American Journal of Agricultural and Biological Sciences 9 (3): 289-293, 2014
ISSN: 1557-4989

doi:10.3844/ajabssp.2014.289.293 Published Online 9 (3) 2014 (http://www.thescipub.com/ajabs.toc)

TYPICAL MEXICAN AGROINDUSTRIAL RESIDUES AS SUPPORTS FOR SOLID-STATE FERMENTATION

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Received 2013-11-20; Revised 2014-02-25; Accepted 2014-03-18

ABSTRACT

Biological wastes contain several reusable substances of high value such as soluble sugars and fiber. Direct disposal of such wastes to soil or landfill causes serious environmental problems. Thus, the development of potential value-added processes for these wastes is highly attractive. These biological wastes can be used as support-substrates in Solid-State Fermentation (SSF) to produce industrially relevant metabolites with great economical advantage. In addition, it is an environment friendly method of waste management. In this study were analyzed six different Mexican agro industrial residues to evaluate their suitability as support-substrate in SSF, between physicochemical properties that have included Water Absorption Index (WAI), Critical Moisture Point (CHP) and Packing Density (PD). The selection of an appropriate solid substrate plays an important role in the development of an efficient SSF process. The results provided important knowledge about the characteristics of these materials revealing their potential for use in fermentation processes.

Keywords: Agro-Industrial Wastes, Solid-State Fermentation, Lignocellulosic Materials

1. INTRODUCTION

The worldwide food, agricultural and forestry industries produce annually large volumes of wastes, which cause serious disposal problem (Rodríguez Couto, 2008). Some examples of these wastes include the bagasse and peels generated in the beverages and juice industries, coffee pulp obtained in the coffee industry and husks from the cereal industries, classified as agro industrial by-products (Graminha *et al*., 2008; Orzua *et al*., 2009). These residues are formed by lignocellulose which in turn is formed by of lignin, hemicellulose and cellulose. The chemical properties of the components of lignocellulosics make them a substrate of enormous nutritional potential and biotechnological value (Howard *et al*., 2003). In the last years, academic and industrial researchers are putting more and more efforts to reduce the amount of these wastes by finding alternative uses.

Solid-State Fermentation (SSF) consists on the microbial growth and product formation on the surface and at the interior of a porous solid matrix, in absence or near absence of free water (Barrios-González, 2012), is a technique used for processing and bioconversion of agro-industrial waste. A great variety of materials have been tested as solid supports for SSF, including coffee by-products (Machado *et al*., 2012), rice and wheat (Khandeparkar and Bhosle, 2006), mango peels (Buenrostro-Figueroa *et al*., 2010), skin of grapes (Botella *et al*., 2007; Rodríguez *et al*., 2010), cranberry (Vattem and Shetty, 2003), pomegranate (Robledo *et al*., 2008), among others. Several of these by-products have been used as supports and/or substrates for production of metabolites of industrial interest, such as organic acids, antibiotics, pigments, flavor and aroma compounds, bioactive molecules and a great variety of enzymes (Martins *et al*., 2011). Biotechnology offers significant advantages, such as high concentration of metabolite obtained product stability and adaptability of microorganisms especially fungi system with low free

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water content (Chen, 2013; Howard *et al*., 2003; Pandey, 2003; Pandey *et al*., 1999; Shah *et al*., 2005).

2. MATERIALS AND METHODS

2.1. Raw Materials

The agro industrial residues used in this study were provided by Mexican local regions and included Sugarcane (*Saccharis officinalis)* Bagasse (SB), Coconut (*Cocos nucifera*) Husk (CH) Corn (*Zea mays*) Cobs (CC), Agave (*Agave salmiana*) fibers, Sotol (*Dasylirion sp*) and candelilla (*Euphorbia antisyphilitica*) stalks.

2.2. Preparation

The materials were pre-treated by boiling during 10 min, washed three times with distilled water and subsequently dried at 60°C for 24-48 h (Mussatto *et al*., 2009a) All of them were milled until to obtain a particle size of 0.60 mm (Orzua *et al*., 2009).

2.3. Physicochemical Characterizacion

Water Absorption Index (WAI), Critical Humidity Point (CHP) and packing density were evaluated to know the potential use as a support in SSF of fibers by agro industrial wastes.

2.4. Water Absorption Index (WAI)

The WAI was determined according to the methodology described by (Orzua *et al*., 2009). About 1.25 g of residue were added to 15 mL of distilled water and the suspension was mixed for 10 min and placed into a 50 mL measured centrifugation tube. Centrifuge was operated at 18,000 g for 10 min. The supernatant was decanted and the gel weight was reported. WAI was expressed as W g gel/g dry support.

2.5. Critical Humidity Point (CHP)

The CHP was estimated using a thermo-balance by placing 1 g of sample impregnated with water at saturation (WAI result) at a temperature of 120°C by 60 min.

2.6. Packaging Density (PD)

PD provides the material comapaction degree, therefore, the available space for mass and energy transfer. Ten grams of each material were placed in standard graduated cylinders and clamped to a shaker and vertically agitated until no change in volume during 5 min was observed.

3. RESULTS

WAI and CHP are highly relevant parameters to take into account when evaluating the potential of different materials for use as support in Solid-State Fermentation (SSF) (Mussatto *et al*., 2009b; Orzua *et al*., 2009).

WAI indicates the sample capacity to absorb water and depends on the availability of hydrophilic groups that bind water molecules and on the gel forming capacity of macromolecules (Mussatto *et al*., 2009a). In the present study, the highest WAI value was found in CH, which was four times higher than those obtained for CC and CS (**Fig. 1**). SB was three times higher than CC and CS. No significant differences ($p \leq 0.05$) were observed between CH and SB values. Materials with high WAI are preferred since facilitate the microorganism growth and development. For CC, WAI was similar to the values reported by Orzua *et al.* (2009) for CH.

CHP represents the amount of water linked to the support, which cannot be used by the microorganism for their metabolic functions.

The materials must have low CHP to facilitate the microorganism cultivation. High values of CHP can affect the microorganism growth because a high proportion of water is bounded to the material and consequently, the microbial species development will be affected (Martins *et al*., 2011). Moo-Young *et al*. (1983) recommended a maximum limit of CHP at 40% for *A. niger* strains in SSF, due to the need for modification of the moisture content in relation to the absorbed media. **Figure 2** shows the CHP values obtained for each waste evaluated in the present work. All supports showed CHP values below the limit reported. The high values of WAI and low values of CHP obtained for AF, CH and SB reveal good potential of these materials for use in SSF processes.

Packing density is another parameter unique to SSF that can be an important process variable. It can be assumed that an increase in packing density causes a reduction in the void space between particles and a concomitant reduction in the area of exchange with the surrounding atmosphere. The lowest PD value was obtained with AF followed by SB and CH (**Table 1**), suggesting good mass and energy transfer by these materials.

Table 1. Packing Density (PD) of different agro industrial wastes

Agro industrial residues	PD (g/cm^3)
Agave Fibers (AF)	0.84
Coconut Husk (CH)	0.82
Corn Cobs (CC)	0.74
Sotol Fibers (SF)	0.80
Sugarcane Bagasse (SB)	0.83
Candelilla Stalks (CS)	0.86

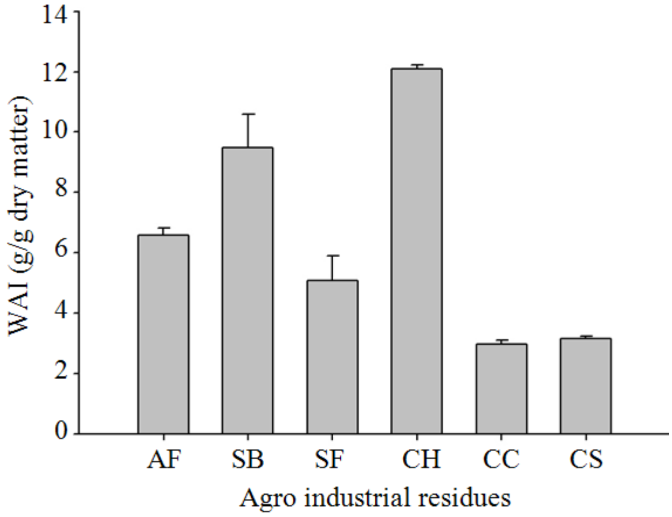

Fig. 1. Water Absorption Index (WAI) of the agro industrial residues: Agave Fibers (AF), Sugarcane Bagasse (SB), Sotol Fibers (SF), Coconut Husk (CH), Corn Cobs (CC) and Candelilla Stalks (CS)

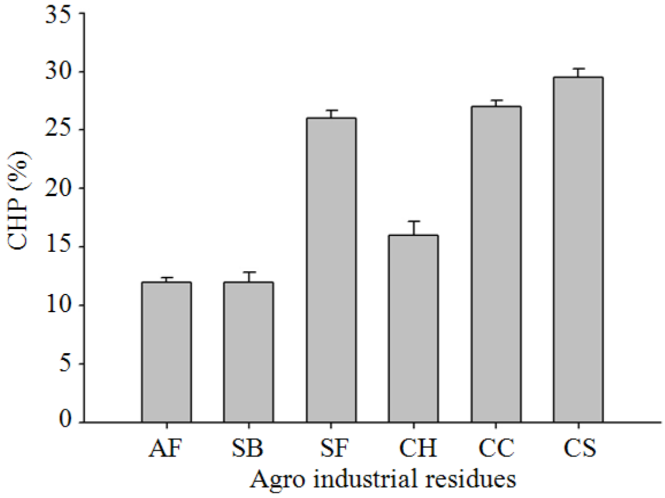

Fig. 2. Critical humidity point of the agro industrial residues: Agave Fibers (AF), Sugarcane Bagasse (SB), Sotol Fibers (SF), Coconut Husk (CH), Corn Cobs (CC) and Candelilla Stalks (CS)

4. DISCUSION

The worldwide food, agricultural and forestry industries produce annually large volumes of wastes, which cause a serious disposal problem. Some examples of these wastes include the bagasse and peels generated in the beverages and juice industries, coffee pulp obtained in the coffee industry and husks from the cereal industries. Most of these residues have a nutritional potential and therefore they are receiving greater attention in terms of quality control and have been classified as agro industrial by-products.

In the last years, academic and industrial researchers are putting more and more effort to reduce the amount of these wastes by finding alternative uses. Due to the composition rich in sugars, which due to their organic nature are easily assimilated by the microorganisms; they could be appropriate for use as raw materials in the production of industrially-relevant compounds under Solid-State Fermentation (SSF) conditions.

The development of an efficient SSF process depends on the selection of an appropriate solid substrate (Rodríguez Couto, 2008) and thus, previous to the material use in SSF it is of great importance to determine its physical-chemical and microbiological characteristics. Two important physical-chemical parameters include the Water Absorption Index (WAI) and the Critical Humidity Point (CHP) (Robledo *et al*., 2008). Considering the requirements above mentioned the present study permitted to know the potential of different agro industrial wastes for use as immobilization carrier in SSF. The physical-chemical properties (WAI and CHP) will be used used as parameters to select the wastes that could be successfully reused in SSF.

5. CONCLUSION

Based on physical-chemical tests it could be concluded that among the 6 agro industrial residues evaluated, 3 of them, namely the agave fibers, sugarcane bagasse and coconut husk have great potential to be successfully used in SSF. In this context, the present study has focussed in the characterization of a variety of agro industrial residues for later use as a support or substrate for the production of industrially relevant metabolites. Such use would be an interesting alternative to add value to these residues besides to be of great economical advantage and an environmental-friendly way for waste management. These facts should be taken into account when formulating a fermentation medium from these residues.

6. ACKNOWLEDGMENT

D.A. Flores-Maltos and J.J. Buenrostro-Figueroa thanks the Mexican National Council on Science and Technology (CONACYT) for the financial support to study their Postgraduate Program at Universidad Autónoma de Coahuila.

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