Journal of Agricultural Science; Vol. 8, No. 1; 2016
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Sugarcane Bagasse Ash as a Seedling Growth Media Component

Charles L. Webber III[1], Paul M. White Jr.[1], Eric C. Petrie[1], James W. Shrefler[2] & Merritt J. Taylor[3]

[1] USDA, Agriculture Research Service, Sugarcane Research Unit, Houma, LA, USA

[2] Oklahoma State University, Division of Agriculture Sciences and Natural Resources, Cooperative Extension Service, Durant, OK, USA

[3] Oklahoma State University, Division of Agriculture Sciences and Natural Resources, Department of Agricultural Economics, Durant, OK, USA

Correspondence: Charles L. Webber III, Research Agronomist, USDA, Agriculture Research Service, Sugarcane Research Unit, Houma, LA 70360, USA. E-mail: chuck.webber@ars.usda.gov

Received: September 29, 2014 Accepted: October 26, 2015 Online Published: December 15, 2015

doi:10.5539/jas.v8n1p1 URL: http://dx.doi.org/10.5539/jas.v8n1p1

Abstract

Bagasse is the fibrous material remaining after removing the sucrose, water, and other impurities (filter mud) from the milable sugarcane. Louisiana sugarcane mills use a portion of the sugarcane bagasse for fuel producing over 20,411 mt of sugarcane bagasse ash (SBA) as a by-product. The purpose of this research was to investigate the use of SBA as an amendment to soilless planting media for the production of vegetable seedlings. The SBA was combined by volume with a commercial soilless growing media into 5 combinations (0%:100%, 25%:75%, 50%:50%, 75%:25%, and 100%:0%, SBA and growing media, respectively). Squash var. 'Straightneck' and cantaloupe var. 'Magnum Hybrid Melon' were planted in each of the 5 different planting mixtures. The research indicates that the addition of SBA can enhance squash and cantaloupe seedling growth depending on the percentage of the ash added to the growth media. Squash plant stalk lengths and total plant fresh weights (stalk, leaves, tops, roots, and total plant) overall responded best at the 75% SBA. Squash dry weights were consistently greater when SBA was added to the soilless media compared to no SBA. The 25% and 50% SBA media produced the greatest cantaloupe leaf fresh weights. Cantaloupe leaf dry weights followed a similar trend, where the 25% and 50% SBA media produced greater plant weights with lesser yields observed at the 75% and 100% SBA levels. This data suggests that the 75% SBA and 25% SBA were certainly suitable potting media combinations for squash and cantaloupe seedling production, respectively.

Keywords: agricultural by-products, bagasse, cantaloupe, fly ash, seedling, squash, soilless growth media, sugarcane

1. Introduction

1.1 Sugarcane Bagasse Uses

In 2014, Louisiana sugarcane farmers harvested 11.6 mt of milable sugarcane from 153,784 ha, producing 1.36 million mt of raw sugar and an estimated 2.7 million mt of bagasse. Global sugar production in 2015 is projected to be over 170 million mt of raw sugar, which would result in over 300 million mt of bagasse (United States Department of Agriculture, 2015). Bagasse is the fibrous material remaining after removing the sucrose, water, and other impurities (filter mud) from the milable sugarcane. The bagasse on a dry weight basis is composed of 40-50% cellulose, 30-35% hemicellulose, 20-30% lignin, and a small percentage other materials (Amin, 2011; Cardona et al., 2010; Drummond & Drummond,1996; Martin et al., 2007; Pandey et al., 2000; Sales & Lima, 2010). The sugarcane bagasse has been used for paper and fiber board production (Amin, 2011; Xin et al., 2002), cattle feed (Nigam, 1990; Pandey et al., 2000), potting media (Jhurree-Dussoruth & Kallydin, 2011; Trochoulias et al., 1990), a source for value added products (i.e. pigments, enzymes, amino acids, and drugs) (Pandey et al., 2000), and energy (thermoconversion and ethanol) (Badger, 2002; Kilicaslan et al., 1999; Martin et al., 2007; Peng et al., 2009; Sun & Cheng, 2002).

1.2 Sugarcane Bagasse Ash Production

It is very common for Louisiana sugarcane mills to use a portion of the sugarcane bagasse to produce steam power to run equipment within the mill and/or as a boiler fuel for the clarification, evaporation, and crystallization processes. Sugarcane bagasse ash (SBA) is a by-product of the thermoconversion of the sugarcane bagasse. Depending on the source of the sugarcane, harvesting methods and thermoconversion efficiency at the mill, the percentage of ash produced from bagasse typically represents a small percentage, 1.5 to 3.0% by weight, of the original sugarcane bagasse (Amin, 2011; Garcìa-Pèrez, 2002). And, although SBA content is low (1.5-3.0%) compared to other agricultural sources such as rice straw, 14.5% (Guo et al., 2009) and wheat straw, 8.6% (Biricik et al., 1999), the large volume of bagasse used for fuel results in massive amounts of SBA that needs to be economically and environmentally handled. If the estimated 50% (Pandey et al., 2000) of the 3 million tons of bagasse produced each year in Louisiana is used for energy conversion at the sugarcane mills, the SBA produced in Louisiana each year would range from 20,411 to 40,823 mt, and an estimated 2.25 to 4.5 million mt of sugarcane bagasse ash globally.

1.3 Sugarcane Bagasse Ash Content and Uses

SBA composition will vary depending on the source of the sugarcane, the harvesting and processing methods, and the cogeneration efficiencies (Payá et al., 2002). The primary components and percentages of SBA are SiO_2 (60%-81%), Al_2O_3 (8%-21%), Fe_2O_3 (5%-6%), CaO (3.1-3.4%), K_2O (1.4-1.5%), MgO (0.1-1.9%), and Na_2O (0.2-1.1%) (Payá et al., 2002; Zandersons et al., 1999). Sugarcane mill owners, operators, and associated researchers have investigated and employed various uses for SBA (Sales & Lima, 2010). Due to the high SiO_2 content (60-81%) and the other components, SBA is a potential replacement for silca in concrete and mortars (Alavéz-Ramírez et al., 2012; Amin, 2011; Cordeiro et al., 2008, 2009; Paula et al., 2010; Sales & Lima, 2010), ceramics (Souza et al., 2011), and as a stabilizing component in compacted clay blocks and bricks (Alavéz-Ramírez et al., 2012; Faria et al., 2012). One of the most common practices is the field application of the SBA with or without combining the ash with the sugarcane mill's filter mud (Barry et al., 1998; Prasad, 1974; Sales & Lima, 2010). The purpose of this research was to investigate the use of SBA as an amendment to soilless planting media for the production of vegetable seedlings.

2. Material and Methods

2.1 Sugarcane Bagasse Ash

Sugarcane bagasse ash was obtained from the Raceland Raw Sugar Corporation, sugarcane mill, Raceland, LA. The Raceland mill is one of 11 sugarcane mills that together processed approximately 153,783 ha and 11,576,403 mt of Louisiana sugarcane in 2014 (American Sugar Cane League, 2015). The SBA was combined by volume with a commercial growing media (Sunshine, Natural & Organic Professional Growing Mix, Sun Gro Horticulture Canada Ltd, 52130 RR 65, P.O. Box 189, Seba Beach, AB TOE 2BO Canada) into 5 combinations (0%:100%, 25%:75%, 50%:50%, 75%:25%, and 100%:0%, SBA and growing media, respectively) which served as experimental treatments. Each of the soilless media treatments were thoroughly mixed prior to placing the mixtures in Speedling (Speedling In., 4447 Old HWY 41, Ruskin, FL 33570, 800-881-4769) trays (128 cells, 26.625 x 13.625, 1.25 inch square x 2.5 inches deep). The mixtures were moistened to facilitate the complete and consistent filling of each of the Speedling trays. The Speedling trays were then planted with either certified organic squash seed 'var. Straightneck' (Main Street Seed & Supply, 401 Main Street, Bay City, MI 48707, 866 229-3276) or cantaloupe seed var. 'Magnum Hybrid Melon' (Petoseed Co., Inc., P.O. Box 4206, Saticoy, CA 93007-4206, USA). Each experiment was repeated twice in the spring of 2015 and included 1 seed type (squash or cantaloupe) × 5 soilless media mixtures (0:100, 25:75, 50:50, 75:25, and 100:0) × 4 replications.

Five seedlings from the center of each tray were harvested 21 days after planting. Each seedling was divided into above and below ground portions. The above ground portion was measured for plant length by measuring the distance from the soilless media surface to the apical meristem. The upper portion of the plant was further divided into leaves and stalks. The soilless media was removed from lower portion of the plants (roots). The fresh weight of the leaves, stalks, and the roots were then determined. The plant portions were then oven dried for 2 days at 60 ^{o}C and then reweighed to determine dry weights. All data were subjected to ANOVA and mean separation using LSD with P = 0.05 (SAS Inc., SAS, Ver. 9.0, Cary, NC).

3. Results and Discussion

3.1 Statistical Analysis

Statistical analysis determined that there were significant interactions among plant species (squash and cantaloupe), experiments, and plant growth medium (0%, 25%, 50%, 75% and 100% SBA); therefore the results will be discussed by plant species with each interaction addressed separately.

3.2 Squash

3.2.1 Squash Stalk Lengths

Significant interactions were detected between the planting media and the experiments for squash stalk length; therefore, the squash stem length data will be discussed by experiment (Table 1). In experiment 1, 75% SBA produced longer stalk lengths than the 100% SBA, and was not different from any other SBA percentage (Table 1). In experiment 2, squash stalk lengths were the greatest for the 100% SBA with a consistent decreasing trend to the 0% SBA (Table 1). In both experiments, the 75% SBA had one of the longest squash stalk lengths for the soilless growth media (Table 1).

Table 1. Impact of sugarcane bagasse ash percentage of growth medium on squash seedling stalk length (mm) averaged across two experiments, four replications per experiment, and five seedlings per replication

SBA[z]	Experiment 1		Experiment 2	
	---mm---		---mm---	
0%	79.5	ab[y]	56.5	c
25%	79.8	ab	61.3	bc
50%	74.5	ab	69.0	b
75%	83.2	a	70.3	ab
100%	72.8	b	82.5	a

Note. [z]Percentage of sugarcane bagasse ash (SBA) in the growth medium based on volume.

[y]Means in a column followed by the same lower case letter are not significantly different at $P \leq 0.05$, ANOVA.

3.2.2 Squash Fresh and Dry Plant Weights

No significant interactions were detected between the experiments and the growth media, therefore the squash plant fresh and dry weights will be discussed averaged across experiments (Tables 2 and 3). The squash seedling fresh weights for the leaves, seedling tops (stalks + leaves), and seedling total fresh weight (stalks + leaves + roots] increased from the 0% SBA to 75% SBA (Table 2). The squash root fresh weights were not consistent, but did peak at the 100% SBA, whereas the stalk fresh weights were not different across the SBA percentages (Table 2). Squash dry weights varied considerably depending on the plant components involved (Table 3). The squash stalks (0.42 g), leaves (0.94 g), and tops (stalks +leaves) (1.35 g) peaked at the 50% SBA, while the root dry weights and total plant weights peaked at the 100% SBA (Table 3).

Table 2. Impact of sugarcane bagasse ash percentage of growth medium on squash seedling fresh plant weights (g) averaged across two experiments, four replications per experiment, and five seedlings per replication

SBA[z]	Fresh Weights									
	Stalk		Leaves		Tops		Roots		Total	
%	---g---		---g---		---g---		---g---		---g---	
0%	3.12	a[y]	6.54	c	9.65	b	1.72	ab	11.37	c
25%	3.25	a	6.92	bc	10.17	b	2.02	a	12.19	bc
50%	3.40	a	7.70	ab	11.11	ab	1.53	b	12.64	abc
75%	3.73	a	8.26	a	11.98	a	1.98	ab	13.97	a
100%	3.40	a	7.73	ab	11.14	ab	2.20	a	13.33	ab

Note. [z]Percentage of sugarcane bagasse ash (SBA) in the growth medium based on volume.

[y]Means in a column followed by the same lower case letter are not significantly different at $P \leq 0.05$, ANOVA.

Table 3. Impact of sugarcane bagasse ash percentage of growth medium on squash seedling oven dried plant weights (g) averaged across two experiments, four replications per experiment, and five seedlings per replication

SBA[z]	Dry Weights									
	Stalks		Leaves		Tops		Roots		Total	
%	---g---		---g---		---g---		---g---		---g---	
0%	0.30	b[y]	0.71	b	1.01	b	0.50	c	1.51	c
25%	0.35	ab	0.83	ab	1.18	ab	0.82	b	2.00	b
50%	0.42	a	0.94	a	1.35	a	0.77	b	2.12	ab
75%	0.36	ab	0.92	a	1.28	a	1.04	a	2.32	ab
100%	0.34	ab	0.85	ab	1.18	ab	1.19	a	2.37	a

Note. [z] Percentage of sugarcane bagasse ash (SBA) in the growth medium based on volume.

[y] Means in a column followed by the same lower case letter are not significantly different at $P \leq 0.05$, ANOVA.

3.2.3 Squash Data Summary

The squash seedling lengths, fresh and dry weights indicate that although there does not seem to be a clear and unequivocal advantage of adding the sugarcane bagasse ash to the squash seedling growth media, there is also not a disadvantage, as far as squash seedling growth, to adding 50% to 75% sugarcane bagasse ash to the growth media. Adding at least the 25% amount consistently shows a positive response, although not always of statistical significance.

3.3 Cantaloupe

3.3.1 Cantaloupe Seedling Analysis

Significant interactions were detected between the planting media and experiments for cantaloupe leaves, fresh ($P \leq 0.0499$) and dry ($P \leq 0.0481$) weights (Table 4), therefore the leaf data will be discussed by experiments (Table 4). Due to the absence of interaction by experiments, the cantaloupe stalk lengths and other seedling fresh and dry weights will be discussed averaged across experiments (Tables 5 and 6).

3.3.2 Cantaloupe Fresh and Dry Leaf Weights

In both experiments, the cantaloupe leaf fresh weights were the greatest for the 25% and 50% SBA media, decreasing with either a lower or greater percentage of SBA (Table 4). The leaf fresh weight interaction between experiments was due to a greater decrease between the 75% and 100% SBA in experiment 2 (2.24 g vs. 1.52 g) compared to experiment 1 (2.07 g vs. 1.62 g) (Table 4). Cantaloupe leaf dry weights followed a similar trend, where the 25% and 50% SBA media produced greater plant weights with lesser yields observed at the 75% and 100% SBA levels (Table 4). Unlike the leaf fresh weights, the interaction between experiments 1 and 2 for the leaf dry weights occurred when comparing the differences between the 25% SBA media and the 0% SBA media (Table 4). Whereas, in experiment 1, there was a significant decrease between the 25% and the 0% SBA media, there was no difference between the 25% and 0% SBA media in experiment 2 (Table 4).

Table 4. Impact of sugarcane bagasse fly ash percentage of growth medium on cantaloupe fresh and dry leaf weights (g) averaged across two experiments, four replications per experiment, and five seedlings per replication.

SBA[z]	Leaves Fresh Weight				Leaves Dry Weight			
	Exp. 1		Exp. 2		Exp. 1		Exp. 2	
%	---g---		---g---		---g---		---g---	
0%	1.64	b	2.42	b	0.29	b	0.59	a
25%	2.66	a	3.02	a	0.53	a	0.56	a
50%	2.58	a	3.20	a	0.46	a	0.62	a
75%	2.07	b	2.24	b	0.33	b	0.40	b
100%	1.62	b	1.52	c	0.25	b	0.38	b

Note. [z] Percentage of sugarcane bagasse ash (SBA) in the growth medium based on volume.

[y] Means in a column followed by the same lower case letter are not significantly different at $P \leq 0.05$, ANOVA.

3.3.3 Cantaloupe Stalk, Plant Tops, Roots, and Total Plant Fresh and Dry Weights

The cantaloupe seedling stalk lengths and other fresh weights (stalks, seedling tops, roots, and total seedling) followed a similar trend as the leaf fresh and dry weights, typically peaking at the 25% or 50% SBA media (Table 5), but never producing higher values at either the 75% or 100% SBA levels compared to the 25% and 50% media. The cantaloupe seedling dry weights also peaked in the 25% and 50% SBA range, with the stalk dry weights not differening among soil media contents (Table 6).

Table 5. Impact of sugarcane bagasse ash percentage of growth medium on cantaloupe seedling stalk lengths and plant fresh weights (g) averaged across two experiments, four replications per experiment, and five seedlings per replication

SBA[z]	Stalk Length		Fresh Weight							
			Stalks		Tops		Roots		Total	
%	---cm---		---g---		---g---		---g---		---g---	
0%	2.26	bc[y]	0.42	cd	2.45	b	1.39	ab	3.84	b
25%	2.96	a	0.69	ab	3.53	a	1.65	a	5.17	a
50%	2.93	a	0.70	a	3.59	a	1.29	b	4.89	a
75%	2.48	b	0.55	bc	2.70	b	1.26	b	3.97	b
100%	2.12	c	0.37	d	1.94	c	0.69	c	2.63	c

Note. [z] Percentage of sugarcane bagasse ash (SBA) in the growth medium based on volume.

[y] Means in a column followed by the same lower case letter are not significantly different at $P \leq 0.05$, ANOVA.

Table 6. Impact of sugarcane bagasse ash percentage of growth medium on cantaloupe seedling oven dried weights (g) averaged across two experiments, four replications per experiment, and five seedlings per replication

SBA[z]	Dry Weights							
	Stalks		Tops		Roots		Total	
%	---g---		---g---		---g---		---g---	
0%	0.16	a[z]	0.60	ab	0.37	b	0.97	bc
25%	0.19	a	0.73	a	0.57	a	1.30	a
50%	0.18	a	0.72	a	0.55	a	1.27	a
75%	0.19	a	0.55	b	0.56	a	1.11	ab
100%	0.16	a	0.47	b	0.34	b	0.81	c

Note. [z] Percentage of sugarcane bagasse ash (SBA) in the growth medium based on volume.

[y] Means in a column followed by the same lower case letter are not significantly different at $P \leq 0.05$, ANOVA.

3.3.4 Cantaloupe Seedling Summary

The 25% SBA consistently produced the greatest cantaloupe seedling growth across the various plant parameters measured, although the 50% SBA media was often not significantly different from the 25% SBFA results (Tables 5 and 6). This data suggests that 25% SBA was certainly a suitable soilless media combination for cantaloupe seedling production.

4. Conclusions

The research indicates that the addition of sugarcane bagasse ash can enhance squash and cantaloupe seedling growth depending on the percentage of the ash added to the growth media. Squash plant stalk lengths and plant fresh weights (stalk, leaves, tops, roots, and total plant) overall responded best at the 75% SBA and the 25% to 100% SBA squash dry weights were consistently greater than the 0% SBA. The 25% and 50% SBA media produced the greatest cantaloupe leaf fresh weights. Cantaloupe leaf dry weights followed a similar trend, where the 25% and 50% SBA media produced greater plant weights with lesser yields observed at the 75% and 100% SBA levels. This data suggests that the 75% SBA and 25% SBA were certainly suitable potting media combinations for the squash and cantaloupe seedling production, respectively. Further research should investigate the impact of adding starter fertilizers to the bagasse amended media to further enhance the growth of the squash and cantaloupe seedlings. Also additional plant species should also be evaluated in their response to bagasse ash amended growth media.

Acknowledgements

The authors want to express their appreciation to the American Sugar Cane League for their partial support of this research. The authors would also like to thank the USDA, Agricultural Research Sevice technicians Lionel Lomax, Christopher Adams, Eric Petrie, Norris Matherne, and Frank Randell for their technical support.

Trade Names or Commercial Products

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

EEO/Non-Discrimination Statement

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

References

Alavéz-Ramírez, R., Montes-García, P., Martínez-Reyes, J., Altamirano-Juárez, D. C., & Gochi-Ponce, Y. (2012). The use of sugarcane bagasse ash and lime to improve the durability and mechanical properties of compacted soil blocks. *Construction and Building Mater., 34*, 296-305. http://dx.doi.org/10.1016/j.conbuildmat.2012.02.072

American Sugar Cane League. (2015). *The Louisiana sugar industry* (pp. 1-8). Retrieved from http://www.amscl.org/Images/Interior/sugar%20industry%20pamphlet/sugarindustrymediakit.pdf

Amin, N. (2011). Use of bagasse ash in concrete and its impact on the strength and chloride resistivity. *J. Mater. Civ. Eng., 23*(5), 717-720. http://dx.doi.org/10.1061/(ASCE)MT.1943-5533.0000227

Badger, P. C. (2002). Ethanol from cellulose: A general review. In J. Janick & A. Whipkey (Eds.), *Trends in new crops and new uses* (pp. 17-21). ASHS Press, Alexandria, VA.

Barry, G. A., Price, A. M., & Lynch, P. J. (1998). Some implications of the recycling of sugar industry by-products. *Proc. Aust. Soc. Sugar Cane Technol., 20*, 52-55.

Biricik, H., Aköz, F., Berktay, I., & Tulgar, A. N. (1999). Study of pozzolanic properties of wheat straw ash. *Cement and Concrete Res., 29*, 637-643. http://dx.doi.org/10.1016/S0008-8846(98)00249-X

Cardona, C. A., Quintero, J. A., & Paz, I. C. (2010). Production of bioethanol from sugarcane bagasse: Status and perspectives. *Bioresource Techn., 101*(13), 4754-4766. http://dx.doi.org/10.1016/j.biortech.2009.10.097

Cordeiro, G. C., Filho, R. D. T., Tavares, L. M., & Fairbairn, E. M. R. (2008). Pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars. *Cement and Concrete Composites, 30*(5), 410-418. http://dx.doi.org/10.1016/j.cemconcomp.2008.01.001

Cordeiro, G. C., Filho, R. D. T., Tavares, L. M., & Fairbairn, E. M. R. (2009). Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete. *Cement and Concrete Res., 39*(2), 110-115. http://dx.doi.org/10.1016/j.cemconres.2008.11.005

Drummond, A.-R. F., & Drummond, I. W. (1996). Pyrolysis of Sugar Cane Bagasse in a Wire-Mesh Reactor. *Ind. Eng. Chem. Res., 35*(4), 1263-1268. http://dx.doi.org/10.1021/ie9503914

Faria, K. C. P., Gurgel, R. F., & Holanda. J. N. F. (2012). Recycling of sugarcane bagasse ash waste in the production of clay bricks. *J. of Environ. Management, 101*, 7-12. http://dx.doi.org/10.1016/j.jenvman.2012.01.032

Garcìa-Pèrez, M., Chaala, A., & Roy, C. (2002). Vacuum pyrolysis of sugarcane bagasse. *J. of Analytical and Applied Pyrolysis, 65*(2), 111-136. http://dx.doi.org/10.1016/S0165-2370(01)00184-X

Guo, G. L., Hsu, D. C., Chen, W. H., Chen, W. H., & Hwang, W. S. (2009). Characterization of enzymatic saccharification for acid-pretreated lignocellulosic materials with different lignin composition. *Enzyme and Microbial Techn., 45*(2), 80-87. http://dx.doi.org/10.1016/j.enzmictec.2009.05.012

Jhurree-Dussoruth, B., Kallydin, H., & Bornes, Q. (2011). Investigation into low-cost medium for hardening of in vitro banana plantlets to promote adoption of disease-free plants. *Acta Hort., 897*, 489-490. http://dx.doi.org/10.17660/ActaHortic.2011.897.69

Kilicaslan, I., Sarac, H. I., Ozdemir, E., & Ermis, K. (1999). Sugar cane as an alternative energy source for Turkey. *Energy Conversion & Management, 40*(1), 1-11. http://dx.doi.org/10.1016/S0196-8904(98)00103-4

Martin, C., Klinke, H. B., & Thomsen, A. B. (2007). Wet oxidation as a pretreatment method for enhancing the enzymatic convertibility of sugarcane bagasse. *Enzyme and Microbial Techn., 40*, 426-432. http://dx.doi.org/10.1016/j.enzmictec.2006.07.015

Nigam, P. (1990). Investigation of some factors important for solid state fermentation of sugar cane bagasse for animal feed production. *Enzyme and Microbial Techn., 12*(1990), 808-811. http://dx.doi.org/10.1016/0141-0229(90)90156-K

Pandey, A., Soccol, C. R., Nigam, P., & Soccol, V. T. (2000). Biotechnological potential of agro-industrial residues. I: sugarcane bagasse. *Bioresource Technol., 74*(1), 69-80. http://dx.doi.org/10.1016/S0960-8524(99)00142-X

Paula, M. O. D., Tinôco, I. D. F. F., & Saraz, J. A. O. (2010). Sugarcane bagasse ash as a partial portland cement replacement material. *Dyna., 77*, 47-54.

Payá, J., Monzó, J., Borrachero, M. V., Díaz-Pinzón, L., & Ordóňez, L. M. (2002). Sugar-cane bagasse ash (SCBA): studies on its properties for reusing in concrete production. *J. Chem Technol. Biotechnol., 77*, 321-325. http://dx.doi.org/10.1002/jctb.549

Peng, F., Ren, J. L., Xu, F., Bian, J., Peng, P., & Sun, R. C. (2009). Comparative study of hemicelluloses obtained by graded ethanol precipitation from sugarcane bagasse. *J. Agric. Food Chem., 57*(14), 6305-6317. http://dx.doi.org/10.1021/jf900986b

Prasad, M. (1974). The effect of filter press mud on the availability of macro-and micronutrients. *Proc. Intern. Soc. of Sugar Cane Technologists, Sudáfrica* (pp. 568-575). ZA. Hayne & Gibson.

Sales, A., & Lima, S. A. (2010). Use of Brazilian sugarcane bagasse ash in concrete as sand replacement. *Waste Management, 30*(6), 1114-1122. http://dx.doi.org/10.1016/j.wasman.2010.01.026

Souza, E., Teixeira, S. R., Santos, G. T. A., Costa, F. B., & Longo, E. (2011). Reuse of sugarcane bagasse ash (SCBA) to produce ceramic materials. *J. of Environ. Management, 92*(10), 2774-2780. http://dx.doi.org/10.1016/j.jenvman.2011.06.020

Sun, Y., & Cheng, J. (2002). Hydrolysis of lignocellulosic materials for ethanol production: A review. *Bioresource Technol., 83*(1), 1-11. http://dx.doi.org/10.1016/S0960-8524(01)00212-7

Trochoulias, T., Burton, A. J., & White, E. (1990). The use of bagasse as a potting medium for ornamentals. *Scientia Horticulturae, 42*(1-2), 161-167. http://dx.doi.org/10.1016/0304-4238(90)90157-A

United Staes Department of Agriculture, Foreign Agricultural Service. (2015). *Sugar: World markets and trade*. Retrieved October 15, 2015 from http://apps.fas.usda.gov/psdonline/circulars/Sugar.pdf

Xin, L., Kondo, R., & Sakai, K. (2002). Biodegradation of sugarcane bagasse with marine fungus Phlebia sp. MG-60. *J. Wood Sci., 48*, 159-162. http://dx.doi.org/10.1007/BF00767294

Zandersons, J., Gravitis, J., Kokorevics, A., Zhurinsh, A., Bikovens, O., Tardenaka, A., & Spince, B. (1999). Studies of the Brazilian sugarcane bagasse carbonisation process and products properties. *Biomass and Bioenergy, 17*(3), 209-219. http://dx.doi.org/10.1016/S0961-9534(99)00042-2

Copyrights