcoholic Fermentation), thermochemical transformation (Combustion, Pyrolysis, Gasification and Cogeneration) and chemical transformation (Transesterification) (ESIN, 2014).

To properly select the technology to be used, it is necessary to characterize agricultural and agroindustrial residues, carrying out the pertinent analyzes. The proximal analysis determines the most efficient thermochemical process while the elemental analysis estimates the possible emissions of polluting gases in the combustion process. The study of structural carbohydrates defines the possible applications in the chemical, pharmaceutical and food industries, while the analysis of total phenolic compounds and antioxidant capacity suggests the concentration of secondary metabolites.

For the recovery and purification of phytochemicals from residues, various techniques and methods are used, among which there are operations traditionally used such as extraction and distillation by steam stripping, and other more novel ones with different stages of implementation such as extraction with supercritical fluids (SFC), membrane separation, gas chromatography (GC), liquid chromatography (HPLC), microwave assisted extraction (MAE), or ultrasound (UAE), high hydrostatic pressure extraction (HHPE), ohmic assisted hydrodistillation, and ohmic accelerated steam distillation, among others (Arun et al., 2020; Mahugo et al., 2009; Khoddami et al., 2013).

3. RESULTS AND DISCUSSION

It is in the bioenergy field where the most progress has been made regarding the use of plant biomass, some countries have implemented a legal framework in this regard, creating suitable conditions for the implementation of biorefineries. However, it is necessary to consider environmental and economic aspects associated with the production chains, which ends up influencing the viability of the process.

The energy conversion processes are affected by the moisture content, since these are better when it does not exceed 40%, in addition, the chemical composition of the biomass will determine the most suitable procedure for its transformation, therefore characterizing the biomass is a fundamental step.

The physical-chemical and microbiological characteristics and the nutritional capacity of agricultural residues determine the different forms of recovery. The use of agricultural residues in the adsorption of dyes and heavy metals has the advantage of its high adsorption capacity and low cost, however, a previous treatment and adaptations must be carried out to improve its performance as a bioadsorbent. Regarding the use of residual biomass in the formulation of balanced feed for animals, it is necessary to clarify that it must be free of inappropriate content such as essential oils or tannins.

Many of these wastes are polyvalent substrates that can produce a series of valuable compounds with various applications, however, despite all the above, much remains to be investigated in the various fields of application, as well as to find mechanisms that allow reducing the technological costs of recovery and processing.

One of the most important challenges in Ecuador is the scalability from the experimental phase to the industrial phase in the recovery of agricultural and agro-industrial waste, despite the multiple advantages it presents for the generation of energy and other products with high added value. The high implicit technological cost and the lack of policies that encourage the use of these wastes are factors that have a great impact on the non-massification of these technologies. For Ecuador, the study of productions from residues of cocoa, banana and African palm is more attractive, due to the volume of their productions.

Both private companies and state agencies must work in synergy to maximize the efficiency of processes in a circular bioeconomy environment; optimizing resource management and reducing environmental pollution within the framework of sustainability and sustainability.

4. CONCLUSIONS

In Ecuador, the most attractive raw materials for the use of agricultural and agro-industrial waste are cocoa, bananas and African palm, due to the volume of their production as well as the possibility of recovering bioactive compounds and chemical substances with high added value of its wastes, which have useful applications in different fields: formulation of balanced feed for animals, elaboration of biopolymers with incorporated phytochemicals and their use in the decontamination of effluents and adsorption agents of heavy metals and hydrocarbons.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

- Ing. Jhon Enrique Zambrano Zambrano. He carried out the study, analysis and writing of the article.

- Dr.C. Alex Alberto Dueñas Rivadeneira. He collaborated with the results analysis and the article.writing
- Lic. Aixa Rosa Gutiérrez Villanueva. She participated in bibliographic search and article writing.