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ARTIFICIAL PAPER FROM PUTTARAKSA *(CANNA INDICA* LINN) AND PLUBPLUENG (*CRINUM ASIATICUM*)

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ABSTRACT: Puttaraksa *(Canna indica*) and Plubplueng (*Crinum asiaticum*) are plants used for decorative landscaping. Their branches and leaves are cut and discarded to enhance the beauty and attractiveness of the flowers. The discarded parts of the plant are burned, which releases greenhouse gases to the atmosphere. Therefore, this research focused on developing a method for producing paper from the leaves of Puttaraksa and Plubplueng. Pulp was produced from these leaves by using three bases; NaOH, KOH and ash solution in a concentration range of 1-5 % (w/v). The pulp was then boiled in a range of 5-25 minutes. The optimal conditions to produce Puttaraksa paper were 15 minutes boiling time in 4% (w/v) KOH. The chemical components of this paper were 93.74 % holocellulose, 1.55% lignin, and 3.66 % extractives. The physical properties of this paper were 66.43 % brightness, 400 mN tearing resistance, and 1.0 kg/cm^2 bursting strength. The optimal conditions to produce Plubplueng paper were 15 minutes boiling time in 4% (w/v) ash solution. The chemical components of this paper were 93.25% holocellulose, 5.41% lignin, and 4.24% extractives. The physical properties of this paper were 68.08% brightness, 340 mN tearing resistance, and 0.5 kg/cm^2 bursting strength. The chemical and physical properties of paper produced from Puttaraksa were similar to paper from mulberry. However, physical properties of Puttaraksa paper were better than those of Plubplueng paper, which make Puttaraksa the better alternative for paper production.

Keywords: Paper, Puttaraksa, Plubplueng, Canna indica, Crinum lily, Holocellulose

1. INTRODUCTION

Pulp and paper producers have to explore new sources of raw materials because of environmental awareness and a shortage of wood. Non-wood fibers are of interest as an alternative raw material for pulp and paper production, because both wood and non-wood fibers are similar in cellulose content. Non-wood fibers are lower in lignin and higher in hemicellose and silica content than wood fibers. Non-wood fibers are mostly agricultural residues and annual plants, such as bagasse, wheat, rice straws, corn stalk and bamboo [1][2]. The pulp and paper mill industry emits greenhouse gases, which harm the environment. [9].

Both wood and non-wood fibers, such as mulberry inner bark [3], have been used as raw materials for paper production [1][2]. Therefore, Puttaraksa and Plubplueng are plants whose non-wood fibers may be new sources of raw materials.

Puttaraksa, Fig.1, is the Thai name of Indian shoot that has the scientific name: *Canna indica* (Cannaceae). Puttaraksa is a perennial rhizomatous herb that grows from a branching, thick, underground rhizome and reaches a height of 1m. Its leaves are large and up to 50 cm long and 25 cm wide [4][5].

Plubplueng, Fig.2, is the Thai name of *crinum lily* that has the scientific name*: Crinum asiaticum*. Its common names are Seashore Lily, Poison Bulb, Bakung, Crinum Lily, Asiatic Poison Lily, Spider Lily, and Seashore Crinum. Plubplueng is an herbaceous perennial plant that can grow in moist areas (swamp, marsh, lake and stream), develops from underground bulbs, and reaches a height of 90 to 120 cm at maturity. Plubplueng leaves are typically long and variegated, with light green to green colors. Plubplueng produces large white fragrant flowers [5].

Puttaraksa and Plubplueng are used for decorative landscaping. Their branches and leaves are cut and discarded to enhance the beauty and attractiveness of the flowers. The discarded parts of these plants are burned, which releases greenhouse gases to the atmosphere.

Therefore, this research focused on producing paper from the branches and leaves of Puttaraksa and Plubplueng. This process could prevent burning the most useful branches and leaves of these plants, and thus lessen the effect on the environment by reducing atmospheric emissions. Paper samples were produced using three kinds of alkaline at varying concentrations and boiling times. The chemical composition and physical properties of each paper produced were compared to those of paper produced from mulberry.

2. EXPERIMENT

2.1 Plant Preparation to Produce Paper

Small pieces of Puttaraksa leaf, 200 g, were boiled for 10 minutes in 1,000 mL of NaOH, KOH and ash that varied in range 1, 2, 3, 4 and 5 % w/v. The 10-minuted boiling time was determined by conducting experiments using boiling times of 5, 10, 20 and 25 minutes. The boiled pulp was adjusted to neutral pH by washing in tap water.

Fig.1 Puttaraksa: *Canna indica*

Fig.2 Plubplueng*: Crinum asiaticum* Linn

The pulp was blended for 15 minutes to disperse the fibers and then soaked in 5% w/v $NaClO_2$ for 10 minutes. Paper was produced from dispersed pulp by using a 10 cm x 10 cm wire screen frame and 3 hrs incubation at 100 ^{0}C. The paper samples weighed approximately 1.00-1.30 g / sheet. Paper was produced from Plubplueng leaf using the same procedure as Puttaraksa. The paper samples were photographed by stereomicroscope and analyzed to determine the chemical components and physical properties.

2.2 Stereomicroscopic Images

2.2.1 ZEISS Stemi DV4.

The papers were photographed by the stereo microscope (ZEISS Stemi DV4). The highest magnifying power of ZEISS Stemi DV4 is 32X (10X eyepiece lens X 3.2X objective lens) and expands to 51.2X by 1.6X extra lens.

2.3 Chemical Components of Paper

2.3.1 Extractives: TAPPIT 204 om-88.1988

Extractives were determined in Soxhlet apparatus by the following; 3 grams of paper were extracted in Ethanol:Benzene(1:2) for 4-5 hrs. The solvent extraction was evaporated, dried, and weighed to calculate the percentage of extractives [6][7].

2.3.2 Holocellulose: Browing

In 250 mL round bottom flask; 2grams paper without extractives, 89 mL distilled water, 0.25 mL acetic acid and 0.75 grams sodium chlorite; boil at 70-80 ^{0}C in water bath for 30 min in fume hood with continuous shaking. Add 0.25 mL acetic acid and 0.75 grams sodium chlorite to the hot solution at the end of the 1st, 2nd and 3rd hrs while shaking flask. Place the flask in ice bath until temperature of solution is below 10 ^{0}C, filter through sintered glass crucible no.3, wash with cold water and acetone, then dry and calculate the percentage of holocellulose [6][7].

2.3.4 Lignin: TAPPIT 222 om-88.1988

In 50 mL beaker in ice bath; 0.5 grams paper without extractives; add 7.5 mL cold 72 % (v/v) H_2SO_4 and stir well. Cover the beaker with watch glass, and place in water bath at 20^{0}C for 1.30 hrs. Stir every 15 min. Pour the solution into a 500 mL round bottom flask containing 200 mL distilled water. Adjust the total volume to 287.5 mL. Reflux the solution for 2 hrs, and then leave solution in 500 mL beaker overnight. Filter through sintered glass crucible no.3, wash with hot water, then dry at 105^{0}C for 3 hrs, cool down, and calculate the percentage of lignin [6][7].

2.4 Physical Properties of Paper

2.4.1 Tearing resistance: Tear Tester

Test the capability to resist tear force by Elmendorf Tearing Tester. Overlap 4 sheets of 50x65 mm paper, and test with Tear Tester**;** ISO 1974:1990 [8].

2.4.2 Bursting strength: Burst Strength

Test resistance to 1x1 m^2 in vertical level of paper. Adjust compression to 8x8 cm paper, and test resistance with Analogue Paper Bursting Strength Tester; ISO 2759 [8].

2.4.3 Brightness: Reflectivity of white light

Brightness test methods in the paper industry; T452: Brightness of pulp, paper, and paperboard (directional reflectance at 457 nm).

Place white paper under paper sample, and test for reflectivity using Brightness apparatus [8].

3. RESULTS AND DISCUSSION

3.1 **Puttaraksa** (Thailand) *Canna indica* Linn.

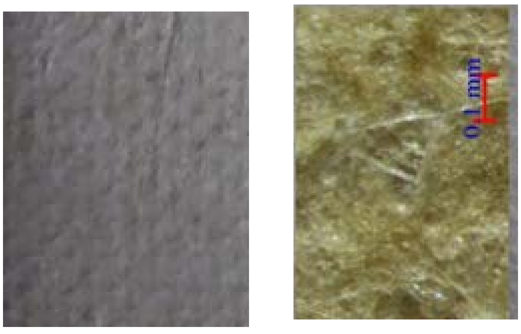
Table 1 showed that elimination of lignin and extractives increased as NaOH concentration increased, but that holocellulose decreased at 5% w/v NaOH. Table 2 showed that the physical properties of paper increased as NaOH concentration increased due to the elimination of extractives and lignin.

Table 1 Chemical components of paper from Puttaraksa pulp boiled in various concentration of NaOH for 10 minutes

[NaOH] % w/v	Extractive (%)	Holocellulose (%)	Lignin (%)
1	6.87	81.48	12.44
2	5.38	82.76	9.85
3	5.16	86.17	2.72
4	4.68	86.59	2.74
5	3.21	83.76	1.96

Table 2 Physical properties of paper from Puttaraksa boiled in various concentration of NaOH for 10 minutes

[NaOH] % w/v	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
1	60.09	300	0.5
2	61.11	360	0.5
3	63.54	380	1
4	65.31	400	1
5	65.93	400	1



(a) (b)

Fig. 3 (a) Puttaraksa paper: 10 minutes boiling in 4% w/v NaOH, 3 hrs incubation at 100 ^{0}C
(b) stereomicroscopic image of its fiber

Figure 3(a) showed the Puttaraksa paper that had been boiled in NaOH. Tables 1 and 2 showed that the optimal conditions for producing paper using NaOH were 10 minutes boiling in 4% w/v NaOH followed by 3 hrs incubation at 100 ^{0}C. Character of paper was light brown, had smooth surface, tough, and could be folded. The stereomicroscopic image, Fig. 3(b), indicated big pore size of its fiber.

Table 3 showed that elimination of lignin and extractives increased as KOH concentration increased, but that holocellulose decreased at 5% w/v KOH. Holocellulose level was highest at 4% w/v KOH. Table 4 showed that the physical properties of paper increased as KOH concentration increased due to the elimination of extractives and lignin.

Table 3 Chemical components of paper from Puttaraksa pulp boiled in various concentrations of KOH for 10 minutes

[KOH] % w/v	Extractive (%)	Holocellulose (%)	Lignin (%)
1	8.86	85.02	4.62
2	7.53	87.70	2.45
3	6.98	88.38	2.06
4	4.93	90.32	1.78
5	4.05	87.43	1.16

Table 4 Physical properties of paper from Puttaraksa pulp boiled in various concentrations of KOH for 10 minutes

[KOH] % w/v	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
1	64.33	300	0.5
2	64.37	340	0.5
3	65.80	350	1
4	66.84	400	1
5	66.85	400	1

(a) (b)

Fig. 4 (a) Puttaraksa paper: 10 minutes boiling in 4% w/v KOH, 3 hrs incubation at 100 ^{0}C
(b) stereomicroscopic image of its fiber

Figure 4(a) showed the Puttaraksa paper that had been boiled in KOH. Tables 3 and 4 showed that the optimal conditions for producing paper using KOH were 10 minutes boiling in 4% w/v KOH followed by 3 hrs incubation at 100 ^{0}C. Character of paper was light brown, had smooth surface, tough, and could be folded. The stereomicroscopic image, Fig. 4(b), indicated small pore size of its fiber. The pore size of this paper was smaller than Fig.3(b).

Tables 5 and 6 showed that ash has less ability to eliminate extractives and lignin than NaOH and KOH. Tearing resistance and bursting strength of the paper were not evaluated.

Table 5 Chemical components of paper from Puttaraksa pulp boiled in various concentrations of ash for 10 minutes

[Ash] % w/v	Extractive (%)	Holocellulose (%)	Lignin (%)
1	12.81	70.72	17.03
2	12.45	73.31	15.88
3	10.51	77.66	13.54
4	8.25	80.29	9.63
5	6.08	74.07	8.51

Table 6 Physical properties of paper from Puttaraksa pulp boiled in various concentrations of ash for 10 minutes

[Ash] % w/v	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
1	53.24	Nd	Nd
2	54.28	Nd	Nd
3	55.26	Nd	Nd
4	58.92	Nd	Nd
5	58.94	Nd	Nd

(a) (b)

Fig.5(a) Puttaraksa paper: 10 minutes boiling in 4% w/v ash, 3 hrs incubation at 100^0C
(b) stereomicroscopic image of its fiber

Figure 5(a) showed the Puttaraksa paper that had been boiled in ash. Tables 5 and 6 showed that the optimal conditions for producing paper using ash were 10 minutes boiling in 4% w/v ash followed by 3 hrs incubation at 100 ^{0}C. Character of paper was light brown, had thick and rough surface, and cracked easily. The stereomicroscopic image, Fig. 5(b) indicated wide pore size of its fiber. The pore size of this paper was bigger than papers from NaOH and KOH (Fig. 3(b) and Fig. 4(b)).

Figure 6 showed that the amount of holocellulose in paper boiled in 4% KOH and in 4% w/v NaOH was nearly the same. This means that the efficiency of KOH was similar to NaOH and better than ash. However, KOH is more safe for the environment than other base.

A comparison of tables 1-6 and Figs. 3-6 indicated that Puttaraksa paper boiled in KOH has good character and fine pore size. Therefore, Puttaraksa pulp boiled in 4%KOH was proceeded to determine the optimal boiling time.

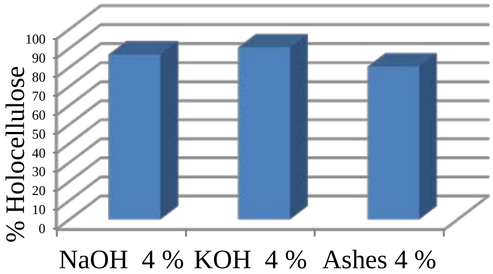


Fig.6 Holocellulose of paper boiled in 4% NaOH, 4%KOH and 4%ash

Table 7 Chemical components of paper from Puttaraksa pulp boiled in 4% w/v KOH at 5 minute intervals

Time (min)	Extractives (%)	Holocellulose (%)	Lignin (%)
5	6.36	85.15	3.94
10	4.93	90.32	1.78
15	3.66	93.74	1.55
20	2.84	89.29	1.37
25	2.39	87.21	0.91

Table 8 Physical properties of paper from Puttaraksa pulp boiled in 4% w/v KOH at 5 minute intervals

Time (min)	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
5	65.43	350	0.5
10	66.24	400	1
15	66.43	400	1
20	66.62	400	1
25	66.69	400	1

Tables 7 and 8 showed that extractives and lignin decreased with increased boiling time in 4% w/v KOH. Holocellulose increased up to 15 minutes boiling time and then decreased. Boiling time did not significantly affect the physical properties, so the optimal boiling time was 15 minutes.

(a) (b)

Fig. 7 (a) Puttaraksa paper: 15 minutes boiling in 4% w/v KOH, 3 hrs incubation at 100 ^{0}C
(b) stereomicroscopic image of its fiber

Figure 7(a) was similar to Fig.3(a). Figure 7(a) showed that Puttaraksa paper was light brown with a smooth surface, and stereomicroscopic image, Fig.7(b), showed its fine pore size. Based upon tables 1-8 and Fig. 3(a)(b)-Fig.7(a)(b), it concluded that the optimal conditions to produce paper using KOH was 15 minutes boiling in 4% w/v KOH followed by 3 hrs incubation at 100 ^{0}C. These conditions produced the highest holocellulose content, highly efficient removal lignin and extractives, and high tearing resistance and bursting strength. The paper had good character and fine pore size.

3.2 Plubplueng

Table 9 Chemical components of Plubplueng pulp boiled in NaOH for 10 minutes

[NaOH] % w/v	Extractives (%)	Holocellulose (%)	Lignin (%)
1	6.69	87.33	18.14
2	5.91	86.89	17.72
3	5.83	89.39	13.00
4	5.37	88.76	12.04
5	3.33	88.49	11.81

Table 10 Physical properties of Plubplueng pulp boiled in NaOH for 10 minutes

[NaOH] % w/v	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
1	54.66	300	0.5
2	55.08	300	0.5
3	58.36	320	0.5
4	58.87	320	0.5
5	58.69	320	0.5

Tables 9 and 10 showed that NaOH concentration had no significant effect on the chemical components and physical properties of Plubplueng pulp.

(a) (b)

Fig. 8 (a) Plubplueng paper: 10 minutes boiling in 3% w/v NaOH, 3 hrs incubation at 100 ^{0}C
(b) stereomicroscopic image of its fiber

Figure 8(a) showed Plubplueng paper produced using 10 minutes boiling in 3% w/v NaOH followed by 3 hrs incubation at 100 ^{0}C. Character of paper was light brown, had a rough surface, and split easily. The stereomicroscopic image, Fig.8(b) indicated wide pore size of its fiber. This and the data in tables 9 and 10 showed that the optimal conditions to produce paper using NaOH were 10 minutes boiling in 3% w/v NaOH followed by 3 hrs incubation at 100 ^{0}C.

Table 11 Chemical components of Plubplueng pulp boiled in KOH for 10 minutes

[KOH] % w/v	Extractives (%)	Holocellulose (%)	Lignin (%)
1	7.92	93.37	10.88
2	6.70	94.15	7.80
3	5.41	94.85	5.39
4	4.91	91.26	4.22
5	4.34	90.92	3.13

Table 12 Physical properties of Plubplueng pulp boiled in KOH for 10 minutes

[KOH] % w/v	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
1	55.71	300	0.5
2	55.43	300	0.5
3	57.36	320	0.5
4	57.78	320	0.5
5	57.61	320	0.5

Tables 11 and 12 showed that all concentrations of KOH extract nearly the same amount of holocellulose. KOH concentration also did not significantly affect the physical properties of paper from Plubplueng pulp.

Figure 9(a) showed Plubplueng paper produced by boiling for 10 minutes in 3% w/v KOH followed by 3 hrs incubation at 100 ^{0}C. Character of paper was light brown, had a rough surface, and split easily. The stereomicroscopic image indicated wide pore size of its fiber. This and the data in tables 11 and 12 showed that the optimal conditions to produce paper using KOH were 10 minutes boiling in 3% w/v KOH followed by 3 hrs incubation at 100 ^{0}C.

(a) (b)

Fig. 9 (a) Plubplueng paper: 10 minutes boiling in 3% w/v KOH, 3 hrs incubation at 100 ^{0}C
(b) stereomicroscopic image of its fiber

Table 13 Chemical components of Plubplueng pulp boiled in ash for 10 minutes

[Ash] % w/v	Extractives (%)	Holocellulose (%)	Lignin (%)
1	6.56	85.10	7.07
2	5.01	86.84	6.42
3	4.61	88.78	6.22
4	3.91	90.17	5.96
5	3.86	88.74	5.48

Table 14 Physical properties of Plubplueng pulp boiled in ash for 10 minutes

[Ash] % w/v	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
1	60.51	300	0.5
2	63.59	310	0.5
3	63.12	320	0.5
4	66.33	320	0.5
5	64.76	320	0.5

Tables 13 and 14 showed that ash could eliminate extractives and lignin to produce high holocellulose content. All paper produced from Plubplueng pulp had similar physical properties.

Figure 10(a) showed Plubplueng paper produced by boiling for 10 minutes in 4% w/v ash followed by 3 hrs incubation at 100 ^{0}C. Character of paper was light brown, had a rough surface, and split easily. The stereomicroscopic image, Fig.10(b), indicated wide pore size of its fiber. This and the data in tables 13 and 14 showed that the optimal conditions to produce paper using ash were 10 minutes boiling in 4% w/v ash followed by 3 hrs incubation at 100 ^{0}C.

(a) (b)

Fig.10 (a) Plubplueng paper: 10 minutes boiling in 4% w/v ash, 3 hrs incubation at 100 °C
(b) stereomicroscopic image of its fiber)

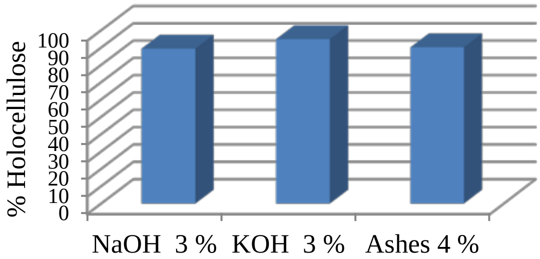


Fig.11 Holocellulose from Plubplueng pulp boiled in 3% w/v NaOH, 3% w/v KOH, and 4% w/v ash

Figure 11 showed that the holocellulose content of Plubplueng paper boiled in 4% ash was nearly the same as paper boiled in 3% w/v NaOH and 3% w/v KOH. This indicated that the efficiency of ash was similar to NaOH and KOH. Since chemical components and physical properties were also nearly the same, 4% w/v ash was used to determine the optimal boiling time of Plubplueng pulp.

Tables 15 and 16 showed that 15 minutes boiling time with 4% w/v ash produced good pulp and paper, but longer times resulted in reduced holocellulose content. Paper from Plubplueng had a bigger pore size and lower strength than paper from Puttaraksa.

Figure 12(a) was similar to Fig.10(a). Figure 12(a) showed that Plubplueng paper was light brown,had a rough surface, split easily, and stereomicro-scopic image, Fig.12(b), showed its wide pore size. Based upon tables 9-16 and Fig. 8(a), (b)-Fig.12(a), (b), it concluded that the optimal conditions to produce Plubplueng paper were 15 minutes boiling in 4% w/v ash followed by 3 hrs incubation at 100 ^{0}C. These conditions produced the highest holocellulose content, highly efficient removal of lignin and extractives, and high tearing resistance and bursting strength. The paper had good character and fine pore size.

Tables 7 and 15 showed that Plubplueng paper has higher levels of extractives and lignin than Puttaraksa paper. Tables 8 and 16 showed that Puttaraksa paper is stronger than Plubplueng paper due to better tearing resistance and bursting strength.

Table 15 Chemical components of Plubplueng pulp boiled in 4% w/v ash at 5 minute intervals

Time (min)	Extractives (%)	Holocellulose (%)	Lignin (%)
5	6.16	89.48	8.58
10	4.55	90.17	5.96
15	4.24	93.25	5.41
20	3.91	92.66	5.04
25	3.69	90.59	4.41

Table 16 Physical properties of Plubplueng pulp boiled in 4% w/v ash at 5 minute intervals

Time (min)	Brightness (%)	Tearing resistance (mN)	Bursting strength (kg/cm^2)
5	61.08	310	0.5
10	66.33	320	0.5
15	68.08	340	0.5
20	63.76	340	0.5
25	63.45	340	0.5

(a) (b)

Fig.12 (a) Plubplueng paper: 15 minutes boiling in 4% w/v ash, 3 hrs incubation at 100 ^{0}C
(b) stereomicroscopic image of its fiber

4. CONCLUSIONS

The optimal conditions for production of Plubplueng paper were 15 minutes boiling time in 4% (w/v) ash. The chemical components of this paper were 93.25% holocellulose, 5.41% lignin, and 4.24% extractives. The physical properties of this paper were 68.08% brightness, 340 mN tearing resistance, and 0.5 kg/cm^2 bursting strength.

The optimal conditions for production of Puttaraksa paper were 10 minutes boiling time in 4% (w/v) KOH. The chemical components of this paper were 93.74% holocellulose, 1.55% lignin, and 3.66% extractives. The physical properties of this paper were 66.43% brightness, 400mN tearing resistance, and 1.0 kg/cm^2 bursting strength.

All stereomicroscope figures showed that paper from Puttaraksa had smaller pore size than that from Plubplueng, so its strength was better than paper from Plubplueng.

The chemical components of paper from Puttaraksa and from Plubplueng were similar to paper from mulberry. The high holocellulose content showed in table 17, showed that both Puttaraksa and

Table 17 Comparison of chemical components of leaf and paper

	Chemical components	
	Holocellulose (%)	Lignin (%)
Puttaraksa leaf	79.62	23.44
Puttaraksa paper at 15 minute boiling time with 4% (w/v) KOH	93.74	1.55
Plubplueng leaf	73.75	18.35
Plubplueng paper at 15 minute boiling time with 4% (w/v) ash	93.25	5.41
Mulberry paper [8]	77.55	7.64

Plubplueng could be used as raw material for paper production. However, a comparison of physical properties showed that Puttaraksa could be a better material for paper production than Plubplueng.

Some researchers have explored alternative plants to use as raw material for pulp and paper production [1][2]. Non-woods were of particular interest as a new source of raw material, especially agriculture residues and annual crops such as rice straw and pineapple leaves[10][12]. However, different plants have different chemical components. Even different species of some plants, such as bamboo, have different chemical compositions, such as extractives, cellulose, holocellulose, ash and lignin [11]. Therefore, any experiment to explore an alternative plant as a new raw material for papermaking must evaluate chemical composition, physical properties, and paper character. This research found that both Puttaraksa and Plubplueng could be suitable for the production of paper and that these annual crops could be new sources of raw material for the papermaker.

5. ACKNOWLEDGMENTS

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