DEVELOPMENT OF GROWING MEDIA FROM SUGAR INDUSTRIAL WASTE

Pusit Asadathorn[1], Worajit Setthapun[1*], Wattanapong Rakwichian[2], and Thassanupan Kusolsatit[3]

[1] Asian Development Institute for Community Economy and Technology,Chiang Mai Rajabhat University, Muang, Chiang Mai, 50300, Thailand

[2] School of Energy and Environment, University of Phayao, Muang, Phayao, 56000, Thailand

[3] Faculty of Agricultural, Nakhon Sawan Rajabhat University, Muang, Nakhon Sawan, 60000, Thailand

[*]*E-mail address*: worajit@gmail.com

Abstract— The main waste from sugar production in Thailand were filter cake, and bagasse ash. These wastes were still increased and generally managed by dumping in landfill. The utilization of these wastes was applied to improve of soil properties as soil conditioner. This research aimed to develop of growing media from sugar industrial waste for sustainable waste management. The scopes of study were to analyze chemical properties of sugar industrial waste for identification of hazardous properties following Thailand's regulation, to determine the optimal mixing condition and size of diameter of developed growing media from sugar industrial waste by stability, bulk density, total porosity, air-filled porosity, water containing capacity, and to explore the optimal mixing condition of developed growing media from sugar industrial waste by the growth condition of Chinese Cabbage (Brassica rapa L.). The results revealed the chemical properties of filter cake, and bagasse ash as non-hazardous waste. These wastes were safe for cultivation utilization. There was no significant difference in bulk density between a mixing ratio and diameter size of growing media, 0.22- 0.33 g/cm^3. However, there was correlation between other parameters (total porosity, air-filled porosity, and water containing capacity) and the mixing ratio and diameter size of growing media. Finally, the growth of Chinese cabbage in developed growing media form sugar industrial waste were found the optimal ratio at 4:1 at 4 mm. In conclusion, the utilization of filter cake and bagasse ash in development of growing media can influenced on stability, total porosity, air-filled porosity, and water containing capacity. This research was shown the alternative waste management for Thailand's sugar industry.

Keywords - Sugar industrial waste, Filter cake, Bagasse ash, Growing media, Waste utilization

I. INTRODUCTION

Thailand was in the top five countries of sugar production in the world [1], and Thailand's sugar industry was manufactured of sugar production around 10,200 million tons in 2014 [2]. Sugar was produced from sugarcane, sugar beets, and cassava [3]. The sugarcanes were the main raw materials in sugar production because the residues from sugar production can be recycled as alternative raw materials in ethanol production and alternative fuel in biomass power plant [1, 4]. The volume of key sugar industrial wastes such as bagasse, filter cake, and bagasse ash depended on the increasing of sugar consumption, however; their conventional waste management were dumping into landfill [5]. The limitation of landfill in Thailand have permitted by Department of Industrial Works (DIW), but the increasing volume of industrial wastes from sugar manufacturing have required the dumping waste site, especially, filter cake, and bagasse ash [6]. Many studies were interesting on utilization of filter cake, and bagasse ash as the recycling materials [7, 8] such as the pozzolanic materials in construction [5, 9], the low-cost adsorbent or zeolite for the removal of organic compounds [10], soil amendment or fertilizer [11-15]. In addition, the study of filter cake, and bagasse ash as fertilizer were found that their wastes composed of nutrient for improvement of soil structure, aeration capacity and micro fauna activities [16-19].

There are four main physical properties of growing media which impact of plant growth including bulk density, moisture, dry matter ash, organic matter, water, air volume porosity, volume collapse [20]. The important of growing media on soil system were their physical properties to provide simultaneously sufficient amount of oxygen and water to the roots [21]. The filter cake of bagasse ash cannot directly develop to growing media, because growing media must be consistent quality in the stability or a consistent structure for the growth of plants [22]. Therefore, the mixing of filter and bagasse in optimal condition were applied to compact them as aggregate or pellet for increasing of stability and oxygen content in the media [23].

*W. Setthapun *Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University, Chiang Mai, Thailand*

This research was considered on the development of growing media as innovative agriculture product from filter cake, and bagasse ash. Therefore, the research objectives were concerned on the analysis of chemical properties of sugar industrial waste for identification of hazardous properties following Thailand's regulation before utilization of growing media as agricultural product, the determination of optimal mixing condition and size of diameter of developed growing media from sugar industrial waste by aggregate stability, bulk density, total porosity, air-filled porosity, water containing capacity, and the determination of optimal mixing condition of developed growing media from sugar industrial waste by the growth condition of Chinese Cabbage (*Brassica rapa L.*). Finally, the findings of this thesis could be used to reduce the sugar industrial waste into landfill by utilization of these wastes to new innovative agricultural product.

II. Materials and Methods

A. Filter cake and bagasse ash

Both of filter cake (Fig. 1) and bagasse ash (Fig. 2) were collected around 100 kilograms by random method from local sugar industry in Phitsanulok Province, they were used for all experiments in this research. They were air dried at room temperature and were applied for all preparations of growing media sample.

Figure 1 Filter cake

Figure 2 Bagasse ash

B. Determination of hazardous properties in filter cake and bagasse ash

This experiment aimed to investigate of hazardous properties in filter cake and bagasse ash from sugar industry by analysis of heavy metal content in the filter cake and bagasse ash [24]. Both of sugar industrial waste were digested by HNO_3 in Microwave Digester and were measured the concentration of heavy metals such as Ag, As, B, Ba, Cd, Cr, Cu, Ni, Pb, Tl, and Zn by Inductively coupled plasma atomic emission spectroscopy (ICP-AES).

C. Preparation of developed growing media in the different size and diameter from filter cake and bagasse ash

The developed growing media were prepared by mixing between filter cake and bagasse ash at various ratios and each ratio was produced to many diameters at 4 mm, 8mm, and 12mm, respectively. The ratios of the mixtures were show in Table I. For the mixing processes of each developed growing media, the filter cake and bagasse ash were mixed, pressed at 47.8 MPa, shaped to 4, 8, 12 mm and dried the developed growing media aggregate at 105±5 °C and 24 hours in oven [16]. The samples of developed growing media aggregate were showed in Fig. 3.

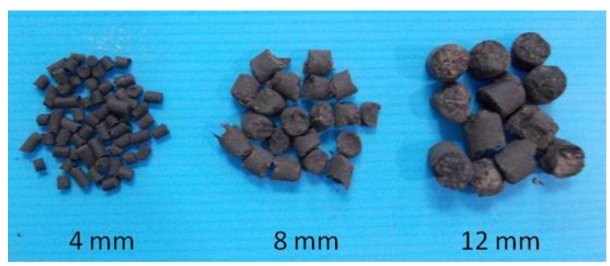

Figure 3 The aggregate sample of growing media from filter cake and bagasse ash

TABLE I Mixing Ratios of Filter Cake and Bagasse Ash for Developed Growing Media

Ratios	Filter Cake (kg)	Bagasse Ash (kg)
5 : 1	5	1
4 : 1	4	1
3 : 1	3	1
2 : 1	2	1
1 : 1	1	1
1 : 2	1	2
1 : 3	1	3
1 : 4	1	4
1 : 5	1	5

TABLE II HEAVY METALS IN FILTER CAKE AND BAGASSE ASH FROM SUGAR INDUSTRY

Heavy Metals	DIW Standard* (mg/kg)	Filter Cake (mg/kg)	Bagasse Ash (mg/kg)
Silver (Ag)	500	0.01	ND**
Arsenic (As)	500	20.36	10.94
Boron (B)	10,000	0.51	0.10
Barium (Ba)	75	1.385	0.10
Cadmium (Cd)	100	ND**	ND**
Chromium (Cr)	2500	0.05	0.02
Copper (Cu)	2500	0.05	0.01
Nickel (Ni)	2000	0.57	0.01
Lead (Pb)	1000	0.95	0.01
Thallium (Tl)	700	0.03	ND**
Zinc (Zn)	5000	30.85	10.06

* Notification of Department of Industrial Works, Ministry of Industry

**Non-Detected (ND)

TABLE III THE PERCENTAGE OF STABILITY OF GROWING MEDIA UNDER DIFFERENT MIXING RATIO AND DIAMETER SIZE

Mixing Ratio	% of Stability of growing media		
	4 mm	8 mm	12 mm
5 : 1	95.26 ab	98.23 ab	97.11 a
4 : 1	93.16 ab	94.35 ab	95.74 a
3 : 1	92.83 ab	94.20 ab	94.26 a
2 : 1	91.86 a	93.99 a	92.22 a
1 : 1	90.44 a	89.48 b	87.89 b
1 : 2	68.56 b	75.55 c	56.45 c
1 : 3	40.08 c	19.77 d	32.71
1 : 4	19.63 d	3.16 e	2.48 e
1 : 5	0.84 e	0.00 e	0.00 e

Means with different letters indicate significant differences among columns for each sample ($p < 0.01$).

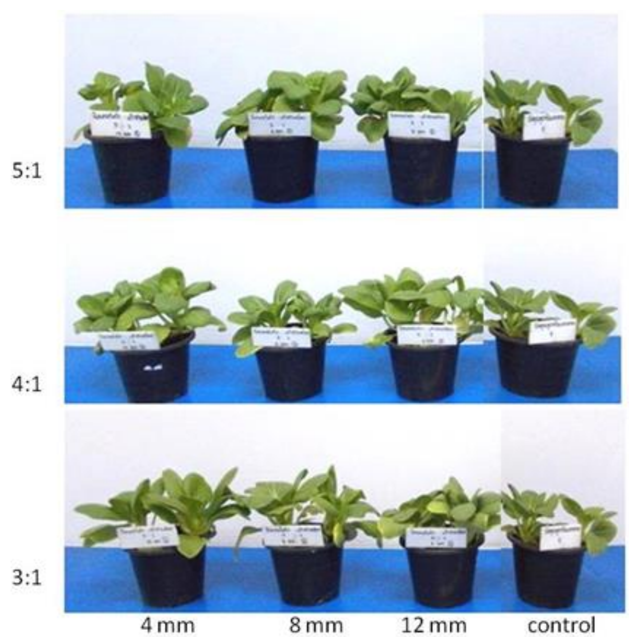

Figure 4 Chinese cabbage at 45 day in the different optimal mixing conditions and diameter shapes

D. Determination of optimal mixing condition of developed growing media from filter cake and bagasse ash by physical properties

All samples of growing media were tested the stability property [20, 25] for selection of three optimal ratios, after that, three optimal ratios were determined on bulk density [25, 26] air-filled porosity [26], water containing capacity [27], and total porosity [21]. The objective of the physical property testing of developed growing media were to study the relationship of the different diameter size of growing media and effect of waste characteristic on diameter size of growing media. Each ratios were tested in triplicate and analyzed by the Pearson Product Moment Correlation Coefficient with SPSS [16].

E. Determination of optimal mixing condition of developed growing media from sugar industrial waste by the growth condition of Chinese cabbage (Brassica rapa L.)

The Chinese cabbage seeds and plants soil were obtained from the local agricultural shop in Phitsanulok Province, Thailand. The selected seeds were soaked in deionized water for 2 hours and sown in plastic pots, which were filled with three optimal mixing conditions and three sizes at 4, 8, 12 mm. of developed growing media from filter cake and bagasse ash. Plant soil were taken as the control. Nine experimental plastic pots and three control plastic pots were prepared and three Chinese cabbage seeds were sown and watered with deionized water during experimental time. All Chinese cabbage samples at 45 days were shown in Fig. 4.

They were measured on the length of shoot and root, and were weighted on fresh weight and dry weight after oven at 105±5 °C and 24 hours. The study of growth condition of Chinese cabbage by using of the developed growing media considered on impact of three mixing ratios, linked to the size of growing medium. The relationship of growing medium mixing ratios and diameter size were determined the effect on the length of Chinese cabbage's shoots and roots. The yield production results were estimated from wet weight and dry weight of Chinese cabbage.

TABLE V EFFECT OF MIXING RATIO AND DIAMETER SIZE OF GROWING MEDIA AGGREGATE ON GROWTH OF CHINESE CABBAGE (45 DAY)

Mixing ratio	Diameter size(mm)	Fresh weight (g/plant)			Dry weight (g/plant)		
		Shoot	Root	Total	Shoot	Root	Total
5:1	4	54.96 ab	2.51 b	57.47 ab	3.41ab	0.32 ab	3.73ab
	8	31.79 d	2.00 b	33.79 d	2.08b	0.28 ab	2.36 b
	12	23.18 e	0.33 b	23.51 e	1.76c	0.15 c	1.90 c
4:1	4	68.50 a	4.89 a	73.39 a	4.95a	0.48 a	5.44a
	8	44.28 cd	1.72 b	46.00 c	3.34ab	0.24 b	3.58c ab
	12	33.67 d	1.58 b	35.35 cd	2.11b	0.27 ab	2.38d b
3:1	4	50.64 b	1.78 b	52.42 b	3.34ab	0.26 ab	3.60 ab
	8	64.21 ab	1.76 b	65.97 ab	4.16ab	0.31 ab	4.47ab
	12	38.17 cdef	1.83 b	40.00 cdef	2.60 b	0.35 ab	2.95 b
F-test		**	**	**	**	**	**

ns meannone of these differences were statistically significant at P<0.01

* mean these differences were statistically significant at P<0.05

** mean these differences were statistically significant at P<0.01or Means in the same column followed by a common letter are not significantly different at P<0.01

III. RESULTS AND DISCISSION

A. Heavy metals analysis of sugar industrial wastes

The filter cake and Bagasse ash were collected from Phitsanulok Sugar Industry Limited Company, Phitsanulok Province, Thailand. The chemical compositions of these wastes were given in Table II. The objective of this testing was to classify type of hazardous waste by the Department of Industrial Works (DIW), Thailand. Department of Industrial Works set the contents of heavy metals in these wastes as the important parameters for identification of hazardous waste (DIW, 2005). Heavy metal contents of filter cake and bagasse ash were low concentrations and they were lower than DIW standard. The Arsenic contents were maximum concentrations in both filter cake and bagasse ash at 20.36 mg/kg and 10.94 mg/kg, sequentially. Cadmium was non-detected in filter cake; while, Silver, Cadmium, and Thallium was non-detected in Bagasse ash. The results of Zinc content in filter cake and Baggase ash were similar to Meunchang *et al.* [17]. These results can have concluded that the filter cake and Bagasse ash were classified as non-hazardous waste, they were being potential for developing to product which relevant to the agricultural production such as fertilizer, soil conditioner, and growing media [17].

B. Optimal mixing condition of developed growing media from filter cake and bagasse ash by physical properties

1) Effect of mixing condition of developed growing media from filter cake and bagasse ash on stability

The results of the stability of the developed growing media were found over than 90% in 4 mm, 8 mm and 12 mm when the amount of filter cake were higher than the amount of bagasse ash. The increasing of bagasse ash had the direct impact on the stability of developed growing media aggregate. Table III were explained that the developed growing media cannot form to aggregate at the mixing ratio of 1:2, 1:2, 1:3, 1: 4, and 1:5. The percentage of stability was dropped when the amount of bagasse ash decreased. They were found that the stability of growing media aggregate from mixing ratio (filter cake and bagasse ash) and diameter size was significant difference. The high amount of filter cake in mixing conditions was better than the high amount of bagasse ash. It possibility that a filter cake may be has lignin, the thermal softening of lignin and the subsequent flow and polymer interpenetration with adjacent biomass particle in a pellet result in the formation of bonds and strong inter particle adhesion [28]. The interesting ratios were considered on 5:1, 4:1, and 3:1 with a significant difference. It concluded that three selected mixing ratios of growing media aggregate were 5:1, 4:1, and 3:1 in all diameter (4 mm, 8 mm, and 12 mm). Growing media must be consistent quality in the meat of the plant material, stability or a slight change or less with the collapse of the plant material or a life long enough to crops for the first time a consistent structure for the growth of plants [22].

2) Effect of mixing condition of developed growing media from filter cake and bagasse ash on bulk density, total porosity, air filled porosity, and water containing capacity

TABLE IV Effect of The Selected Mixing Condition of Developed Growing Media on Bulk Density, Total Porosity, Air-Filled Porosity and Water Containing Capacity

Mixing ratio	Diameter size (mm)	Physical properties of growing media			
		Bulk density (g/cm^3)	Total porosity (%Vol)	Air-Filled Porosity (%Vol)	Water containing capacity (%Vol)
5:1	4	0.33	42.24 c	24.97 a	17.26b
	8	0.26	45.24 c	25.39 a	19.84b
	12	0.26	41.17 c	23.73 a	17.45b
4:1	4	0.29	52.96 b	25.10 a	27.87a
	8	0.27	50.74 b	19.36 b	31.24a
	12	0.24	59.96 a	24.90 a	35.06a
3:1	4	0.30	42.80 c	25.64 a	17.16b
	8	0.27	32.08 d	14.26 c	17.82b
	12	0.22	44.26 c	24.67 a	19.65b
F-test		ns	**	**	**

ns meannone of these differences were statistically significant at P<0.01

** mean these differences were statistically significant at P<0.01 or Means with different letters indicate significant differences among columns for each sample (p < 0.01).

According to stability test of the developed growing media, three ratios (5:1, 4:1, and 3:1) were analyzed physical properties including bulk density, total porosity, air-filled porosity (AFP) and water containing capacity (WCC). All results were reported in Table VI. It found that the physical properties vary on a mixing ratio and diameter size of growing media aggregate. There was no significant difference in bulk density between a mixing ratio and diameter size of growing media, 0.22- 0.33 g/cm^3. However, there was correlation between other parameters (total porosity, air-filled porosity, and water containing capacity) and the mixing ratio and diameter size of growing media.

The specification of "ideal growing media" were indicated on 80-85% of porosity, 20-30% of air-filled porosity, and 4-10% of water containing capacity by De Boodt and Verdonck in 1972. None of ideal growing media developed in this research but the developed growing media that approaches inside that ideal growing media was in the selected mixing ratio at 4:1 with 4 mm of growing media's diameter.

It can determine the volume % of air-filled porosity and volume of water containing capacity of the different growing media aggregate. Gas relative diffusivity was shown to reach maximum value with the 2-4 mm sizes and to rapidly diminish as fragment sizes were increased from 4 to 20 mm or decreased to 1-2 mm. [29]. The main advantage of growing media over soil-cultivations, however, its physical characteristics and specifically, its ability to provide simultaneously sufficient levels of both oxygen and water to the roots [30]. The different plant need the different air-filled porosity requirements and that frequent irrigation can override any benefits of good air-filled porosity [27]. It can conclude that, there is a difference in physical properties of mixing ratio and diameter size of all developed growing media. There are increase air-filled porosity and which decrease water containing capacity. The composition of a growing media depends on the culture technique, kind of plant and other factors but they can make a standardized mixing ratio and diameter size of growing media aggregate [31].

C. Optimal mixing condition of developed growing media from sugar industrial waste by the growth condition of Chinese cabbage (Brassica rapa L.)

All growing media in experiment proved to be good enough to give satisfying final plant product. Plants were most fresh and dry weight, when they were grown in the growing media at the mixing ratio 4:1 and diameter size 4 mm (Table V). The lowest fresh and dry weight was, when plant was grown in the growing media at the mixing ratio 5:1 and diameter size 12 mm. It was revealed that the different materials used as medium by hydroponics vegetable affected on root fresh weight, root length and trunk fresh weight [32]. Plant bioassay for substrates is suitable for routine testing. The growth of Chinese cabbage (Brassica rapa L.) are more responsive to poor-quality peat media [33]. The influence of mixing ratio and diameter size of growing media on the plant growth is connected with their physical properties. The growing media aggregate of mixing ratio 4:1 and diameter size 4 mm was nearly level of the air-filled porosity (25.10 % by Volume) and the water containing capacity (27.87 % by Volume), which optimum of plant growth. The most effect can see in case of root weight. A generally acceptable air-filled porosity level for is >13%. However, the high percentage of air-filled porosity can optimize air supply to the root, it can compromise the percentage of water holding capacity and therefore the ability of growing media to retain sufficient available water to plant growth. [34]. Gas relative diffusivity was shown to reach maximum value with the 2-4 mm sizes and to rapidly diminish as fragment sizes were increased from 4 to 20 mm or decreased to 1-2 mm. root growth parameters were significantly and positively correlated to gas relative diffusivity but showed no correlation with air filled porosity [35]. The main advantage of growing media over soil-cultivation is, however, its physical characteristics and specifically, its ability to provide simultaneously sufficient levels of both oxygen and water to the roots [30].

IV. Conclusion

From these findings, they were found to be feasible to development of growing media form sugar industrial waste. Sugar industrial waste, filter cake and bagasse ash can be develop into growing media.

- The mixing ration and diameter size of growing media aggregate influence on aggregate stability. The optimal mixing ratio was 5:1, 4:1, and 3:1, diameter size was 4, 8, and 12 mm.
- There was a difference in physical properties of mixing ratio and diameter size of growing media aggregate. The composition of a growing media depends on the culture

technique, kind of plant and other factors but they can make a standardized mixing ratio and diameter size of growing media aggregate**.**

- The growing media form mixing ratio 4:1 and diameter size 4 mm. was suitable for plant growth.

In summary, Sugar industrial waste, filter cake and bagasse ash had a good potential of being used as a plant growth substrate. It can be application for development of plant growth substrates or growing media as growing media aggregate products.

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Pusit Asadathorn
Ph.D Student at Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University, Chiang Mai, Thailand

Worajit Setthapun
Dean at Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University, Chiang Mai, Thailand

Wattanapong Rakwichian

Assoc. Prof. Dr. at School of Energy and Environment, University of Phayao, Phayao, Thailand

Thassanupan Kusolsatit

Assistant Prof. Dr. at Faculty of Agricultural, Nakhon Sawan Rajabhat University, Nakhon Sawan, Thailand