Opuntia like a feedstock in a biorefinery to arid and semi-arid zones

E.T. Quintanar[1], C.A. Lucho[1], R.I. Beltrán[1], C. Coronel[1], G.A. Vázquez[1]

[1]Department of Chemistry, Autonomous University of State of Hidalgo, Mineral de la Reforma, Hidalgo, 42184, Mexico

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Presenting author email: qu216586@uaeh.edu.mx

Opuntia sp. is a crop with high biomass production (600-800 ton/ha•year) and low agricultural requirements. *O.* species are found distributed in arid and semiarid zones as North, Center, and South of Latin America, Center and South of Africa, Middle Orient, Australia, and India (Stintzing and Carle, 2005). One characteristic of this crop is a high water content around 90%. In this water fraction, we can obtain active compounds as mucilage. On another hand, in the solid fraction we found another active compound as pectin and lignocellulosic waste. In *O.* sp. actives compounds as mucilage and pectin are responsible to make possible their resistance and the survivor in arid and semi-arid zones. The mucilage is a hydrocolloid with diverse applications as a coagulant to wastewater treatment (Sáenz *et al*., 2004), as pills coating (Sepúlveda *et al*., 2007), as edible coatings in fruits to extend shelf life (Nájera-García *et al*., 2018), and anti-hyperglycemic agent (Andrade-Cetto and Wiedenfeld, 2011). On another hand, the pectin is a complex polysaccharide, used mainly like and food additive in products with high and low sugar contents, preserving sensory characteristics (Rodríguez and Sandoval, 2003).

In Mexico, *O.* sp. is the one of the most important in de Mexican diet, as prickly pear and vegetable nopal, so in all the country have 233 000 hectares of cultivated and in the case of wild species occupied of 3 million of hectares. Considerate this crop that is produced all time, the source of lignocellulosic biomass is constant to considerate a viable feedstock in a biorefinery. So, in this work the proposal about the biorefinery is to obtain four products, including a biofuel as biogas. All the data that is represent here are experimental. The biorefinery have two streams, the first to obtain biogas and biofertilizer by an anaerobic digestion that works in a bioreactor (Yang et al., 2015; Quintanar-Orozco et al., 2018), and the second stream is to obtain with an integral form pectin and mucilage like shows the Figure 1.

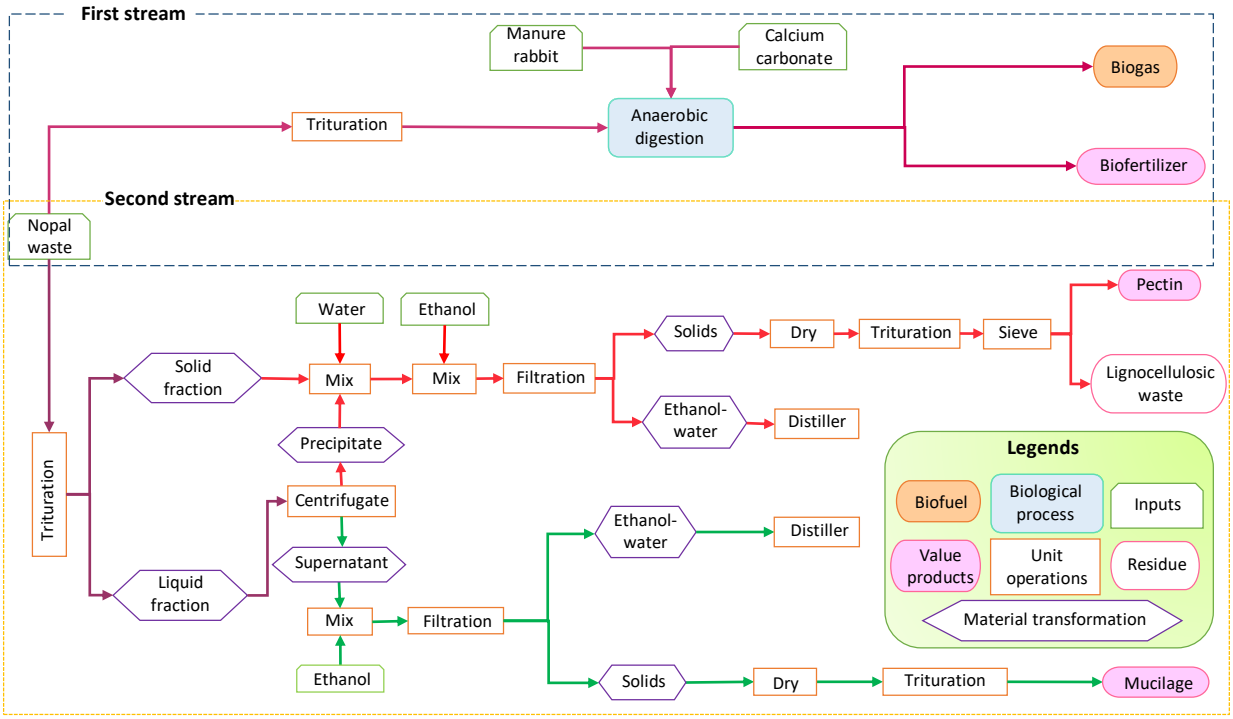

Figure 1. Flux diagram of *Opuntia*'s Biorefinery

The cladodes of *Opuntia* sp. that were selected as feedstock had two years of maturity and were recollected of the Hidalgo, Mexico. The cladodes were cut in small pieces to obtain the fractions liquid and solid using a juice extractor. The first stream describes the process of obtaining biogas and biofertilizer by an anaerobic process. The cladode was triturated and mixed to get a homogenous mix. The inoculum was obtained from manure rabbit, and the pH was adjusted with calcium carbonate. The second stream describes the pectin and mucilage extraction process using various processes and technologies most sustainably.

The yield of pectin and mucilage, also the physicochemical characterization is shown in the Table 1, and Table 2, respectively. The final product as biogas had a yield of 257 $mL/g_{volatile\ solids}$ with 65% of methane, and the physicochemical characterization of biofertilizer was reported by Quintanar-Orozco *et al* (2018).

Table 1. Characterization of pectin from cladodes of *Opuntia* sp.

Parameter	Pectin
Yield (%)*	50
Pb	LDL
Ca (ppm)	2.52 ± 0.04
Protein (µg/mL)	72.96 ± 4.61
Moisture (%)	5.67 ± 0.21
Ash (%)	28.07 ± 0.93
Total reducing sugar (g/L)	32.22 ± 1.22
Galacturonic acid (µg/mL)	97.96 ± 16.96
Esterification degree (%)	99.48 ± 0.04

Table 2. Characterization of mucilage from cladodes of *Opuntia* sp.

Parameter	Mucilage
Yield (%)*	2
Pb (ppm)	LDL
Fe (ppm)	154.81 ± 2.96
Zn (ppm)	469.62 ± 17.7
Cd (ppm)	LDL
Mg (ppm)	18 769 ± 107
Moisture (%)	5.67 ± 0.21
Ash (%)	28.07 ± 0.93
Galacturonic acid (µg/mL)	99.48 ± 0.04

dry weight; LDL:* lower than the detection limit

The proposal of biorefinery with waste nopal is a good option to generate biofuel and also extract two active products with high value-added. The pectin obtained in this proposal could be comparative with the citrus pectin degree analytic, consideration the high esterification degree and the galacturonic acid content, also the protein content is major than we can find in the citrus pectin. The mucilage has a galacturonic acid content similar that other researches have been reported, but in this case, the mucilage is obtained by only physical processes.

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