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THE INNOVATIVE PRODUCTION OF SUGARCANE JUICE CLARIFICATION MATERIALS FROM SUGAR INDUSTRY BY-PRODUCTS

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ABSTRACT

The clarification process of sugarcane juice is the process for removal of impurities to obtain clarified sugar with high quality. Clarification materials are added to enhance the efficiency and yield of the clarification process. The objective of this research is synthesis of clarification materials by using bagasse ash as a starting material and study the optimum conditions for sugarcane juice clarification process. The bagasse ash consists of silicon dioxide, calcium oxide and aluminum oxide as main components. The test results of scanning electron microscope (SEM) showed that clarification materials prepared from bagasse ash showed spherical structure with several pores on the surface. The clarification process efficiency shows that clarification materials prepared from bagasse bottom ash was effective in color removal of 97.78% and 89.41% for sugarcane juice and sugar solution, respectively. In addition, it also increases the brix content. The optimum dosage of clarification materials is 6 grams in 100 ml of sugar solution.

Keywords: Sugarcane Juice, Bagasse ash, Clarification process, Sugar Industry.

INTRODUCTION

Sugarcane is one of Thailand's major agricultural crops which is the main raw material in the sugar industry. A major concern of the sugar industry is the presence of impurities in sugarcane juice including pigments, flavonoids, phenolic acids, and organic acids which contribute to dark brown color of juice and impact both the final product's quality and the accuracy of quality control analysis [1]. The composition of these complex impurities varies based on factors such as cane species, climate, harvest, and storage method [2]. To produce clear syrup and high quality of sugar, it is essential to remove these impurities. Therefore, a clarification process is necessary to reduce impurities particles and color in sugarcane juice before sugar production [3].

Sugarcane juice clarification is the process for removal of suspended and non-sucrose impurities such as minerals and proteins to obtain clarified sugarcane juice with high purity. The clarification process occurs through coagulation, flocculation, and precipitation of colloids and pigmented substances. These impurities are subsequently removed by decanting and filtration [4]. An effective clarification process leads to high-quality sugar and increased sugar yield.

Clarification materials and clarification aids are added to enhance the efficiency and yield of the clarification process. It can make a substantial contribution to the removal of impurities. Clarification materials that are widely used include: clay, activated carbon, bentonite, polyelectrolytes, and magnesium oxide. [4-5]. The efficiency of the clarification materials is controlled by the properties of materials, molecular size, ionic charge, and hydrophobicity [6].

However, in the sugar cane industry, sugarcane juice is primarily processed to produce sugar, resulting in various key by-products from manufacture such as bagasse, molasses, filter muds and bagasse ash. Several byproducts have the potential to serve as feedstock to produce platform chemicals and industrial products. For example, bagasse residue from sugar cane after sugar milling process can be utilized as fuel in sugar boilers to generate steam and electricity, fulfilling the factory's energy requirements. Furthermore, in a few studies, bagasse residue is a promising raw material for color removal adsorbents production. [7] The objective of this research was to utilize bagasse ash as a starting material for sugarcane juice clarification materials production and study the optimum conditions for sugarcane juice clarification process.

EXPERIMENTAL

A. Sugarcane Juice

Sugarcane juice was obtained from sugar factory production in Nakhon Sawan province, Thailand during the period of normal processing operations, then it was kept frozen at -18 ºC. The frozen sugarcane juice was thawed at room temperature about 30 ºC before the experiments.

B. Materials

Bagasse ash was obtained from sugar factory production in Saraburi province, Thailand. All chemicals, sodium hydroxide (NaOH) was purchased from KEMAUS, hydrochloric acid (HCl) from RCI labscan limited, ferric chloride ($FeCl_3$) from LOBA CHEMIE PVT. LTD., natural clay, natural zeolite, aluminum chloride and sodium bicarbonate ($NaHCO_3$) from KEMAUS. All reagents were used AR grade without further purification.

C. Synthesis of clarification materials

(Method I; SS, SG, BF)

The starting raw materials (natural clay, bagasse fly ash and bagasse bottom ash) were grinded into powder and mixed with natural zeolite, aluminum chloride and ferric chloride (mol ratio as shown in Table 1) and fused at 500-600 ºC for 1 hour. The solid form of fused product was added into DI water at 60 ºC, stirred for 30 min. The obtained product was activated at 80 ºC for 1 hour by hydrothermal treatment. The solid was filtered using Whatman NO.42 and dried in hot air oven at 105 ºC for 24 hours. The obtained product of clarification materials characterization by Energy Dispersive X-Ray Spectrometer (EDX) and Scanning Electron Microscope (SEM).

D. Synthesis of clarification materials Type II

(Method II; AF)

The starting raw materials (bagasse bottom ash) were grinded into powder and mixed with natural zeolite, aluminum chloride and ferric chloride (mol ratio as shown in Table I) and fused at 500-600 ºC for 1 hour. The 50%w/v solution form of fused product was stirred at 80 ºC for 1 hour. The obtained product was activated at 80 ºC for 30 min and 30 ºC for 1 hour by hydrothermal treatment. The solid was filtered using whatman NO.42 and dried in hot air oven at 105 ºC for 24 hours. The obtained product of clarification materials characterization by Energy Dispersive X-Ray Spectrometer (EDX) and Scanning Electron Microscope (SEM).

Table I: Mol ratio of various clarification materials

Clarification materials	Starting raw materials	Fe:OH	Al:OH
SS	Natural clay	3.28	25.64
SG	Bagasse fly ash	2.61	4.81
BF	Bagasse Bottom ash	3.32	4.78
AF	Bagasse Bottom ash	3.32	4.78

E. Experimental Procedure

The clarification process was carried out in batch reaction using mini-Jar Test apparatus for investigation of physicochemical treatment. This research studies the optimum dosage of clarification materials (2-10 gram) on clarification efficiency (Brix and ICUMSA) by adjusting the pH of the sugarcane juice with sodium bicarbonate ($NaHCO_3$). The experimental process was rapid mixing at 200 rpm for 15 minutes and sedimentation for 30 min. The sample was collected and subjected to various analyses by Atago Digital Hand-held Pocket Refractometer for brix content and ICUMSA Method GS1/3-7(2002) for color removal efficiencies.

RESULTS AND DISCUSSION

A. Characteristic of clarification materials.

This research has prepared 4 types of clarification materials with difference starting material: natural clay, bagasse fly ash, bagasse bottom ash with method I and bagasse bottom ash with method II which called as SS, SG BF and

AF, respectively. Chemical analysis of bagasse ash using X-Ray Fluorescence Spectroscopy (XRFS) has been conducted to estimate the chemical composition. It was found that both fly bagasse ash and bottom bagasse ash consists of silicon dioxide, calcium oxide and aluminum oxide as main components.

Table II. Chemical analysis of bagasse ash by XRFs

Composition	**Chemical Content (Wt.%)**	
	Fly ash	**Bottom ash**
SiO_2	58.00	58.00
CaO	14.60	16.70
Al_2O_3	12.70	11.90
Fe_2O_3	6.77	6.20
K_2O	2.18	2.00
MgO	2.07	1.75
P_2O_5	1.60	1.29

Table III. Chemical analysis of clarification materials by EDX

Composition	**Chemical Content (Wt.%)**		
	SG	**BF**	**AF**
C	18.8	14.50	23.05
O	39.86	44.62	38.05
Al	10.72	19.72	15.78
Si	23.13	3.06	11.65
Cl	1.78	0.69	0.78
Ca	2.08	0.18	0.47
Fe	2.51	14.83	10.22
Cu	1.64	0.65	0.00

The mineral composition of clarification materials prepared from bagasse ash was analyzed by using Energy Dispersive X-ray Spectrometer (EDX). The finding demonstrates that clarification materials consist of aluminum, silicon, calcium and ferric.

The texture and morphology of clarification materials were studied by Scanning Electron Microscope (SEM) as shown in Fig.1. The clarification materials exhibit a mixed geometric shape with unshaped crystals. The clarification materials synthesis from bagasse bottom ash with method II shown spherical structure with several pores on the surface as seen in Fig.1 (D).

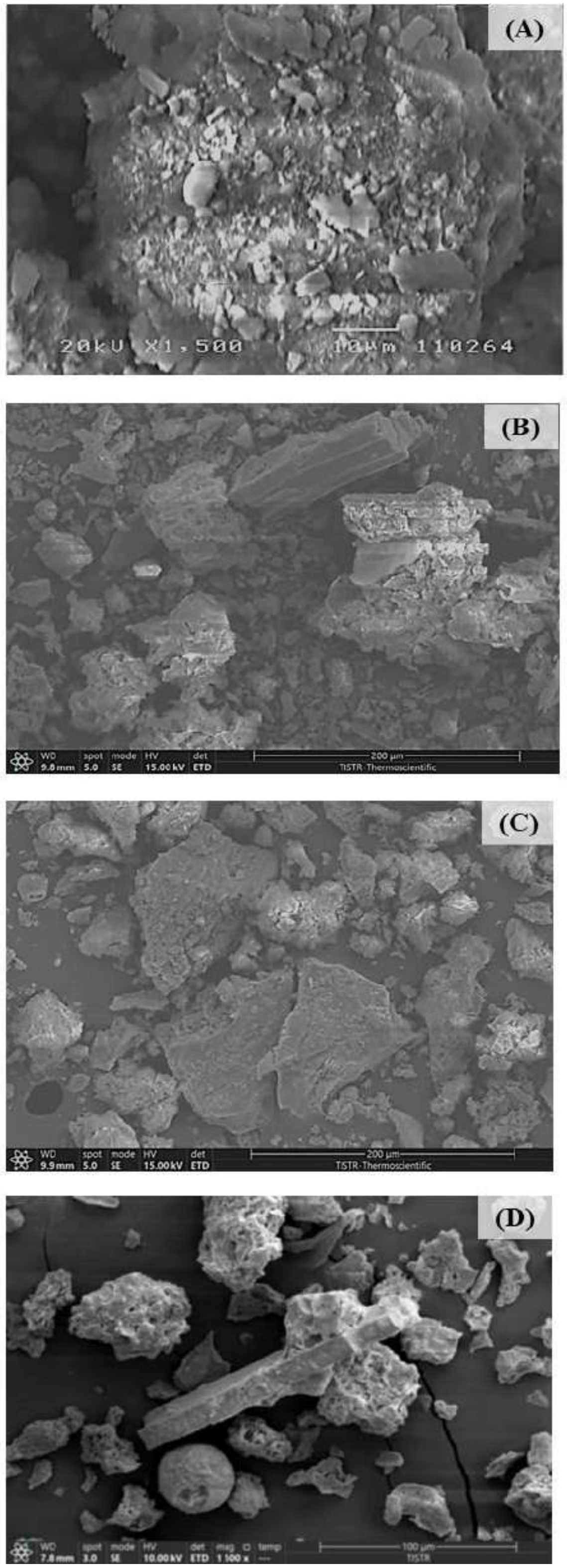

Fig.1. SEM images of clarification materials synthesis from natural clay (A), bagasse fly ash (B), bagasse bottom ash with method I (C) and bagasse bottom ash with method II (D).

B. Clarification Process of Sugarcane Juice

The dark brown sugarcane juice before and after pH adjust with sodium bicarbonate ($NaHCO_3$). was analyses for brix content and color in ICUMSA unit, results shown in Table IV. The results showed that the brix content and color of sugarcane juice after pH adjust is higher than raw sugarcane juice.

Table IV. Properties of sugarcane juice before and after pH adjust with sodium bicarbonate.

Parameter	Sugarcane juice	
	Before pH adjust	After pH adjust
Brix	13.1	14.5
Color (ICUMSA)	5,104.64	9,330.75

The result of clarification process with various clarification materials and polyaluminum chloride (PAC) as clarification aid shown in Table V and Fig.2. The color of sugarcane juice in ICUMSA unit decreased while brix content was higher. The result shown that clarification materials synthesis from bagasse bottom ash with method II (AF) is the most effective.

Table V. The Clarification performance of sugarcane juice with various clarification materials with PAC as clarification aid

Clarification materials	Parameter	
	Brix	Color (ICUMSA)
Raw sugarcane juice	14.5	9,330.75
SS + PAC	23.2	224.65
SG + PAC	24.2	343.33
BF + PAC	23.1	281.79
AF + PAC	23.3	217.15

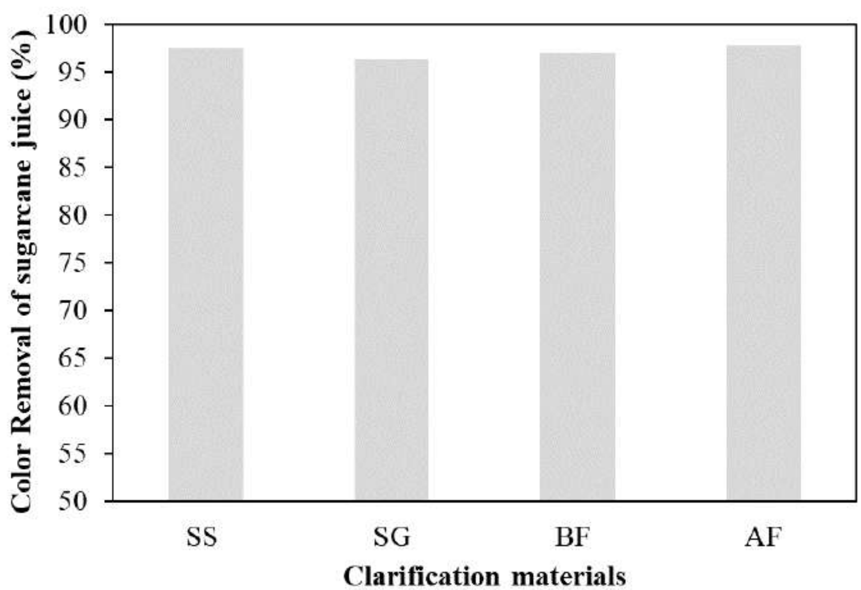

Fig.2. Color removal of sugarcane juice with various clarification materials

C. Clarification Process of Sugar Solution

This research studied the clarification process of sugar solution by using 30%W/V of sugar solution prepared from raw sugar. The clarification performance efficiency of various clarification materials without clarification aid is shown in Table VI and Fig.3.

Table VI. The clarification performance of sugar solution with various clarification materials without clarification aid

Clarification materials	Parameter	
	Brix	Color (ICUMSA)
Raw sugar solution	30.9	1,025.48
SS	29.9	223.89
SG	29.0	359.47
BF	29.7	238.10
AF	29.5	108.62

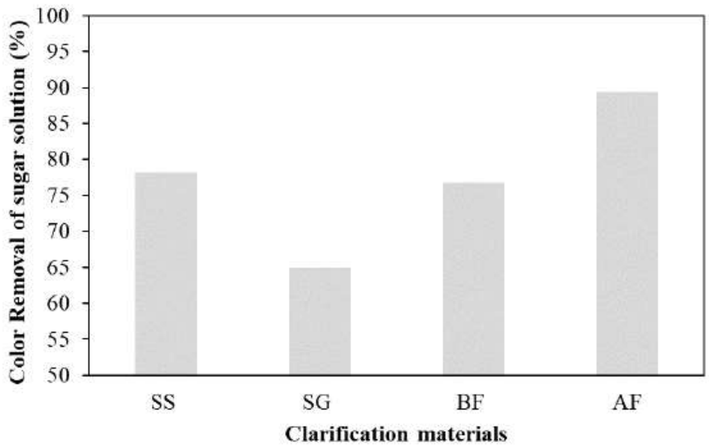

Fig.3. Color removal of sugar solution with various clarification materials

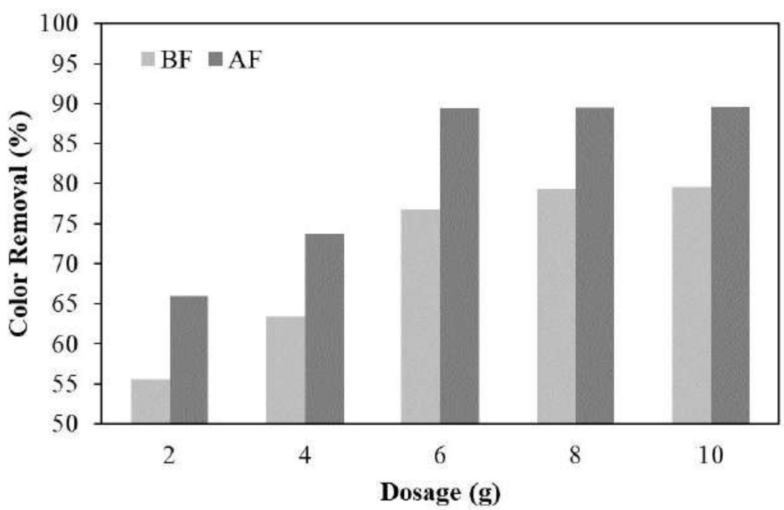

Fig.4. The effect of various clarification materials dosage on color removal.

The results found that all clarification materials showed lower color and higher brix content. The clarification materials synthesis from bagasse bottom ash with method II (AF) showed highest performance efficiency on clarification process of sugar solution.

In the batch experimental study, the optimum dosage of clarification materials was applied for 100 ml of sugar solution. The optimum dosage of clarification materials both BF and AF is 6 grams which show the high performance on Fig. 4.

In addition, the clarification efficiency comparison between clarification materials synthesis from bagasse bottom ash with method II (AF) and commercial clarification materials (lime and alum) was studied, the result shown in Table VII and Fig.5. The results found that clarification materials synthesis from bagasse bottom ash with method II (AF) is more effective in color removal than commercial clarification materials.

Table VII. The clarification performance of sugar solution with various clarification materials

Clarification materials	Parameter	
	Brix	Color (ICUMSA)
Raw sugar solution	30.9	1,025.48
AF	29.5	108.62
Lime	37.4	591.62
Alum	31.6	252.63

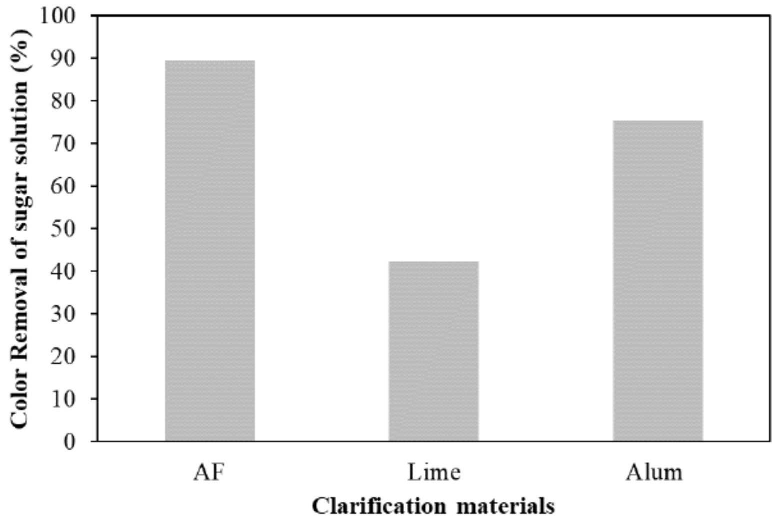

Fig.5. The clarification efficiency comparison on color removal.

CONCLUSION

The result from XRFs indicated that both fly ash and bottom ash consists of silicon dioxide, calcium oxide and aluminum oxide as main components. The natural clay, bagasse fly ash and bagasse bottom ash were used as starting raw materials to synthesis clarification materials. The result from EDX and SEM indicated that clarification materials consist of aluminum, silicon, calcium and ferric as a main component and exhibit a mixed geometric shape with several pores on the surface. The performance efficiency of clarification process with various clarification materials shows that the optimum clarification materials is AF which prepared from bagasse bottom ash with method II. The AF clarification materials show color removal of 97.78% and 89.41% for sugarcane juice and sugar solution, respectively. The optimum dosage of clarification materials is 6 grams in 100 ml of sugar solution.

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