Bioproducts from agro-industrial plant residues: opportunities for sustainable reuse

Bioprodutos de resíduos agroindustriais vegetais: oportunidades ao reaproveitamento sustentável

DOI:10.34117/bjdv7n9-208

Recebimento dos originais: 07/08/2021
Aceitação para publicação: 01/09/2021

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ABSTRACT
The expansion of agricultural production is increasingly accelerated, as a result of the greater need for food caused by population growth and, consequently, this growth results in the generation of greater amounts of waste. In general, the inspection of public environmental agencies and society demand from agribusinesses actions that increasingly seek the use of new environmental technologies for the destination of production residues, which can drastically reduce the impacts caused to the environment, in addition to add

commercials values and increase the profitability of the projects. This study aimed to analyze the potential of the elaboration of bioproducts with agro-industrial residues for agricultural crops and that have the potential application for the Extreme South of Bahia region, Brazil, by conducting a descriptive survey of the generation that occurred in other regions. This systematic review was carried out by searching for scientific articles in the SciELO, Scopus and Web of Science databases, using the keywords "bioproduct" and "waste", in the years 2015 to 2021. The articles reported 93 agro-industrial residues derived from 48 agricultural products that generated more than 200 bioproducts, which demonstrates the potential of the theme for the creation of several bioproducts in the region, mainly with sugarcane residues. Considering the high production of sugarcane and the consequent generation of residues from this cultivation in the Extreme South of Bahia, this study indicates several opportunities for returning these discarded goods to a new productive cycle (Reverse Logistics), which can provide environmental, economic and environmental benefits. for the region.

Keywords: Environmental technology. Extreme South of Bahia. Reverse Logistic. Sugarcane.

RESUMO
A expansão da produção agrícola está cada vez mais acelerada, fruto da maior necessidade por alimentos ocasionado pelo crescimento populacional e, consequentemente, este crescimento resulta na geração de maiores quantidades de resíduos. De uma forma em geral, a fiscalização dos órgãos públicos ambientais e a sociedade cobram das agroindústrias ações que busquem cada vez mais o uso de novas tecnologias ambientais para destinação dos resíduos da produção, o que pode reduzir drasticamente os impactos causados ao meio ambiente, além de agregar valores comerciais e aumento da rentabilidade dos empreendimentos. Este estudo objetivou analisar o potencial da elaboração de bioprodutos com resíduos agroindustriais para culturas agrícolas e que apresentem potencial aplicação para a região do Extremo Sul da Bahia, Brasil, através da realização de um levantamento descritivo da geração ocorrida em outras regiões. Esta revisão sistemática foi realizada através da busca de artigos científicos nas bases *SciELO*, *Scopus* e *Web of Science*, utilizando as palavras-chave "*bioproduct*" e "*waste*", publicados de 2015 a março de 2021. Os artigos reportaram 93 resíduos agroindustriais derivados de 48 produtos agrícolas que geraram mais de 200 bioprodutos, o que demonstra o potencial do tema para a criação de vários bioprodutos na região, principalmente com resíduos de cana-de-açúcar. Considerando a elevada produção de cana-de-açúcar e consequente geração de resíduos deste cultivo no Extremo Sul da Bahia este estudo indica diversas oportunidades de retorno destes bens descartados a um novo ciclo produtivo (Logística Reversa) o que pode proporcionar benefícios ambientais, econômicos e sociais para a região.

Palavras-chave: Tecnologia Ambiental. Extremo Sul da Bahia. Logística Reversa. Cana-de-açúcar.

1 INTRODUCTION

Population growth in recent decades has increased the demand and consumption of food and vegetable fibers worldwide, generating an expansion in agricultural production. Consequently, this growth results in the expansion of the generation of residues from the production itself, as in the agro-industries that process food and vegetable fibers (Bernardino et al. 2018).

At the same time, several environmental damages are caused by the consumption of fossil fuels and the increase of greenhouse gases in the atmosphere, which drive the need for less polluting energy sources with better cost/benefit ratio, in addition to reducing the emission of harmful gases (Ullah et al. al. 2019). One of the viable alternatives is the use of biomass rich in lignocellulosic materials for the production of components through chemical and biochemical conversion (Pereira Jr. et al 2008). For example, glucose and xylose, which are fermentable sugars from biomass and are used in the production of xylitol, ethanol, biodiesel, bio-oil and inputs used as energy in industrial processes (Casoni et al. 2019).

In this context, the Extreme South of Bahia, Brazil, which is comprised of the municipalities of Alcobaça, Belmonte, Caravelas, Eunápolis, Guaratinga, Ibirapuã, Itabela, Itagimirim, ltapebi, ltamarajú, ltanhém, Jucuruçu, Lajedão, Medeiros Neto, Mucuri, Nova Viçosa, Porto Seguro, Prado, Santa Cruz Cabrália, Teixeira de Freitas and Vereda, has an economy strongly linked to the sectors of agriculture, forestry, livestock and agribusiness of cellulose, ethanol, cachaça and food. Thus, the region that is also known around the world for its beautiful landscapes, stunning beaches and large area of preserved Atlantic Forest (Almeida and Teixeira 2010), needs to seek new sustainable opportunities for the economy, mainly through the biomass generated by these agroindustries.

Among the cultures of food products in these municipalities, the cultivation of pineapple, cocoa, coconut, papaya, watermelon, coffee, cassava, sugarcane, palm heart, black pepper and annatto (SEAGRI BA 2017). In addition to non-food production from eucalyptus plantations, which move around R$2.8 billion in the local economy, with 10,400 direct jobs in large processors installed in the region (SEI 2019). However, the development of these productions causes the generation and accumulation of agro-industrial residues from an environmental point of view. The accumulation of this material on the ground can lead to the release of leachate, contaminating the water sources that supply cities and the emission of polluting gases such as carbon dioxide and methane into the atmosphere, intensifying the greenhouse effect and its consequences.

Currently, interest in the proper disposal of agro-industrial waste or its use in a new production cycle (Reverse Logistics) has grown in an attempt to add environmental values and benefits. It should be noted that new public policies have been created in Brazil, and this idea has been reinforced. In 2020, the National Bioinput Program was implemented (Decree No. 10,375 of May 26, 2020) which aims to encourage solid waste treatment practices and technologies for the generation of bioinputs, for the economic, social and environmental strengthening of the agricultural sectors and forestry of the country (Brazil 2020).

The use of Reverse Logistics proves to be a tool for the sustainability of agricultural crops in the Extreme South of Bahia and the elimination of the negative impacts caused by their residues in a region of rich biodiversity (Leite 2017). This study aimed to carry out a systematic review by surveying scientific articles in the SciELO (SLO), Scopus (SC) and Web of Science (WOS) databases, published from 2015 to March 2021, in search of new alternatives for the use and reuse of waste agro-industrial products produced by agricultural crops and that have potential application to the Extreme South region of Bahia, Brazil.

2 MATERIALS AND METHODS

The survey was carried out by searching for scientific articles in the SciELO (SLO), Scopus (SC) and Web of Science (WOS) databases published from 2015 to March 2021, using the keywords "bioproduct" and " waste" in the English language to cover a larger number of publications. Figure 1 summarizes the methodological sequence used in the study.

Figure 1: Steps of the systematic review.

Source: Faria 2019 – adapted.

3 RESULTS AND DISCUSSION

The search resulted in 756 publications, 3 in SLO, 649 in SC and 104 in WOS. After reading the abstracts and titles, the articles that were in duplicate and those that did not agree with the theme of the review were excluded, resulting in the exclusion of 216 articles. After reading in full, 23 articles were disregarded, for not using plant agro-industrial residues or for not presenting bioproducts as a result of the study. After this screening, 110 articles were selected for data extraction. Table 1 shows the data obtained from the screening of the systematic review.

Table 1: Criteria adopted for systematic review and researched database.

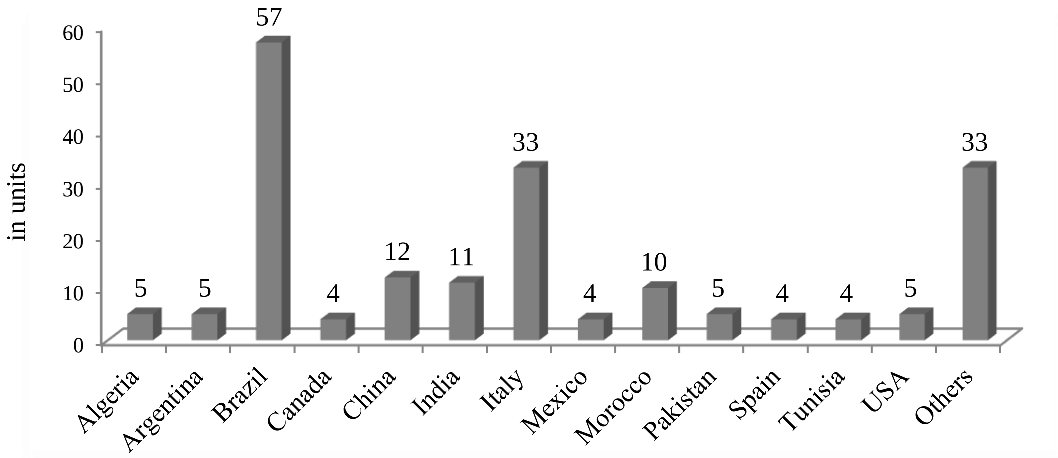
STAGE	SCREENING	SciELO (Units)	Web of Science (Units)	Scopus (Units)
1	Search keywords ("bioproduct" and "waste")	03	104	649
2	Years of Publication (2015 to March/2021)	02	83	483
3	Publication type (article Only)	02	60	287
4	Jobs excluded by duplication	00	02	26
5	Works excluded after reading the abstract	01	21	166
6	Works excluded after reading the article	00	05	18
Total works analyzed		01	32	77

Source: Own elaboration.

The environmental problems caused by the accumulation of plant product residues have been a major concern for environmentalists, government officials, and researchers around the world. The use of these residues in the production cycle of new products appears as an alternative action to reduce these pollutants.

In this race, Brazil and the USA, present among the largest agricultural producers in the world, stand out in the leadership in the ranking of the number of bioproducts reported in the articles, with 57 and 33 citations, respectively (Figure 2).

Figure 2: Place of origin of the residues used in the generation of bioproducts.



Source: Own elaboration.

Another aspect observed is the quantity of articles with citations of bioproducts originated from production residues (Table 2). Of the total 48 crops registered, sugarcane, corn, wheat, orange and forest species stand out, totaling together 41.5%.

Table 2: Quantity of articles that cited products that generated waste for the production of bioproducts.

Products	Number of Articles
Sugarcane	20
Corn and Forest Species	16
Wheat	10
Orange	09
Barley	07
Grass and Rice	06
Grape and Potato	05
Beetroot, Olive, Palm Oil, Seaweed and Sunflower	04
Cashew, Coconut, Coffee, Cotton, Lemon and Soybeans	03
Artichoke, Banana, Baru, Cassava, Castor Bean and Peach	02
Acai, Apple, Bamboo, Cabbage, Caja, Cherry, Chestnut, Cocoa, Hemp, Jaca, Jatropha, Mango, Melon, Oat, Papaya, Peanut, Saffron, Sorghum, Tomato, Walnut and Watermelon,	01

Source: Own elaboration.

Cajá, coffee and jackfruit residues were the only crops collected in the State of Bahia, Brazil. The fermentation and hydrolysis processes carried out with the coffee husk presented, in its composition, a percentage of sugar above 60%, proving to be a potential source for the production of alcohol, biofuels and other sources of bioenergy (Rambo et al. 2015). As for cajá and jackfruit seeds, the process showed potential for the production of ethanol and cellulolytic enzymes through saccharification (Marques and Aguiar-Oliveira 2020).

Frame 1 briefly describes the cultures and their respective residues that originated bioproducts and bioinputs through the processes described in the publications. In these data, it is possible to observe the diversity of bioproducts generated by agro-industrial residues, such as levulinic acid (Abaide et al. 2019), essential oils (Tavares et al. 2020), xylose (Padilla-Rascón et al. 2020), carrageenan (Solorzano-Chavez et al. 2019), bio-oil (Casoni et al. 2019), biosurfactant (Ni'Matuzahroh et al. 2020) and lactic acid (Ahmad et al. 2020) obtained from rice residues (straw), forest species (husk), olive (seed), sugarcane (bagasse), sunflower (seed husk), corn (cob) and grape (vinasse), respectively.

Frame 1: Crops and their respective residues that generate bioproducts and bioinputs by different processes.

Culture	Residue	Bioproduct/bioinput and process	Reference
Acai	Seed	Production of levulinic acid, formic acid and bioenergy by hydrolysis and fermentation.	Rambo et al. 2015
Algae	Stem and leaf	Production of MDF (medium intensity fiberboard) by drying, crushing and compacting; Biogas and biofuel production by extraction; Production of binding agent in the production of briquettes by crushing and compacting.	Alamsjah et al. 2017; Sathish et al. 2015; Tedesco et al. 2017; Thapa et al. 2015
Apple	Bagasse	Production of xylitol and 2G ethanol by acid hydrolysis and fermentation.	Leonel et al. 2020
Artichoke	Stem and Leaf	Bioenergy production by extracting phenolic compounds; Production of flavonoids and condensed tannins by extraction.	Kammoun et al. 2020; Lavecchia et al. 2019
Bamboo	Stem and Leaf	Production of levulinic acid, formic acid and bioenergy by extraction and hydrolysis.	Rambo et al. 2015
Banana	Leaf	Composite production by extraction; Production of levulinic acid, formic acid and bioenergy by extraction and hydrolysis.	Rambo et al. 2015; Nataraj et al. 2018
Barley	Brewery beans	Production of xylanolytic enzymes (α-arabinofuranosidase, β-xylodase and xylanase) by extraction; Production of animal feed by hydrolysis and fermentation; Production of Polyhydroxyalkanoates by hydrolysis; Production of Arabinoxylans and biobutanol by microwave pretreatment and hydrolysis; Production of microencapsulated biopigments by extraction and lyophilization; Production of Polyhydroxyalkanoates and lignocellulolytic enzymes by fermentation and hydrolysis; Production of xylitol, bioethanol and biogas by fermentation.	Bartkiene et al. 2017; Corchado-Lopo et al. 2021; Coronado et al. 2020; Llimós et al. 2020; López-Linares et al. 2020; Rubio et al. 2020; Terrasan and Carmona 2015
Baru	Endocarp Mesocarp	Production of 5-hydroxymethylfurfural and biochar by hydrolysis and pyrolysis; Production of biochar and bio-oil (fatty acids) by slow pyrolysis.	Rambo et al. 2020a; Rambo et al. 2020b
Beetroot	Cossets	Production of lactic acid and bioethanol by hydrolysis and fermentation.	Díaz et al. 2017; Karimi et al. 2018; Mohammed and Wan Dagang 2019; Srivastava et al. 2020
	Molasses	Bioflocculant, cellulase and xylanase production by hydrolysis; Cellulosic H_2 production and potential fishmeal substitute (rich in protein) by fermentation.	
Cabbage	Leaves	Biocatalyst production (industrial effluent treatment) by extraction.	Joel et al. 2020
Caja	Seed	Production of ethanol and cellulolytic enzymes by saccharification.	Marques e Aguiar-Oliveira 2020
Cashew	Pseudofruit	Glucose production by hydrolysis; Ethanol and xylitol production by hydrolysis and fermentation.	Medeiros et al. 2016; Medeiros et al. 2017; Reis et al. 2017
Cassava	Bagasse	Production of succinic acid, bioethanol and glucose syrup by biodigestion.	Padi and Chimphango 2020; Srivastava et al. 2020
	Husk	Cellulosic production of H_2 by fermentation.	
Castor bean	Seed and Pie	Production of stearic acid, linoleic acid, oleic acid, palmitic acid and biogas by extraction; Biochar production by pyrolysis.	González-Chávez et al. 2015; Silva et al. 2021
Cherry	Lump	Biochar production by slow pyrolysis.	Pollard e Goldfarb 2021

Chesnut	Husk	Production of phenolic compounds and butyrate by hydrolysis and fermentation.	Morana et al. 2017
Cocoa	Husk	Production of bio-oil, biochar and gas by pyrolysis.	Milian-Luprón et al. 2020
Coconut	Husk	Briquette production by crushing and compacting; Biofuel production by hydrothermal and sequential acid treatment.	Mariano et al. 2020; Nunes et al. 2019; Rambo et al. 2015
	Pulp	Production of formic acid, levulinic acid and bioenergy by extraction and hydrolysis;	
Coffee	Husk	Production of formic acid, levulinic acid and bioenergy by extraction and hydrolysis; Production of bio-oil, biochar and biogas by pyrolysis.	Akond and Lynam 2020; Milian-Luprón et al. 2020; Rambo et al. 2015
	Straw	Production of plasticizers in cement paste by extraction.	
Corn	Liquor	Biosurfactant production by fermentation; Biosurfactant production by extraction; Production of glucan, lignin and xylan by hydrolysis; Production of potential fishmeal substitute (rich in protein) by hydrolysis and fermentation; Bioflocculant production by fermentation; Production of biofuel, bioenergy and bio-oil by pyrolysis; Production of succinic acid, biodiesel, charcoal and electricity by fermentation and pyrolysis.	Almeida et al. 2017; Barnabé et al. 2019; da Silva et al. 2020a; Fini et al. 2016; Gomes et al. 2016; Hong et al. 2016; Hwangbo et al. 2019; Kabir et al. 2019; Karimi et al. 2018; Mandalika and Runge 2017; Mohammed and Wan Dagang 2019; Ni'Matuzahroh et al. 2020; Sharma et al. 2020; Srivastava et al. 2020; Wang et al. 2019; Xu et al. 2021
	Straw	Production of cellulase, endoxylanase and xylosidase enzymes by hydrolysis; Xylane production by extraction; Production of ethanol, biosorbents and butanol by hydrolysis and fermentation; Production of succinic acid, biodiesel, charcoal and electricity by fermentation and pyrolysis; Bio-oil production by pyrolysis; Production of furfural alcohol by hydrolysis and evaporation; Biosurfactant production by hydrolysis.	
	Cob	Cellulosic production of H_2 and xylanase by fermentation.	
Cotton	Fibril and Gin	Production of cellulose nanocrystals (reinforcing agent in nanocomposites, polymers, gels and emulsions) by extraction.	Grewal e Khare 2018; Jordan et al. 2019; Jordan et al. 2021
	Pie	Lactic acid production by simultaneous saccharification and co-fermentation.	
Forest Species	Husk, Leaf, Root, Sawdust and Stem	Production of essential oils (antioxidant) and hydrolates (anti-inflammatory) by distillation and hydrodistillation; Briquette production by crushing and compacting; Production of succinic acid, biodiesel, charcoal and electricity by fermentation and pyrolysis; Production of biochar, bio-oil (biobitumen) and herbicide (aqueous fraction) by pyrolysis; Production of 5-hydroxy-methyl-furfural, acetic acid, formic acid, lactic acid, levulinic acid, vulinyl acid, glucose, hydroxybenzaldehyde, syringaldehyde, vanillin, and xylose by hydrolysis and oxidation; Production of formic acid, levulinic acid and bioenergy by extraction and hydrolysis; Production of biofuel, bio-oil and bioenergy by pyrolysis; Production of activated carbon by calcination; Production of BioJet (aircraft fuel) by hydrothermal liquefaction and pyrolysis.	Barnabé et al. 2019; Cervi et al. 2021; Fini et al. 2016; Gu et al. 2018; Heinz et al. 2017; Maciel et al. 2020; Martín et al. 2017; Ndukwe et al. 2020; Nunes et al. 2019; Oleson and Schwartz 2016; Ponte et al. 2019; Rambo et al. 2015; Sharma et al. 2020; Srinivas et al. 2016; Tavares et al. 2020; Zhao et al. 2019

	Sludge	Cellulase and xylanase production by hydrolysis; Ethanol production by hydrolysis, saccharification and fermentation.	
Grape	Bagasse	Production of food biocolor by extraction; Production of lactic acid and bioemulsifier by hydrolysis and fermentation; Production of tannins, lignin and polyphenols by extraction; Production of anti-allergen, hydrolytic enzymes and ethanol by fermentation; Production of plant substrate by composting and vermicomposting; Lactic acid production by simultaneous hydrolysis and fermentation; Production of ferulic acid and p-coumaric acid by hydrolysis and fermentation; Production of microencapsulated biopigment by extraction and lyophilization.	Ahmad et al. 2020; Kammoun et al. 2020; Montibeller et al. 2018; Rubio et al. 2020; Veses et al. 2020
	Stem and Leaf	Cellulose pulp production by pulping process; Production of food additives by fermentation; Production of activated carbon by activation of carbon dioxide; Production of phenolic compounds (phenylethanoids, hydroxybenzoic acids, hydroxycinnamic acids, flavonols, anthocyanins) by extraction; Lactic acid production by alkaline treatment and microwave fermentation; Tartaric acid production by solubilization and precipitation.	
	Seed	Biocontrol agent production by fermentation; Production of fungal biomass (rich in protein) by fermentation; Production of nutritional supplement by extraction; Protein production by fermentation; Synthetic fuel production by catalytic copyrolysis.	
	Vinasse	Production of plant substrate by composting.	
Grass	Stem and Leaf	Production of levulinic acid, formic acid and bioenergy by extraction and hydrolysis; Production of biofuel and bio-oil by pyrolysis; Production of binding agent in the production of briquettes and pellets by crushing and compacting; Biofuel production by extraction.	Fini et al. 2016; Rambo et al. 2015; Sharma et al. 2020; Sun et al. 2020; Thapa et al. 2015
	Straw	Ethanol production by hydrolysis.	
Hemp	Stem and Leaf	Biocomposite production by crushing and compacting.	Solle et al. 2019
Jackfruit	Seed	Production of ethanol and cellulolytic enzymes by saccharification.	Marques e Aguiar-Oliveira 2020
Jatropha	Oil	Cellulosic production of H_2 by fermentation.	Srivastava et al. 2020
Lemon	Bagasse and Husk	Production of d-limonene and pectin by hydrolysis; Production of IntegroPectin by extraction and lyophilization; Production of CytroCell and IntegroPectin by hydrodynamic cavitation and extraction.	Fidalgo et al. 2016; Presentato et al. 2020Scurria et al. 2021
Mango	Lump	Production of starch ester fluid (an additive to control oil drilling fluid loss) for nucleophilic replacement.	Marques e Aguiar-Oliveira 2020
Melon	Husk, Pulp and Seed	Production of fatty acids and hydrogen by anaerobic fermentation.	Greses et al. 2021
Nut	Husk	Lignin production by hydrolysis.	Li et al. 2018
Oat	Husk	Production of biochar, bio-oil and synthesis gas (syngas) by pyrolysis.	Srivastava et al. 2020
Olive	Bagasse	Production of biophenol with high concentration of hydroxytyrosol by extraction.	Delisi et al. 2018; Khounani et al.

	Lump	Xylose production by acid treatment and steam explosion followed by hydrolysis.	2021b; Padilla-Rascón et al. 2020; Young et al. 2019
	Bagasse Oil	Production of clavulanic acid by fermentation; Animal feed production by extraction and transesterification.	
Orange	Bagasse and Husk	Production of pectin by microwave hydrodiffusion; Production of d-limonene, pectin and xylanase by hydrolysis; Production of aromatized ethanol, d-limonene, linalool, pectin, flavonoids and condensed tannins by extraction; Production of CytroCell and IntegroPectin by hydrodynamic cavitation and extraction; Production of soil corrective by composting; Biobutanol production by fermentation.	Ciriminna et al. 2018; da Silva et al. 2020b; Debernardi-Vázquez et al. 2020; Fidalgo et al. 2016; Ganen et al. 2020; Kammoun et al. 2020; Nicoletti et al. 2019; Scurria et al. 2021; Ullah et al. 2019
Palm oil	Residual waters	Production of biodiesel and polyhydroxyalkanoates by extraction and hydrolysis.	Junpadit et al. 2017; Mohammed and Wan Dagang 2019; Tareen et al. 2020; Urrutia et al. 2021
	Oil	Bioflocculant, cellulase and xylanase production by hydrolysis; Biofuel, hydroxymethylfurfural and furfural production by extraction.	
	Pie	Biodegradable composite production by delignification.	
Papaya	Seed	Production of biodiesel, biolubricants and beauty products by extraction.	Hossain et al. 2020
Peach	Lump Endocarp	Production of lignin by hydrolysis; Cellulosic production of H_2 by fermentation.	Li et al. 2018; Srivastava et al. 2020
Peanut	Husk	Bioflocculant, cellulase and xylanase production by hydrolysis.	Mohammed and Wan Dagang 2019
Potato	Husk	Bioplastic production by extraction; Bioflocculant production by fermentation; Biogas production by anaerobic digestion.	Alrefai et al. 2020; Bartkiene et al. 2017; Karini et al. 2018; Mohammed and Wan Dagang 2019; Samer et al. 2019
	Licor	Production of potential substitute for fishmeal (rich in protein) and animal feed by hydrolysis and fermentation.	
Rice	Husk	Production of levulinic acid, formic acid and bioenergy by hydrolysis and fermentation; Bioflocculant, Cellulase and Xylanase production by hydrolysis.	Abaide et al. 2019; Mohammed and Wan Dagang 2019; Ni'Matuzahroh et al. 2020; Rambo et al. 2015; Srivastava et al. 2020
	Bran	Production of biosurfactant by hydrolysis; Cellulosic production of H2 by fermentation.	
	Straw	Production of levulinic acid, dimethyl-furan, butanol, cellobiose, glucose and ethanol by hydrolysis and fermentation.	
Saffron	Straw	Bioethanol, bio-oil and biodiesel production by extraction.	Khounani et al. 2021a
Sorghum	Straw	Biofuel and bioenergy production by pyrolysis.	Sharma et al. 2020
Soy	Husk	Bioflocculant, cellulase and xylanase production by hydrolysis; Production of levulinic acid, formic acid and bioenergy by extraction and hydrolysis.	Mohammed and Wan Dagang 2019; Rambo et al. 2015; Rodrigues et al. 2017
	Molasses	Biosurfactant production by extraction.	
Sugarcane	Bagasse	Production of bio-oil, biochar, synthesis gas (syngas), levoglucosan and ethanol by pyrolysis; Cellulase and xylanase production by fermentation;	Akond and Lynam 2020; Almeida et al. 2017; Bernardino et

		Carrageenan, 4G ethanol (glucose hydrolyzate), glucose and xylanase production by hydrolysis; Briquette production by crushing and compacting; Lactic acid production by simultaneous saccharification and co-fermentation. Production of biosurfactant and plasticizer in cement paste by extraction; Production of soil corrective by composting.	al. 2018; Bezerra et al. 2020; Cervi et al. 2021; Coimbra et al. 2021; Cortes et al. 2020; da Silva et al. 2020a; David et al. 2019; Debernardi-Vázquez et al. 2020; Gama et al. 2019; Gomes et al. 2016; Grewal and Khare 2018; Karimi et al. 2018; Ponte et al. 2018; Roldán et al. 2017; Rulli et al. 2019; Santos et al. 2020; Solorzano-Chavez et al. 2019; Ullah et al. 2019
	Molasses	Bioaroma and SCP (single cell protein) production by fermentation; xylanase production by hydrolysis; Production of biochar, biogas, bio-oil and fertilizer (aqueous) by pyrolysis.	
	Straw	Bioaroma and SCP (single cell protein) production by fermentation; 2G ethanol production by hydrolysis and fermentation; Biojet air fuel production by hydrothermal liquefaction and pyrolysis.	
	Pie	Biosurfactant production by incubation.	
	Vinasse	Production of potential fishmeal substitute (rich in protein) by hydrolysis and fermentation; Bioaroma and SCP (single cell protein) production by fermentation; Production of vinasse films plasticized with glycerol by evaporation and drying.	
Sunflower	Seed Husk and Stem	Production of biochar, biogas and bio-oil (rich in levoglucosan, furfural and tar) by pyrolysis; Ethanol and xylitol production by hydrolysis, fermentation and extraction.	Casoni et al. 2019; Martínez-Cartas et al. 2019; Rulli et al. 2019; Urrutia et al. 2021
	Seed	Biosurfactant production by incubation.	
	Residual oil	Bioinsecticide production by pyrolysis.	
Tomato	Bagasse	Lignin production by extraction.	Kammoun et al. 2020
Watermelon	Husk, Pulp and Seed	Production of fatty acids and hydrogen by anaerobic fermentation.	Greses et al. 2021
Wheat	Bran	Production of cellulase, xylanase and poultry feed by fermentation; Production of potential fishmeal substitute (rich in protein) by hydrolysis and fermentation; Production of animal feed by hydrolysis and fermentation; Production of poultry feed by fermentation; Xylanase production by fermentation; Production of xylanolytic enzymes by extraction and fermentation.	Bartkiene et al. 2017; Gama et al. 2019; Gomes et al. 2016; Grewal and Khare 2018; Kabir et al. 2019; Karimi et al. 2018; Mupondwa et al. 2017; Slaný et al. 2020; Solle et al. 2019; Taddia et al. 2020
	Straw	Production of lactic acid and ethanol by simultaneous saccharification and co-fermentation; Biocomposite production by crushing and compacting; Production of butanol and ethanol by hydrolysis and fermentation.	

Source: Own elaboration.

The production of biosurfactants from plant residues is a cleaner option to existing synthetic surfactants, which are generally petroleum-based and are widely used in industrial sectors (Nitschke and Pastore 2002). Among the biosurfactants, those developed by the residues of rice, sugarcane, sunflower, corn and soy are those that demonstrate greater surface and interfacial activities, low toxicity, biodegradability, stability in high ionic strength and the use of alternative substrates in production by fermentation (Felipe and Dias 2017).

In fact, biosurfactants are promising and viable alternatives for the reuse of agro-industrial residues and several successful cases have been registered. In Indonesia, it was obtained from corn cob with good stability results in terms of pH, temperature and salinity variation (Ni'Matuzahroh et al. 2020). In Brazil, in the state of Pernambuco, the surfactant produced from the tailings of the corn steep liquor showed excellent results in the oil industry (Almeida et al. 2017) and in the food industry (da Silva et al. 2020a). Other products also obtained excellent results in the production of biosurfactants such as soy molasses (da Silva et al. 2020a). and sugarcane (Almeida et al. 2017), with potential for the oil industry, being more efficient than guar gum, which is a polymer widely used in the food industry (da Silva et al. 2020a). On the other hand, the biosurfactant obtained from vinasse, even with good results, still suggests new studies before its commercial use (Rulli et al. 2019). To improve the quality of biosurfactant production from rice and sunflower residues, it was necessary to add corn and sugarcane residues, respectively (Ni'Matuzahroh et al. 2020; Rulli et al. 2019).

In the Extreme South of Bahia, the amount of sugarcane produced represents more than 50% of the total production of the main food crops (Cerqueira Neto 2014). Most of this production is intended for the production of ethanol in three plants located in Ibirapuã, Medeiros Neto and Santa Cruz Cabrália. The production capacity of these three plants is 1.93 million liters of ethanol per day (ANP, 2020). In addition to these, the state of Bahia has another ethanol plant and also has 30 registered establishments for the production of cachaça and 15 of brandy, with more than 100 registered products, corresponding to 5% (60 million liters/year) of the Brazilian production of cachaça and brandy (Brazil 2019). However, it is estimated that there are 7,000 cachaça/aguardente producers, most of which are not registered (SEBRAE/BA); which leads us to question the occurrence of this situation in the study region.

During the 2019 harvest, sugarcane production in this region exceeded 2.96 million tons (IBGE 2019), which generated 740 thousand tons of bagasse, 207.2 thousand tons of straw, 88.8 thousand tons of filter cake and 2.66 million liters of vinasse (Dias et al. 2012; IPEA 2012). These generated residues represent an economic opportunity for the region with the development of bioproducts, in addition to reducing environmental impacts.

Sugarcane, given the large number of reports, proves to be an agronomic crop with great potential for the development of bioproducts (Bernardino et al. 2018; Ullah et al. 2019; Solorzano-Chavez et al. 2019; Grewal and al. Khare 2018; Cervi et al. 2021; Ponte et al. 2019; Karimi et al. 2018; Akond and Lynam 2020; Almeida et al. 2017; Bezerra et al. 2020; Coimbra et al. 2021; Cortes et al. 2020; da Silva et al. 2020a; David et al. 2019; Debernardi-Vázquez et al. 2020; Gama et al. 2019; Gomes et al. 2016; Roldán et al. 2017; Rulli et al. 2019; Santos et al. 2020) (Table 3). Several successful examples are reported, mainly in Asian countries. In Pakistan, protein-rich flour was made from vinasse (Karimi et al. 2018). In India, they used bagasse in the production of lactic acid, widely used in the food industry as an acidulant and preservative, and in the pharmaceutical industry for the production of antiseptics (Grewal and Khare 2018).

As noted in Table 3, there is a wide variety of processes that can be used in the production of bioproducts and bioinputs. Processes such as calcination (Gu et al. 2018), hydrodistillation (Tavares et al. 2020), lyophilization (Rubio et al. 2020), anaerobic anaerobic digestion (Alrefai et al. 2020), extraction (Akond and Lynam 2020), fermentation (Coimbra et al. 2021), enzymatic hydrolysis (Corchado-Lopo et al. 2021), hydrothermal liquefaction (Cervi et al. 2021), saccharification (Marques and Aguiar-Oliveira 2020), transesterification (Khounani et al. 2021b) among others, they are difficult to implement due to the great procedural and technological complexity, which requires greater investment, especially in equipment and infrastructure, making it difficult to implement as a strategy for the use of waste in the Extreme South of Bahia. The simplest processes that facilitate implementation in the region are found in other bioproducts, such as soil corrective using orange peel and sugarcane bagasse (Debernardi-Vázquez et al. 2020) for composting, biochar using pie castor bean (Silva et al. 2021), sunflower seed (Casoni et al. 2019), cherry kernel (Pollard and Goldfarb 2021), filter cake and sugarcane molasses (Bernardino et al. 2018; Santos; Santos). et al. 2020), branches, stems, roots and leaves of trees (Martín et al. 2017), oat husk (Srivastava et al. 2020), baru endocarp/mesocarp (Rambo et al. 2020a; Rambo et al. 2020b), coffee and cocoa husks (Milian-Luprón et al. 2020) obtained by pyrolysis and briquettes using tree branches, trunks, roots and leaves (Nunes et al. 2019; Ponte et al. 2019), husk from coconut (Nunes et al. 2019) and sugarcane bagasse (Ponte et al. 2019) through crushing and compaction.

Regarding forest species residues, it appears that the production of eucalyptus is very strong in the Extreme South of Bahia, where it entered in the early 70s and currently has 3 pulp and paper industries that have more of 450,000 hectares of land for eucalyptus production (Koopmans 2006). In these industries, the residues of forest species from planting and production are used in the generation of electricity (EPE 2018).

In view of the described scenario, the Extreme South of Bahia has the possibility of using and/or reusing agricultural crop residues, mainly sugarcane, for the generation of bioproducts/bioinputs, demonstrated for the 48 agricultural products that generated 93 types of waste, developing more than 200 bioproducts/bioinputs, in the articles discussed. This entire context is due to the high volume and variety of waste generated, which brings the need to adapt the destination, in addition to expanding the possibilities of reuse to provide the reach of a sustainable production system in the region.

4 CONCLUSION

The use of agro-industrial vegetable residues in the Extreme South of Bahia for the elaboration of bioproducts and bioinputs emerges as an economic opportunity, adding value to the product and reducing the environmental and social impacts caused by production in a region with large areas of preserved forest.

Considering the high production of sugarcane and the consequent generation of residues from this crop in the Extreme South of Bahia, this study indicates a significant number of bioproducts developed by different processes from sugarcane residues (bagasse, molasses, straw, pie and vinasse) which allows for several opportunities to return these discarded goods to a new production cycle (Reverse Logistics), providing environmental, economic and social benefits for the region.

The absence or low bibliographic production with other high production crops in the region (cassava, cocoa, coconut, coffee and papaya) is a potential source of new reverse logistics studies, which may contribute to the sustainability of these segments.

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