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Removal of ash from sugarcane leaves and tops

Anocha Chaow-u-thai[1], Sudsakorn Inthidech[2], Sampan Rittidech[3], Adisak Pattiya[1*]

[1]*Bio-Energy and Renewable Resources Research Laboratory, Faculty of Engineering, Mahasarakham University,Kamriang, Kantharawichai, MahaSarakham 44150, Thailand*

[2]*Manufacturing and Metallurgical Engineering Laboratory, Faculty of Engineering, Mahasarakham University,Kamriang, Kantharawichai, MahaSarakham 44150, Thailand*

[3]*Heat-Pipe and Thermal Tools Design Research Unit (HTDR), Faculty of Engineering, Mahasarakham University, Kamriang, Kantharawichai, MahaSarakham 44150,Thailand*

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Abstract

This paper presents findings on the removal of ash from sugarcane leaves tops by applying two main techniques including biomass size selection and biomass washing. In the size selection technique, biomass samples were ground and sieved into <0.250, 0.250-0.425, 0.425-0.85 and 0.85-2.00 mm. In the washing technique, samples were washed with water and dilute acid solution. The biomass samples after being subjected to both techniques were analysed for their ash content. The result showed that the biomass particle size of 0.85-2.00 mm gave lowest ash content for both sugarcane leaves and sugarcane tops. It was also found that the effectiveness of the removal of ash from sugarcane leave and tops was mainly dependent on the washing solution and residence time applied. The most effective method for the ash removal was by hot water for 24 hours, which could remove up to 65.35% and 69.01% of the ash in sugarcane leave and tops.

*Corresponding Author: Adisak Pattiya ✉ adisak_pattiya@yahoo.com

Introduction

Sugarcane is a perennial plant of the genus *Saccharum*. The main sources of sugarcane are in Brazil, India, China, Thailand, Mexico and Australia (FAO, 2012). Typically, sugarcane is grown for sugar production. Lately, sugarcane is also a feedstock for ethanol production. The demand for sugar and ethanol industries is increasing. Therefore, it is expected that the residues would be increased accordingly. Residues from sugarcane plantations include bagasse, leaves and tops. The bagasses are traditionally used as a fuel in the sugar factories to generate electricity for their own usage. The leaves and tops are mostly burnt in the fields and are not efficiently used for energy. Only small part of the leaves and tops are used as a compost and animal feed. The amount of the leaves and tops is approximately 500 million tonnes per year (FAO, 2012; Pattiya, 2011). These biomass residues could be used for energy production by thermochemical conversion processes such as combustion, gasification and pyrolysis. Typically, these processes prefer low biomass ash content because the ash in biomass could be problematic during the process. For example, in combustion and gasification, biomass is heated at high temperature and part of the ash component could melt and cause slagging, corrosion and blockages. In fast pyrolysis process for bio-oil production, the alkali and/or alkaline earth metals or biomass ash could act as catalysts for char-forming and cracking reaction, producing more char and non-condensable gases, respectively (Shafizadeh, 1968; Wang *et al.*, 2007). This, therefore, lowers the bio-oil yield. Since the ash content of sugarcane leaves and tops is rather high (7-13%) compared to typical woody biomass, removal of ash from this residues would be beneficial to several applications. Abdullah *et al.* (2010) reported that the smallest biomass particle size contained highest ash content due to the soil contamination when collecting biomass from field. This implies that if biomass is ground and sieved into different size ranges, one could select the biomass of suitable particle size that contains lowest ash content. This technique is called "biomass size selection". Another technique applied for removing ash from biomass is referred to as "biomass washing". Jenkins *et al.* (1996) reported that by flushing 100 g of wheat straw with 20 litres of distilled water at 20-25°C, the ash content could reduce significantly from 13% to 4.2%. Another previous study showed that when *Festuca arundinacea* grass was washed with distilled water at 25°C for 2 hours with continuous stirring at 40 rpm, the ash content of the grass decreased from 7.3% to 4.4% (Fahmi *et al.*, 2008).

Although some previous studies showed that the two techniques had potential for removal of biomass ash, no work has been carried out on sugarcane leaves and tops even though they are globally abundant. In addition, little work had been done on investigating the effects of washing process parameters such as stirring, washing temperature, washing time and washing liquids. It is therefore the objective of this current study to investigate these process parameters.

Materials and methods

The raw biomass materials applied in this work were sugarcane leaves (SL) and sugarcane tops (ST) obtained from north-east Thailand. The biomass samples were dried to reduce the moisture content below 10 wt%. Two biomass ash reduction methods were employed, which included size reduction and selection, and biomass washing. The size reduction and selection method involved grinding the biomass samples to particle size less than 2.00 mm, and sieving the ground sample to particle size ranges of <0.250, 0.250-0.425, 0.425-0.850 and 0.850-2.00 mm. Each size of the samples was subsequently analysed to determine the contents of volatile matter, fixed carbon and ash by following the ASTM E872-82 and E1755-01 methods. Fig.1 illustrates the experimental procedure.

In biomass washing technique, 7 grams of each sample with a particle size range of 0.425-0.85 mm was washed with 500 ml of room temperature (28°C) water, hot (80°C) water, and 0.05% hydrochloric acid (HCl) solution for 1, 3, 6, 12 and 24 hours. After washing, the sample was filtered through a 4 µm sieve. In the case of acid washing, the sample was further rinsed with water until the pH of the solution became neutral. Then, the sample was dried in an oven at 105°C for 24 hours or until constant weight. The dried biomass samples were tested for their ash content. All experiments were carried out in triplicate and the average values were reported.

Results and discussion

Removal of ash by biomass size reduction and selection

Two biomass samples, namely sugarcane leaves and tops, were ground and sieved into <0.250, 0.250-0.425, 0.425-0.850 and 0.850-2.000 mm. All of the biomass samples after the size reduction and sieving were analysed for their proximate analysis to determine the volatile matter, fixed carbon and ash contents. The results are summarized in Table 1. It is obvious from the table that the ash contents of both sugarcane leaves and tops were highest at the particles less than 0.250 mm, which were 10.5% and 12.8%, respectively. The reason why the small biomass particles contained significant amount of ash is possibly because part of the fine particles was soil or dust, which contained high amount of silica. Similar findings by Abdullah *et al.* (2010) reported that the ash content of oil palm empty fruit bunch (EFB) of particle size ranges of <0.150, 0.150-0.250, 0.250-0.300 and 0.355-0.500 mm were 8.94%, 7.46%, 6.70% and 4.83%, respective. This indicates that if one wants to obtain the low ash biomass, the biomass may be reduced in size by, for example, grinding, and remove the small or fine biomass particles by selecting the larger biomass particles.

Table 1 also shows that the biomass samples of 0.425-0.850 mm and 0.850-2.000 mm had little difference in ash content. In addition, the size 0.425-0.850 mm of both biomass samples appeared to possess the lowest ash content compared to the other size ranges.

Table 1. Proximate analysis of sugarcane leaves and tops (wt%, dry basis)

Biomass	Particle size (mm)	Volatile matter	Fixed carbon	Ash
Sugarcane leaves	<0.250	74.5±0.9	14.9±1.1	10.6±0.4
	0.250-0.425	76.9±1.1	16.1±1.1	7.0±0.1
	0.425-0.850	77.6±1.0	15.5±1.2	6.9±0.1
	0.850-2.000	78.0±1.0	15.5±0.9	6.5±0.4
Sugarcane tops	<0.250	72.4±1.4	14.7±1.2	12.9±0.9
	0.250-0.425	73.9±1.4	17.9±1.6	8.2±0.3
	0.425-0.850	73.6±0.7	18.4±0.5	8.0±0.2
	0.850-2.000	73.3±0.2	19.0±0.2	7.7±0.1

According to Table 1, the volatile matter contents of both biomass types were lowest when the particle size range was <0.250 mm. This is related to their highest ash content. The volatile matter content is generally important in many biomass conversion processes. For example, in fast pyrolysis process for bio-oil production, low volatile matter is an indication for low bio-oil yield. When considering the fixed carbon of the sample, it is apparent that the lowest fixed carbon content occurred with the smallest biomass particles. This is true for both sugarcane leaves and tops. The high fixed carbon content is beneficial in some applications such as for slow pyrolysis bio-char production. Lower fixed carbon implied lower bio-char yield and quality in terms of carbon sequestration. When considering all of the findings in Table 1, it could be therefore induced that the small or fine biomass particles of <0.250 mm have drawbacks in thermochemical conversion processes. Therefore, removing this size range by size reduction and selection would improve the quality of the biomass.

Removal of ash by washing with water at room temperature

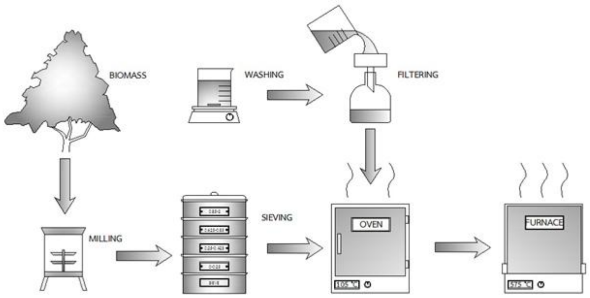

Fig. 1. Flow diagram of the experimental procedure.

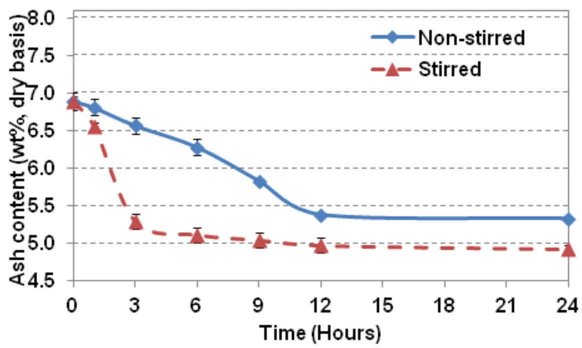

Fig. 2. Effect of room temperature water washing time on ash content of sugarcane leaves.

Since the particle size range of sugarcane leaves and tops that gave lowest ash content was 0.425-0.850 mm, this range was then selected for washing experiments. Experiments carried out using water at room temperature (28°C) as washing liquid were carried out to investigate the effects of stirring while washing and the residence time on ash removal. The results are depicted by Figs.2 and 3 for sugarcane leaves and sugarcane tops washing, respectively. It is apparent from the graphs that the biomass ash content decreased with increasing washing time. It was also found that stirring during washing was beneficial to the removal of ash as it provided well mixing. This result is more significant in the case of sugarcane leaves washing, especially during the first 9 hours of washing. The ash content of sugarcane leaves was decreased from 6.89% to 5.33% or up to 27.05% of the original ash was removed after washing with room temperature water without stirring for 24 hours and with stirring the ash content was further decreased to 4.93%, or up to 33.45% of the original ash was removed. Likewise, the ash of sugarcane tops was reduced from 8.04% to 5.54, or 35.50% of the initial ash was removed after washing with water at 28°C without stirring for 24 hours, and it was further reduced to 5.31%, or 38.84% ash removal when stirred washed. When comparing the removal of ash from both biomass residues, it had been shown that the ash reduction for both feedstocks was rather similar, which was in the range of 33-39%. Previous work by Das *et al.* (2004) showed that when washing sugarcane bagasse with water at 25°C for 24 hour, the ash content was decreased from 1.83% to 1.02%, or equivalent to a reduction of 44.26%. This is slightly higher than the sugarcane leaves and tops washing reported in the present work.

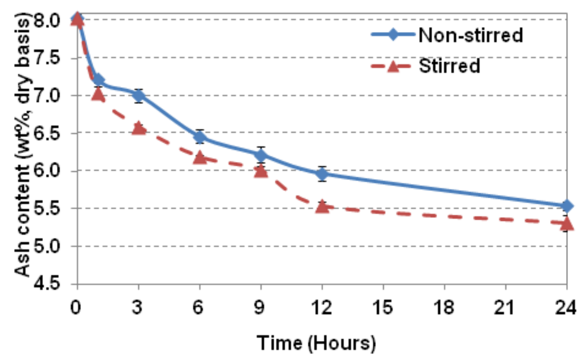

Fig. 3. Effect of room temperature water washing time on ash content of sugarcane tops.

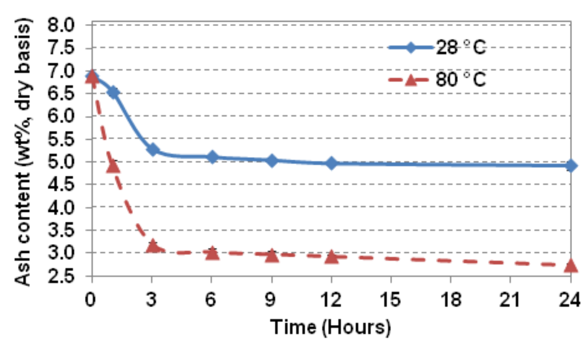

Fig. 4. Effect of water-washing temperature on ash content of sugarcane leaves.

Removal of ash by washing with hot water

The sugarcane leaves and tops samples were washed with water at 80°C for 1-24 hours. The ash contents of the hot water washed samples were compared with those of the room temperature water washed samples in Figs. 4 and 5. It is obvious from the graph that the use of hot water could enhance the removal of ash for both type of biomass, even after washing for 3 hours. The ash content of sugarcane leaves was reduced from 6.89% to 2.74% after stirred washing for 24 hours. This corresponds to 65.35% of ash removal, compared to 27.05% when washing with water at room temperature. For sugarcane tops, the ash content was decrease from 8.04% to 2.85% after stirred washing for 24 hours, which corresponds to 69.01% of ash removal, compared to 33.45% when applying room temperature water. Teng and Wei (1998) reported that the ash content of rice hull was decreased from 13% to 8.4% (44.3% reduction) when washing with hot (80°C) water for 2 hours. However, they did not report the comparison of this result with the room temperature washing. Nevertheless, the present findings prove that temperature of washing did affect the ash removal from sugarcane residues. More specifically, high temperature washing could enhance the biomass ash removal.

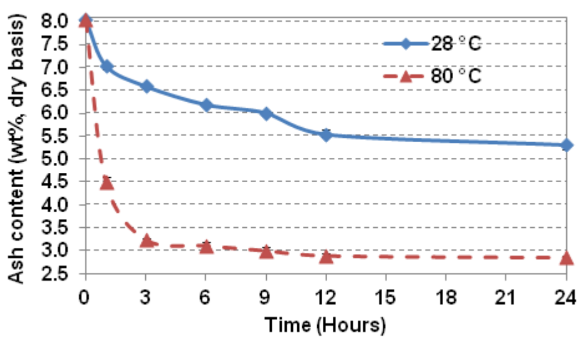

Fig. 5. Effect of water-washing temperature on ash content of sugarcane tops.

Removal of ash by washing with dilute acid solution

Illustrated by Figs. 6 and 7 are the experimental results of washing sugarcane leaves and tops samples with 0.05% hydrochloric acid solution room temperature for 1-24 hours in comparison with those with room temperature. For sugarcane leaves (Fig. 6), the ash content was decreased from 6.89% to 4.89% when washing was carried out for only 1 hour. Further increase in the residence time to 24 hours hardly affected the ash content. Similarly, the ash content of sugarcane tops (Fig. 7) was decreased from 8.04% to 4.78% after 1 hour washing and further increase of the residence time could not reduce any more ash. In terms of ash removal percentages, approximately 38-47% of the sugarcane leaves and top ashes were removed by stirred washing with dilute acid solution for only 1 hour.

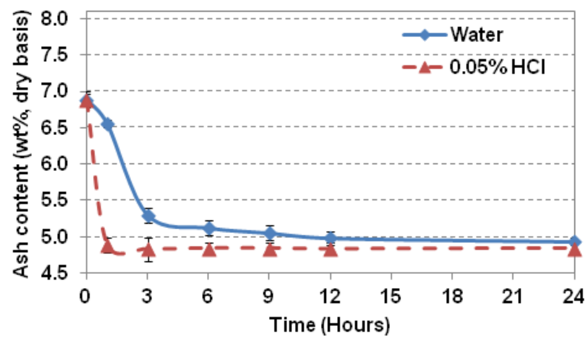

Fig. 6. Effect of acid washing time on ash content of sugarcane leaves.

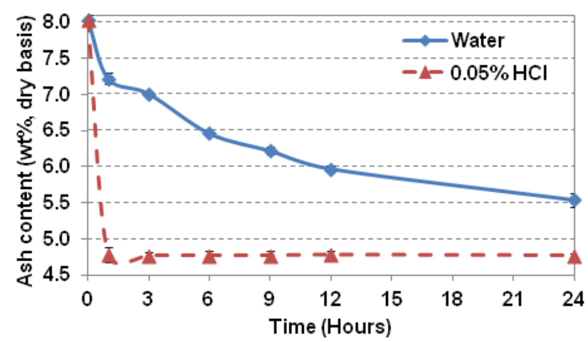

Fig. 7. Effect of acid-washing time on ash content of sugarcane tops.

Conclusions

According to the experimental results, it can be concluded that all of the biomass removal techniques were effective to a certain extent. The most effective technique for sugarcane leaves and tops was the hot water stirred washing for 24 hours since nearly 70% of ash could be removed. Although the hot water washing technique was rather effective, a more simple technique like biomass size reduction and selection may be a better choice if economics is the main issue as the latter could also remove part of the ash as well. In washing techniques, process parameters found to influence the ash removal included stirring, residence time, washing temperature and the use of dilute acid.

Acknowledgements
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