Reclamation of Waste Kaolin in Palm Oil Mill

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Abstract

Kaolin slurry with specific gravity of 1.12-1.14 is normally used for separation of palm kernel and palm shell in palm oil milling process. Oil and other contaminants occurred during the separation were anticipated to affect on the specific gravity of kaolin, thus decreased the separation capability. Consequently, new batch of virgin slurry is needed. To reduce the kaolin cost, a method to reclaim the spent kaolin is needed. In laboratory study, treatment by hot water (50, 70, 90 and 100ºC) and by alkaline (1% NaOH) (0.5, 1.0, 2.0 and 2.5 M). It was found that treatment by hot water at 100ºC and 1% NaOH of 2.5 M, the spent kaolin regained its specific gravity at 1.50 and 2.59, respectively. Therefore, the reclaimed kaolin had the specific gravity equal to that of the virgin kaolin (2.6). There is no significant difference in the range of NaOH concentrations tested, thus the 1.5 M NaOH was selected for the industrial application. The reclaimed kaolin had the specific gravity of 2.57 while its slurry had the specific gravity of 1.14. It could separate 95% of palm kernel with only 1.5% palm shell contaminated. Comparison of the composition of reclaimed kaolin and virgin kaolin revealed that their composition were slightly difference in some major components. The percentage of Al_2O_3 and SiO_2, were decreased while that of K_2O and CaO were increased. Economic analysis indicated an attractive return worth for kaolin reconditioning investment.

Keywords : kaolin, specific gravity, NaOH, reclamation, palm oil mill

Introducton

In the palm oil milling process the kernel palm oil (KPO) is produced separately. The palm kernel was obtained after the nuts are cracked in the ripple mill and separated from the shell by heavy media separation (HMS) principle. The specific gravities of oil palm shell and kernel are 1.44 and 1.14, respectively. The slurry of kaolin with specific gravity of 1.14 is normally used as the separation media. The slurry is the mixture of kaolin (specific gravity 2.6) and water at ratio of 230g/l. Loss of kaolin in the process (carried out by the shell and kernel) together with dust contamination reduce the specific gravity, which regularly compensates by adding fresh kaolin. However, after approximately one week, the odor suggested that the whole batch of the slurry should be discharged due to oil (from the kernel) contamination. A palm oil mill with a capacity of 45 ton of fresh fruit bunch per hour usually spends 112,500 Baht (3,750 USD) per month for the kaolin.

Akinwande et al. (2014) investigated thesuitability of alkaline activated clays on vegetable oil refining, a case study of Shea butter. The authors discovered that alkaline activation had significant effect on the structure, morphology and adsorptive power of the clay. The result indicated that alkaline concentration required to achieve maximum bleaching power is 0.5 M and 5 M for NaOH and KOH respectively. The percentage free fatty acid content of the Shea oil was reduced by 65% and 75% for oil bleached with NaOH activated clays and KOH activated clays respectively. Okwara and Osoka (2006) studied the influence of caustic activation of Nigerian local clays on palm oil bleaching. Their findings indicated that the adsorption capacity for bleaching earth increased up to 79% at the optimum concentration of 1.0 N NaOH.

This paper reports the reconditioning the spent kaolin by NaOH compared to hot water in laboratory scale. Economic analysis is also presented.

Materials and Methods

Recondition of spent kaolin by hot water method

The spent kaolin slurry was taken from Asian Palm Oil Mill, Krabi, Thailand. The sample was sieved by a 40 mesh screen to remove palm kernel and shell. The slurry was added into the 1 L cylinder and recorded the precipitation rate every 15 min until constant volume of spent kaolin was obtained. After discarding the clear solution, the spent kaolin was weighed (wet weight), then divided into 2 parts. The first part was dried at 100ºC till constant weight (used as a control). The second part was washed with hot water at 50, 70, 90 and 100 ºC using 1:1 ratio, mixed by placing on 200 rpm shaker for 10 min and allowed precipitation to occur. The wet spent kaolin samples were taken to determine for moisture content (dried at 100ºC), specific gravity (Thongton and Boonlom, 1990), % yield, and chemical composition. The amount of reconditioned kaolin for preparation of slurry with required specific gravity (compared to the amount of virgin kaolin used). The appearance of reconditioned kaolin of every treatment was recorded.

Recondition of spent kaolin by alkaline method

The spent kaolin slurry was taken from Asian Palm Oil Mill, Krabi, Thailand. The sample was sieved by a 40 mesh screen to remove palm kernel and shell. The reconditioning consists of the following processes, add 1% (v/v) of NaOH (0.5, 1.0, 1.5, 2.0, 2.5 M), stir well, separate for the sediment (after 6 hour setting) to be dried (100ºC, 12 h). The dried sample was determined for percentage yield, specific gravity, chemical compositions and the possibility of reuse.

Analytical Method

Specific gravity of the kaolin was determined using a pycnometer analysis as described by Thongton and Boonlom (1990) while the specific gravity of the shell and a kernel the palm were analyzed using instead of water method following Sukapong Sirinupong (2001). Chemical composition of the kaolin; MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, Fe_2O_3, Rb, SrO, Cl, Na_2O, P_2O_5 and SO_3, were determined using X-ray fluorescence spectrometer.

Results and Discussion

Recondition of spent kaolin by hot water

Recondition of spent kaolin using hot water at various temperatures (50-100°C) indicated that temperature at 100°C gave the highest specific gravity (1.50) and yield (83%). To prepare the kaolin slurry with specific gravity of 1.14, 527 g/L of reconditioned kaolin was required which was 2.2 times higher than that used by the virgin kaolin (230 g/L) (Table 1). Using temperature at 50, 70 and 90°C gave the specific gravity of 1.30, 1.35 and 1.40, respectively, with the reconditioned kaolin quantity of 994, 797 and 674 g/L, respectively, used for preparation of slurry with specific activity of 1.14. The sedimentation of spent kaolin took about 6 h and required 12 h to dry. While the virgin kaolin was white (Figure 1A), the spent kaolin had grey color (Figure 1B). Reconditioning with the hot water at 50 and 70°C, the kaolin showed dark gray (Figure 1C and 1D) while those at 90 and 100°C treatment gave light gray (Figure 1E and 1F). The specific gravity values of virgin kaolin (2.60) was 1.6 times higher than that of the reconditioned kaolin at 100°C treatment (1.50). This was due to the fact that high temperature (hot water at 100°C) could change only the the physical property of the kaolin that affected the liquid limit (L.L.) of the kaolin. This resulted in the increase of its strength (Ingles and Metcalf, 1972). Therefore, recondition by hot water was inappropriate and chemical reconditioning would be tested.

Table 1 Effect of hot water temperature on stabilization of spent kaolin.

Treatment	Characteristic of kaolin	Yield (%)	pH	Moisture (%)	Specific gravity	Kaolin required (g/L)
Pure kaolin	no smell, creamy color	100	7.8	88.55	2.60^{E}	230^{A}
No wash hot water	rancid, grey	75	6.5	45.83	1.20^{A}	2230^{E}
Hot water 50°C	rancid, dark grey	81	7.2	61.50	1.30^{B}	994^{D}
Hot water 70°C	rancid, dark grey	78	7.4	56.05	1.35^{B}	797^{D}
Hot water 90°C	rancid, light grey	79	6.8	49.91	1.40^{C}	674^{C}
Hot water 100°C	no smell, light grey	83	7.1	88.22	1.50^{D}	527^{B}

^{A,B,C,D,E} = Means within a column with the same lowercase superscript letter are not signifi cantly different ($P < 0.05$).

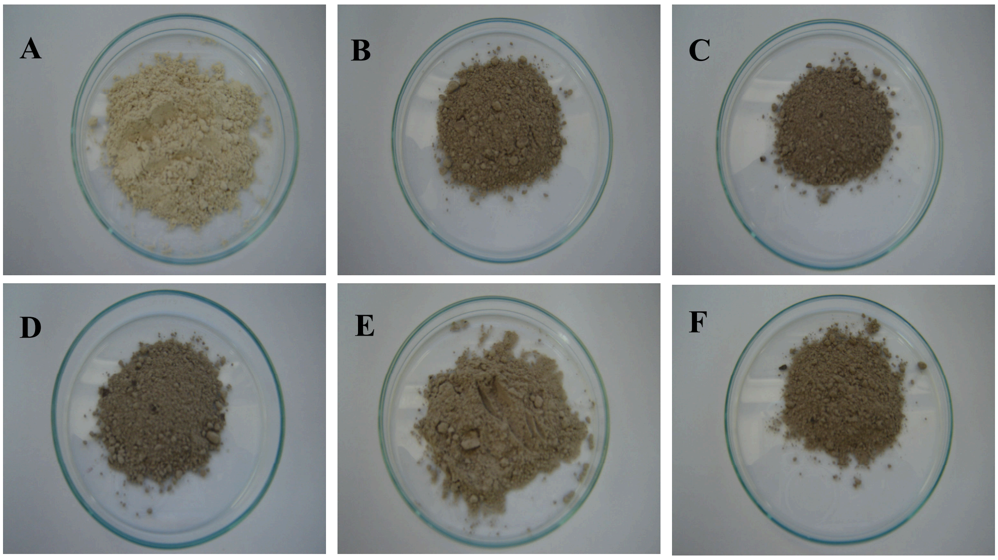

Fig.1 Effect of temperature on characteristic of pure kaolin (A), spent kaolin (B), kaolin reconditioned at 50^{o}C (C), kaolin reconditioned at 70^{o}C (D), kaolin reconditioned at 90^{o}C (E), and kaolin reconditioned at 100^{o}C (F).

Recondition of spent kaolin by alkaline method

Table 2 gives results of NaOH-treated kaolin. The NaOH concentrations of 0.5 M to 2.5 M, with the increment of 0.5 M were used. While the virgin kaolin was white (Figure 2A), the spent kaolin had grey color (Figure 2B). Reconditioning with the 1.0 and 1.5 M NaOH, the kaolin showed dark gray (Figure 2C and 2D) while those at 2.0 and 2.5 M NaOH treatment gave gray white (Figure 2E and 2F). The results showed that the higher concentration of NaOH resulted in higher specific gravity of the reconditioned kaolin. The optimum bleaching parameters (clay dose and bleaching time) for palm kernel oil were determined using alkaline activated clay locally sourced in Nigerian. Activation was carried out using NaOH and KOH. (Salawudeen et al, 2014)

The maximum specific gravity of the kaolin and percentage of yield were 2.59 and 87%, respectively. The pH is slightly less than the virgin kaolin.

In order to obtain the slurry of 1.14 specific gravity, a certain amount of the kaolin must be mixed with water. For one liter of water, 230 g of virgin kaolin is needed, while 232-234 g of the reconditioned kaolin is required (last column of Table 2). Statistical analysis revealed that there is no significant different ($p<0.5$) within NaOH concentrations of 1.5-2.5 M. Therefore, it is recommended that, for the minimum cost, the concentration of 1.5 M should be applied in the mill.

Table 2 Effects of NaOH concentration on reconditioning of used kaolin.

Treatment	Characteristic of kaolin	Yield (%)	pH	Moisture (%)	Specific gravity	Kaolin required (g/L)
Virgin kaolin	no smell, grey white	100	7.8	88.55	2.60 ^{B}	230 ^{A}
NaOH 0.5 M	rancid, grey	78	6.4	64.10	2.55 ^{A}	240 ^{B}
NaOH 1.0 M	rancid, dark grey	83	6.8	75.77	2.56 ^{A}	236 ^{B}
NaOH 1.5 M	no smell, dark grey	76	7.1	87.32	2.58 ^{B}	234 ^{A}
NaOH 2.0 M	no smell, grey white	87	7.3	87.43	2.58 ^{B}	234 ^{A}
NaOH 2.5 M	no smell, grey white	87	6.5	88.22	2.59 ^{B}	232 ^{A}

^{A,B} = Means within a column with the same lowercase superscript letter are not signifi cantly different (*P* < 0.05).

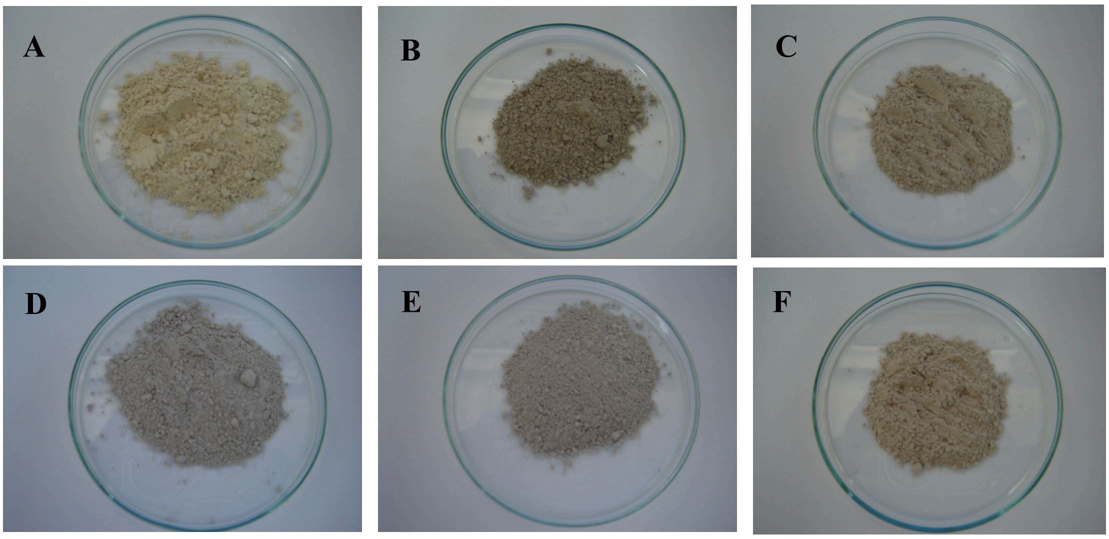

Fig.2 Effect of NaOH concentration on recondition of spent kaolin (A), 0.5 M (B), 1.0 M (C), 1.5 M (D), 2.0 M (E) and 2.5 M (F).

Composition of kaolin

Table 3 shows the compositions of virgin kaolin, spent kaolin and reconditioned kaolin (with 1.5 M NaOH). It is obvious that the spent kaolin was degraded in many compositions. The change of percentage of major compositions such as Al_2O_3 (15.63 to 12.75%), SiO_2 (73.05 to 56.98) and K_2O (2.43 to 0.37) is expected to be responsible for the decrease of the specific gravity. The loss of those compounds was explained by the shell-and-kernel carry-out. The presence of Cl (0.31%) and P_2O_5 (0.37%) might be the result of kernel and shell contamination. The treatment by NaOH altered the percentage of some compounds as was evidenced by the presence of Na_2O. The interaction of Na^+ has resulted in the increase of hardness of the reconditioned kaolin, and thus the specific gravity (Ingles and Metcalf, 1972).

Table 3 Composition of virgin kaolin, spent kaolin and reconditioned kaolin of Asian Palm Oil Co, Ltd.

Compounds	Chemical Composition (mass %)		
	Virgin kaolin	Spent kaolin	Reconditioned kaolin (with 1.5 M NaOH)
MgO	0.90	0.84	0.84
Al_2O_3	15.63	12.75	13.25
SiO_2	73.05	56.98	59.11
K_2O	2.43	0.37	4.09
CaO	0.81	1.26	1.59
TiO_2	0.34	0.29	0.39
Fe_2O_3	3.39	3.13	3.17
Rb	0.04	0.04	0.04
SrO	0.07	0.05	0.08
Cl	-	0.31	0.33
Na_2O	-	-	0.81
P_2O_5	-	0.37	0.28
SO_3	-	-	0.24

Economic assessment

The specific consumption of kaolin was found to be 3 kg/ton FFB. The Asian Palm oil mill process 200,000 ton FFB/year, which means consumption of 600,000 kg of kaolin. This amount represents a material cost of 1,800,000 Baht (60,000 USD) a year. The clay bath has capacity of 400 l, which contains about 92 kg of kaolin. With the recovering rate of 87% and NaOH market price is 125 Baht/kg, the recovering cost is 1 USD per 80 kg of reconditioned kaolin (solution of 1.5 M and 1% used costs 1 USD/batch of slurry). The economic analysis is presented in Table 4.

Table 4 Economic analysis of the reconditioning process.

Kaolin options	Kaolin condition	Kaolin used (kg/year)	Cost (Baht)
Business as Usual	Virgin	600,000	1,800,000
Investement in reconditioning	Reconditioned (87% yield)	522,000	208,800
	Virgin kaolin compensated	78,000	234,000
	Total		442,800
Saving per year			1,357,200

It is clear that the investment for kaolin reconditioning processs gives yearly return in term of (virgin) kaolin saving of 1,357,200 Baht (45,240 USD). As the reconditioning process is very simple, this saving can easily cover the investment cost within a month. In addition, the kaolin waste to be handled is significantly reduced to 78,000 kg per year (only 13% of the previous). However, it is not possible that the kaolin can be reconditioned for ever. Supposing that in the following cycle about 50% of the reconditioned kaolin must be removed from the process, the saving would now be 691,200 Baht/year, which is still very attractive.

Conclusions

The kaolin slurry has life limitation due to oil and dust contamination during shell and kernel separation. The dispose of the spent kaolin causes financial burden as well as pollution to be treated. The reclamation of the kaolin is achieved by alkaline (NaOH) treatment. A 1% of 1.5 M NaOH is sufficient to revitalize the spent kaolin. It was found that 87% of kaolin can be recovered for reused. Economic analysis showed that the reconditioning process is feasible.

Acknowledgments

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