

# **NEW ERA OF CLEANER PRODUCTION IN MULBERRY PAPER INDUSTRY**

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## **Summary**

New approach of cleaner production to mulberry paper industry has been adopted by chemical engineers to minimize chemicals and energy consumption. Material and energy balances are still in use to analyze the process efficiency. Some modifications on equipment are also handy and economically proposed. Out of those basic cleaner production techniques, the change of chemical like sodium hydroxide to more environmental friendly acetic acid is challenging. Alternative chemical for bleaching step such as ozone and/or hydrogen peroxide are considered to be used instead of chlorine since its derivatives are known to be cancer inducers and also accelerate green house effect. Owing to this traditional process, mulberry paper production is labor intensive. Therefore, new management should be introduced to imprint cleaner production concept into every single human. This will be the key to bring all the theoretical proposals into the effective practice without hesitation.

## **Keywords**

Mulberry paper, cleaner production, ozone bleaching, acetic pulping

## **INTRODUCTION**

Mulberry which is the main raw material of mulberry paper making is obtained from the local farmers and more than a half of the demand is imported from Thailand's neighboring countries like Lao and Myanmar. The demand for mulberry for the paper production has increased from 380 tons in 1989 to 4700 tons in 1995 [1]. However, the actual estimated demand for mulberry is about 68,000 tons per year [2].

Mulberry paper has been produced and well known as a handmade paper in Thailand for more than a thousand years [3]. Nowadays, handmade mulberry paper is still widely produced in villages. Only six small and medium scale factories commercially produce machined mulberry paper. The largest factory consumes 1,000 tons of dry inner mulberry bark per year [1]. Owing to the dramatically increasing mulberry paper consumption and exports, significant changes are encouraged for higher production and optimization of raw material and energy utilization. As far as the environmental concerns, use of alternative chemicals that are less toxic for pulping and bleaching processes are also of interest.

The chemical engineering concept of material and energy balances is applied in this study. The cleaner production options like equipment modifications and design as well as new chemicals for pulping and bleaching will also be discussed.

## **MULBERRY**

The scientific name of mulberry is *Broussonetia papyrifera Vent* and belongs to the family Moraceae [4]. The fiber is obtained from the inner bark of the mulberry. Mulberry is a good raw material for paper making because it contains long fibers (8.02 mm), less lignin (4.9% dry weight), high pentosan (12.9% dry weight) and high alpha-cellulose (60.9% dry weight) [4], [5], [6]. However, this chemical composition depends on the age of mulberry. Generally, the best cultivation is 6-12 months [3], [4].

Mulberry paper is unique and is a good material for letter paper, bank note, business card, wrapping paper, handicrafts, hand made flowers etc. According to its special characteristics such as its strength, ink receptivity and stability etc., it can be used in many applications such as paper for oil painting, filter paper, paper clothes and tea bags [3], [4]. The most popular product of mulberry paper is Thai hand made umbrella. The principle importers of the mulberry products are Japan, European countries, Canada, Australia and U.S. [3]. The products are generally in the form of finished product, papers and pulp. Certainly, mulberry paper has a great impact on Thai economy and reflects life style of people involved.

## **MULBERRY PAPER PROCESS**

Kraft process is main process applied in the mulberry paper production. The main chemicals are sodium hydroxide for pulping and chlorine for bleaching. The production can be roughly divided into 7 steps (Figure 1).

### **Raw material selection and preparation**

The appropriate size of mulberry is 3 to 5 cm in diameter. Only inner bark is used, typically steam or heat is applied to ease the peeling. The fiber obtained from this method is quite clean. However, dry bark is more preferable for machined paper making as it is easy for transportation and handing. Generally, dry mulberry inner bark is classified into 4 grades, SA, A, B and C. SA is the best grade which represents young mulberry aged 6-12 months, no defect or contamination and has white color [3], [4]. In case of dry bark, soaking step is required. Average time of soaking is 24 - 48 hours.

### **Digestion**

Sodium hydroxide 10-15 % is used. For SA grade mulberry NaOH use can be reduced to as low as 8%. The average digestion time is 3-5 hours [3], [4]. The chemical dose and the operating conditions of digestion step are shown in table 1.

<b>Item</b>	<b>Quantity</b>
Sodium hydroxide (NaOH)	10-15 % by wt.
Liquid/dry bark	10 : 1
Temperature of digestion	100 °C
Time required	3-5 hr.
Yield of unbleached pulp	54 % wt.

**Table 1: Chemical dose and operating conditions of digestion step [3], [4]**

### **Washing**

The cooked bark is removed from the digester to a series of concrete tanks for washing. Each tank has fresh water coming in at the top and water discharge at the bottom. Cooked bark is manually turned during washing. This washing operation is repeated 2 or 3 times.

### **Bleaching**

The purpose of this process is to whiten the pulp. Unbleached pulp will be loaded to the bleaching tanks. The common bleaching chemicals normally are sodium hypochlorite or calcium hypochlorite. The details of bleaching chemicals and conditions are shown in table 2.

<b>Item</b>	<b>Quantity</b>
Sodium hypochlorite (NaOCl)	4 % wt of unbleached pulp
Pulp consistency	6%
Operating temperature	40 °C
Time required	6-12 hrs.
Pulp yield	52 % wt. of bark

**Table 2: Bleaching chemical and conditions [3], [4]**

### **Washing**

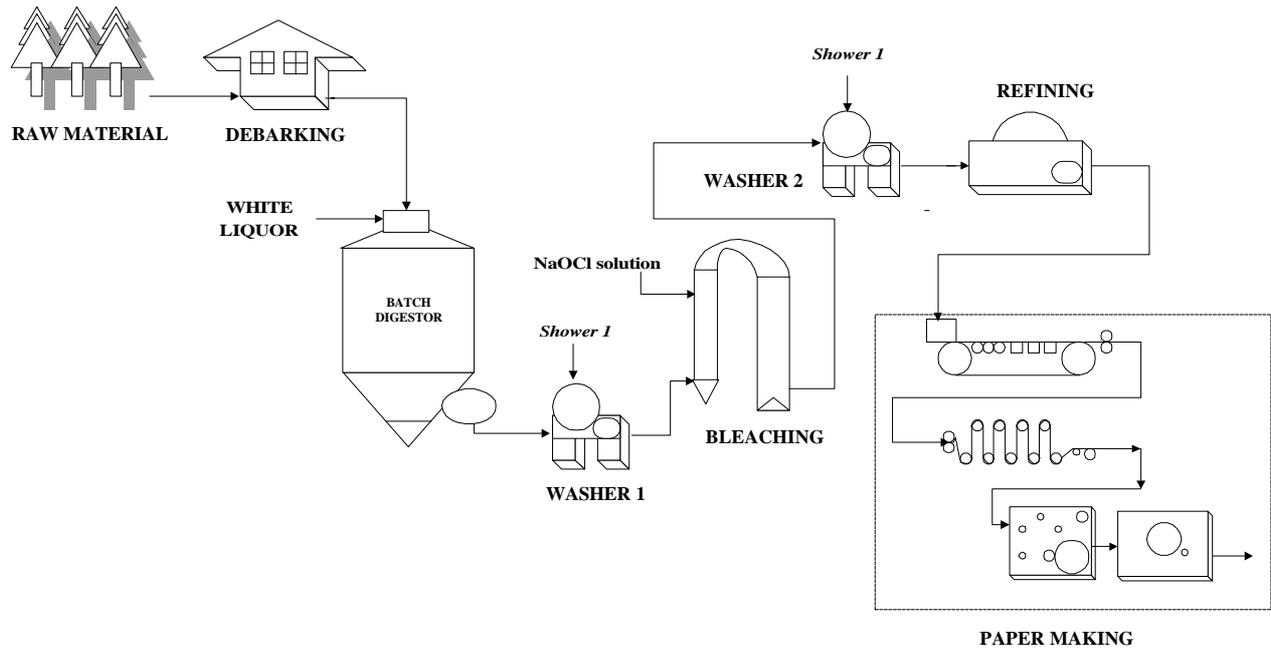
The bleached bark is transferred to the concrete tanks for washing. Similar to the previous washing step, this washing is performed 2-3 times or until the smell of chlorine disappears. Generally, contaminated and defective pulp are also manually removed in this step.

### **Refining or beating**

As mentioned earlier, mulberry pulp is quite long, therefore, an effective beater is required. Time required for beating depends on the characteristics of bleached pulp. Normally, for 3 kg of pulp one hour of beating is required. Now, the pulp fiber is ready to make the mulberry paper, so it is fed into the paper making step.

## Paper making

The pulp fiber is suspended in the concrete tanks. For sheet forming the pulp fiber must have a consistency of approximately 2 % . This paper making unit consists of many unit operations such as: sheet forming, transferring, pressing, and drying. Finally, we obtain the mulberry paper.



**Figure 1: Mulberry pulp and papermaking process**

## CLEANER PRODUCTION OPTIONS

Unlike, other pulp and paper processes, the process of mulberry pulp and paper is more traditional and is labor intensive. The applied chemicals and operating conditions mostly depend on the experience of the staff. Most of the time, excess chemical is applied to make ensure product quality. Water is used intensively each step and accounts for the main cost of production. In the past, water cost had been ignored as most factories were located near the river or national water resource.

### Process Adjustment

Based on material and energy balances, these following cleaner production options are proposed.

- The quality of bark must be consistent in one cook to obtain the homogeneity of the cooked pulp.
- The optimum chemical concentration should be investigated at any grade of mulberry inner bark material to avoid the excess use of chemicals.

- Counter current pulp wash is recommended in the washing step instead of batch washing to save water. The application of air bubbling and ultrasonic techniques are also of interest to increase the efficiency of rinsing.
- Water from the washing step is encouraged for reuse in soaking step. However, detailed study on the effects of reused water on pulp characteristic has to be investigated.
- Turning or mixing is recommended to reduce time of soaking, digestion, and washing.
- Automatic water control is suggested to save water.
- Recycle of the final stage waste water to use in the process is proposed. This would need some special water treatments like reverse osmosis or ozone to improve the quality of water.
- Waste water in each step should be separated and treated separately. Extra treatment need to be considered for waste water from the pulping step which contains long molecules of lignin and tannin.

### **Equipment Modifications**

In terms of energy conservation and environmental concerns, some mulberry pulp and paper making machines and equipment are recommended to improve or modify.

- The indirect steam digesters are recommended to be used instead of current direct steam digester for a better heat contribution. This modification will improve the consistency of cooked bark.
- New appropriate design of digesters with lids and sampling ports are suggested in order to save energy and manually check quality of cooked pulp. At present the no lid digesters are widely used as it is convenient for sample checking and manually agitating.
- Recycling piping system need to be installed at the washing and soaking steps.
- Some modifications of the washing system to counter current flow as recommended in the previous section have to be made after cooking and bleaching.
- More machines are to be applied and installed in order to reduce human labor. This substitution is more crucial in the big cities where the wage is high and skilled labor is lacking. However, this modification will be effective when the process is more organized and systematic.

### **Alternative Chemicals**

Sodium hydroxide and chlorine are the main chemicals in mulberry pulping and bleaching. Sodium hydroxide is a strong base and hard to degrade. In fact, NaOH can be recycled and reused but needs a complex treatment. Similarly, chlorine is also claimed to be toxic chemical which relates to the green house effect. Therefore, the alternative chemicals are proposed.

- Hydrogen peroxide or Sodium peroxide is long known to be used instead of NaOH [3], [7]. However, these two alternative chemicals are not in use because they are more expensive than chlorine [3].
- Steam explosion can be applied as the raw material pretreatment before the digestion step to reduce the NaOH consumption. This technique claims to get a better product quality in terms of yield, paper properties and low energy consumption [8].
- Formic and acetic acid, Formacelle technique, is an alternative technique for mulberry pulping. The detailed experiment and feasibility study of this technique on mulberry paper

is now under-investigation. Formacelle technique has been successfully applied for other wood like pine and gives a better paper quality. Nevertheless, acetic acid can be recycled [9].

- Oxygen and ozone with and without hydrogen peroxide can be utilized in the bleaching step. Extensive studies are currently being carried out on their appropriate ratio and technique.

### **Alternative Waste Water Treatment**

Waste water from pulp and paper industries contain chemical, pigment and low degradable substances. Biological treatment both aerobic and anaerobic has been used. This is an active on-going research topic to get higher removal efficiency and less treatment time. Like other factories, Thai mulberry paper factories also have space limitations. Some factories are located near the resident area. Therefore, alternative waste water treatment of non-chemical treatment or low space consumption are needed.

- Strong sunlight and high temperature of water in Thailand is conducive to microalgae treatment. The system is completely environmental friendly and low cost as no equipment and chemical are needed. Moreover, the biomass of microalgae can be dried and use for animal feed and fertilizer [10].
- Ozone treatment followed by reverse osmosis is proposed. This treatment is very effective and the advantage of this technique is that it is environmentally friendly. Treated water can be reused in the process. However, this treatment would need high capital investment even though the operating cost is low.

### **Training and Management**

- Training must be provided for the workers in order to have an overview of cleaner production concepts.
- Group brain storming needs to be arranged for total QC circle setup.
- To imprint and promote the cleaner production concept, the regular seminar and brain storming of people in each section should be arranged.
- Information on good raw material handling should be provided to the farmers.
- Good agricultural practice must be informed to control the quality of raw material.

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