Review Article

Bamboo Utilization in Myanmar*[1]

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Introduction

At present, when the environmental problems are spreading over the entire globe, from the viewpoint of conservation and use of forest resources, bamboos will become very important materials because they are regenerable resources and their growth rate is very fast.

The great services of bamboos in our daily life are well known to all of us, the Asians. But we do not appreciate blessing of any object that is very close to us in our everyday life. A good example is air. In Japan, for some time after the war, export of articles for daily use was encouraged as a means of getting foreign currencies, and manufacture of bamboo wares was active. After that, when the plastics industry grew rapidly, substitutes of bamboo wares were made of plastics. Partly due to their novelty, these plastics eventually expelled bamboo from a number of articles for daily use. Recently, however, the environmental pollution by dioxin has been posing serious problems. Dioxin is generated when waste plastics such as vinyl chloride are burnt. In near future, the plastics industry will be forced to use materials that can coexist with natural environment. Under such conditions, bamboo materials are now attracting much attention. This case of bamboo clearly shows that the products of the modern material civilization are produced exclusively for their convenience, and the level of their loads on the environment has not been considered at all. It has passed mere fifty years after the changeover from natural materials to plastics, but, another changeover back to natural materials will be made again. But most of the bamboo processors have disappeared in Japan. It will be hard to restore the bamboo ware industry. As this example shows clearly, industries and materials for daily life that have large loads to the environment are destined for disappearance. The roles of bamboo in the field of articles for use in daily life will be closed up.

The roles of bamboos as environmental materials will increase more and more in future. The recognition of bamboo materials will change in Europe and America. However, to meet the needs of the industrially advanced countries, it is not sufficient to use materials that give less load to the environment. In addition to their material functions, other functions for design and application and standardization will be needed.

1. Role of Bamboos in Myanmar

Europeans and Americans do not use bamboo very well. That is why bamboos have not been a subject of sciences. In contrast, in Asian countries, bamboos have been used in the daily life over a long period. Wisdom concerning the uses of bamboos has been accumulated and transmitted by the people. In Japan and probably in Myanmar, and generally speaking, most of intellectuals of Asia are believers of natural sciences and civilization of the West. We may say that they have shown slight disrespect for traditional cultures and wisdom of the people of their countries. As a result, the Asian intellectuals, just like the Europeans and Americans, hardly know bamboos. Having no adequate knowledge, they may swallow statistical figures blindly to develop utilization plans of bamboo in many cases.

It is a matter of course that, in utilizing bamboos, we must have a comprehensive approach, including considerations of their ecologies and material properties of the respective bamboos.

Japanese cooperation with Myanmar in relation with the use of bamboos of Myanmar was mentioned in a report published by Resources Bureau of Science and Technology Agency of Japan in 1968. The title of the report is Utilization of Bamboo Resources of Southeast Asia : On Promotion of Bamboo Pulp Industry. But apparently there have been no new development since then.

To fully utilize the functional properties of bamboo as a plant in our daily life, we keep three points in mind. First, we need research on the ecology, tissue structure and physicochemical properties of bamboo. Secondly, We need to learn the wisdom concerning bamboos utilization accumulated by the people of Myanmar. Finally, we need research to check the wisdom in the light of scientific findings.

In Myanmar, there are about 90 species of bamboo. There are 8,318 ha of bamboo forests in Bago Yoma forest, 777,000 ha in Rakhine State, about 162,000 ha in Taninthayi division. In total, there are 947,318 ha of bamboo forests. This figure does not include the growing stocks of Sagaing, Kachin and Shan. Thus the actual area of bamboo forests seems to be much larger than that.

According to the report of 1968[1)], the area of bamboo forests in Bago Yoma forest is 759,713 ha. This figure includes bamboo forests where the mixing ratio of bamboo with other trees is 50 percent or higher. The growing

*[1] This article is the abstract of the special lecture to the people of the Government of Myanmar titled "The Trend of the World Economy and a Road to Economic Self-Sufficiency of Myanmar".

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stock is estimated to be 54 million tons. Anyway, among various countries of Southeast Asia, Myanmar ranks second next to India, in the growing stock of bamboo. The bamboo forest area of Myanmar is estimated to be two million hectors. We may safely say that skillful utilization of these bamboo resources is the key to successful conservation of the forest resources of Myanmar.

Bamboo is used in a variety of purposes as materials for daily life. And recently, its functions as an environmental material are beginning to attract one's attention. In a process of carbonizing bamboo, materials of varied degrees of carbonization are produced. Now we are beginning to know that we can produce a diverse range of products by changing the degree of heat treatment. The products range from sooted (smoke - stained) bamboo, of which surface alone is carbonized, to bamboo charcoal that is completely carbonized. These products vary in internal surface area and adsorption. If these products can be used in a good combination, they will be able to fix and eliminate pollutants that are now posing serious problems in the industrially advanced countries. Thus an enormous demand for bamboo products can be expected from these countries, and these products have a high potential to become important export products of high added value. Naturally, they can be used as bamboo charcoal, a fuel. It serves a double purpose.

Bamboo forests of Myanmar differ from those of other countries of Southeast Asia in that they are concentrated in some areas. Thanks to this characteristic, if you give a good bamboo forest management, you will be able to produce bamboo materials at a high production efficiency close to that of agriculture. Many kinds of bamboo available for us will cover most of the possible applications of wood resources, such as pulp production, construction, agricultural materials, environmental materials, fuel, and articles of daily use.

Here I repeat again, but please remember bamboos are one of the most suitable natural resources for Southeast Asia. Please consider by yourselves whether these important resources have been used fully in your country.

In Japan, and in Southeast Asia, many of the national leaders and scholars received education in the West, and in many cases they do not know much about the current conditions of their own countries. And because of this, they lack viewpoints for effectively utilizing the resources of their countries. Bamboos have been suffering most from this. Research on bamboos is retarded because bamboos are not present in Europe and America. However, for Asian researchers, bamboos should provide an unrivaled sphere of research. I hope this is a good chance for you to start to consider and investigate bamboos seriously.

Now, according to the latest materials[2] received from Myanmar, the major species of bamboo growing in Myanmar are as shown in Table 1[2]. The exact figure of the total growing area for nearly 90 species of bamboo, including the major species of bamboo listed in Table 1, is not certain, but we can safely estimate it at least 950,000 ha.

The major useful bamboos of Myanmar can be roughly divided by region as shown in Table 2[1]. The materials at hand, concerning bamboo resources of Myanmar, are quite limited. However, on the basis of these materials,

Table 1. Major species of bamboo growing in Myanmar[2].

Common Name in Myanmar	Scientific name	Overall Length (feet)	Girth (inch)	Area
Kyakhat	*Bambusa arundinacea*	20–50	1.5–2	Pago Yoma Forest
Kyathaung	*Bambusa polymorpha Monro*	80	9.5–18	Pago Yama Forest
Kyat-wah	*Cephalostachyum burmanicum*	40–50	6–12	Taninthayi Division
Kayin-wah	*Mellocanna bambusoides*	30–60	3– 9	Rakhine Yama Forest
Talagu-wah	*Dendrocalamus longispathus*	60	12–24	Pyinmanar Division
Tin-wah	*Cephalostachyum pergricile*	70–60	4.5–9	Pago Yama Forest
Hta-myin wah	*Dendrochloa distans*	70	18	Thaninthayi Township
Hti-yoe wah	*Thyrosostachys siamensis*	30–40	4.5–6.5	Yangon Township
Myin-wah	*Dendrocalamus stricus*	50	4– 6	Pago Yoma Forest
Shwe wah	*Bambusa vulgaris*	—	—	—
Wah gyi	*Dendrocalamus calostachyus*	80	12–24	Maymyo Township Northan Shan State
Wah gok	*Oxytenanthera albociliata*	—	—	—

Table 2. The main regional bamboo distribution in Myanmar[1].

Distribution region	Area ($\times 10^4$ ha)	Main bamboo species
The basin of the Kaladan and the Lemuru River belong to the Arakan mountain range. 1,000–2,500 m above sea level	100 (Estimation)	*Mallocanna baccifea* *Bambusa polymorpha* *Bambusa tulda*
The upper reaches of the Tenserim River	about 70	*Bambusa arundinacea* *Dendrocalamus stricus*
Pyin mana and Toungoo region	about 40	*Cephalostachyum pergracile*
Tharrawady and Yangon region	about 7	*Thyrosotachys oliveri*

possible measures for effective utilization of these bamboo resources will be discussed.

Regarding data on bamboos of Myanmar, the basic data will be needed, that is,

(a) species of bamboo, state of distribution (location, growing stock), and amount that can be cut;
(b) ecological and histological features of each species, and physical properties;
(c) current state of use of bamboo resources in Myanmar; and
(d) physical distribution and commercial trade of bamboo resources, namely, cutting areas, trading centers, methods of transport and routes, processing plants, and mechanism of selling products.

Then, on the basis of these data, we must analyze the present conditions, and establish the effective use of bamboos in Myanmar.

2. Smoke Drying of Wood and Bamboo Materials

Smoke drying has been practiced since early times, as one of wood drying methods. It might have been practiced in Myanmar from old times. The same method is used for smoking different meat. In wood turning, this method is used to dry the works. Wood drying by this smoke drying has been neglected up to the present, because the drying efficiency and precision of the method were claimed to low. This method is claimed to have such demerits that it is difficult to control temperature and humidity, it generates uneven drying due to uneven circulation of smokes, the surface color of the material is turned black due to adhesion of soot, and it poses the danger of fire because temperature control is difficult. These demerits, however, were derived from observation of the existing smoke drying kiln, and they were not derived from proper scientific evidences. It is clear from the fact that literature on this smoke drying method is nil.

These claims were made by specialists of drying. They set steam drying and the internal fan type drier, then being the mainstream of wood drying, as the standard.

The natural sciences are splendid means for clarifying the principles of nature. We have been using these means to investigate the principle and results of smoke drying in detail. Dry smoking was found to be effective in drying woods and bamboos. It was also found to be effective in equalizing or strengthening internal stresses. These stresses cause warping, distortion and cracking. Another important finding is this. Thermal degradation products contained in smokes and components of woods or bamboos react with each other to generate certain products. These products improve dimensional stability of the material. In the case of bamboo, these products prevent bamboo log from cracking due to drying, and increase its resistance to insect damage, mould and decaying fungi. In short, these products can significantly diminish three major defects for bamboo utilization, cracking, decaying and insect damage. In utilizing bamboos of Myanmar, this smoke drying will be effective as a preprocessing of all bamboo to be used as materials for construction, agriculture, fishery, articles of daily use, interior and exterior decoration.

(1) How Heat Is Transferred in Smoke Drying

Most of the wood drying techniques use air as the medium of heat transfer, and conductance and convection as the methods of heat transfer. As the medium of heat transfer, air has a very low efficiency. Both conductance and convection take much time and they are difficult to control. However, there is another method of heat transfer. It is radiation, and an important method. Smoke drying has special features. It uses this heat radiation in addition to heat conductance and convection. Another feature is that in place of air, an inefficient heat transfer medium, it uses mixed gases, unburned gas. This unburned gas is produced by burning a heat source, waste wood or bamboo under the condition of incomplete combustion. The main components of this gas are air, steam and carbon particulate. First, we check heat value and thermal conductivity of each component.

Specific heat is the quantity of heat (expressed in calories) required to raise 1 degree C in temperature for 1 gram of a material. Specific heat of air is 0.2366 (20–440°C). Specific heat of water is 1 (water temperature: 15°C). Specific heat of carbon is 0.204 (200°C). Mean specific heat of wood is 0.324 in the range from 0 to 100°C.

Now, green wood log has a high moisture content (from 100 to 200%). Because water has a high specific heat, when the kiln temperature rises in the smoke drying process, the moisture in the log serves to prevent rapid increase in log temperature.

On the other hand, as the specific heat of carbon particulate floating in the kiln is lower than that of air, the mixed gases of carbon and air have a larger heat accumulation effect than air alone.

Next, We compare the thermal conductivities. Thermal conductivity of air is 5.33×10^{-6} ($\mathrm{Cal} \times \mathrm{cm}^{-1} \mathrm{s}^{-1} \mathrm{deg}^{-1}$) at 0°C, and 6.81×10^{-5} at 100°C. Thermal conductivity of carbon is 8.49×10^{-3} and thermal conductivity of water is 1.64×10^{-3}. Thermal conductivity of carbon is about 125 times as large as that of air at 100°C. And thermal conductivity of water is about 24 times as large as that of air. This means, the greater is the quantity of carbon in the kiln or the greater is the quantity of steam in the kiln, the greater is the thermal conductivity of the mixed gases than that of air alone.

Heat conductance is a phenomenon in which heat is transferred, through a material, from a high temperature part to a lower temperature part. Convection is a phenomenon in which heat is transferred by a flow of a fluid such as gas and liquid. Radiation is a phenomenon in which energy is directly transferred to a material in the form of electromagnetic waves, and the electromagnetic waves are absorbed by the material and changed into thermal energy. This radiation does not require heating of media such as air and water. One merit of smoke drying process is that it can effectively utilize heat of black - body radiation of carbon contained in smokes. In the temperature range (from 20 to 150°C) of smoke drying process, electromagnetic waves of 7 to 10 microns in wave length are radiated. These electromagnetic waves are clearly in the range of far - infrared rays. Thermal radiation of these electromagnetic waves is absorbed by the log to raise the log temperature from the inside of the log.

The effect of black - body radiation heat of carbon contained in the unburned gas is quite effective. We can see this effect clearly in the experimental results shown in

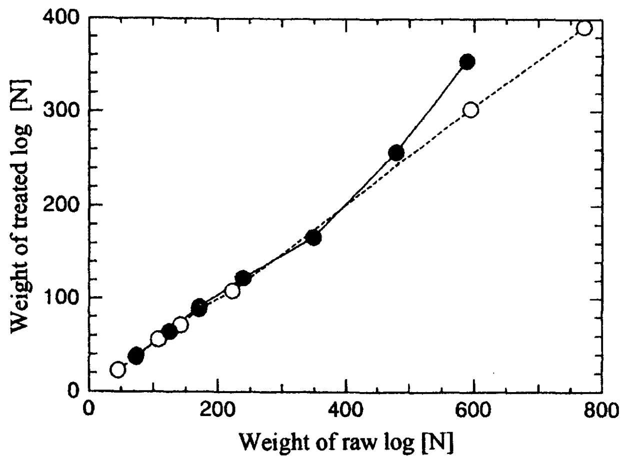


Fig. 1. Comparison with KD and Smoke dry.

Fig. 1. A pair of logs being different in length but having the same moisture content were dried by combustion of kerosene - fired gas burners. Another pair of logs were dried by smoke drying. The difference is not significant in the shorter logs. In the case of the longer logs, the graph of the combination of conduction and convection only is off the straight line. This indicates the degree of drying is worse.

(2) Mechanism of Smoke Drying

Now, we will consider how the dimensions of wood and bamboo are stabilized and their warping, cracking and distortion are reduced by smoke drying.

Before that, first we will examine the field of forces of a tree or bamboo growing on the ground. The tree or bamboo must stand vertically against the gravity. It must support its own weight, and it must resist against external forces such as wind. To meet these requirements, trees and bamboos have various contrivances. Growth stress is one of such contrivances.

Stress is defined by this equation

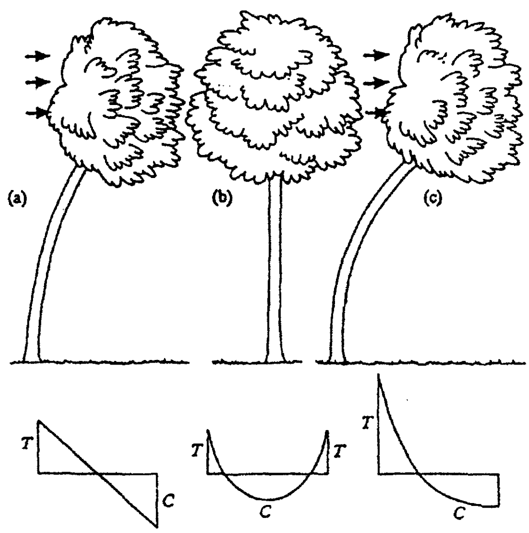
$\sigma = P/A$

where σ: stress, P: load, A: area.

When a weight of which weight is P is placed on a section of a material having a sectional area A, the ratio of the weight of this weight to the sectional area of the loaded material is called "stress".

Pulling, pushing or bending an object having a fixed form is applying an external force to the object. This force is the same as the load P.

Now, suppose strong wind is blowing against a standing tree, and the trunk of the tree is being bent by the wind. As shown in Fig. 2, the tree is bent by the wind, and as shown in the diagram the trunk is pulled on one side that is blown by the air. As a result, a tensile stress is generated. In contrast with this, the opposite side of the trunk is compressed to generate a compressive stress. The magnitude of the tensile stress and that of the compressive stress are identical. In a cross section of the trunk, as shown in the bottom of Fig. 2, the largest tensile stress (T) acts at the surface of the trunk on the wind - blown side. A compressive stress (C) having the same magnitude as T acts at the surface of the trunk on the opposite side. Stress distribution in the cross section of the trunk changes linearly.



(a) Tree bent by the wind with *no* pre-stress in wood. Stress distribution across the trunk is linear and maximum tension and compression are equal.
(b) Pre-stressed tree in a calm. The outside of the trunk is in tension all round; the inside is in compression.
(c) Pre-stressed tree in a strong wind. Compression stress is *halved* and this tree can bend *twice* as far as the one in (a).

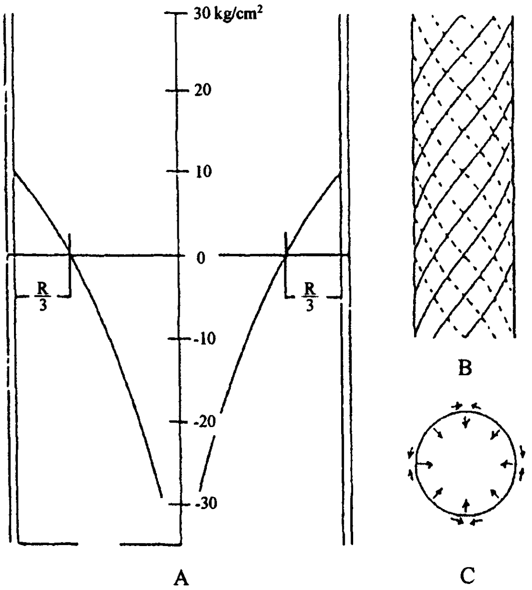
Fig. 2. Illustration of the pre-stressed mechanism in wood. Why trees don't fall down[3].

A different stress distribution in the cross section of the trunk is shown in the bottom of Fig. 2 (b). It shows the stress distribution of prestressing in which T is present at the surface of the trunk and the largest C is present in the pith at the center of the trunk. Suppose wind blows and the same tensile force is applied to the tree. In the case of (b), a tensile stress two times as large as that of (a) acts on the wind - blown side, and the compressive stress at the surface of the trunk on the opposite side is one half of that of (a). Trees and bamboos generate prestresses in advance by means of tissues. These prestresses can cope with external forces. Such a stress is generally called growth stress.

In the case of timber, the distribution of growth stresses in the direction perpendicular to the cross section (direction of fibers) of the trunk is shown in Fig. 3. Stresses change at one third of the radius from tensile ones to compressive ones. The largest compressive stress is at the pith. In addition to this, there are forces that act in the circumferential direction of the trunk to clamp the entire trunk, just like the forces of hoops of a barrel. When these forces are more complex, tissue structures are formed as if long pieces of cloth are bound over the surface of the trunk spirally, and in S-shape and Z-shape alternately.

When we get desired timbers from a tree, these growth stresses cause warping, distortion, twisting, and cracking. Removal of these growth stresses is the key to successful utilization of timbers.

It is said that for any logs of the same tree kind the magnitudes of growth stresses in the outer circumferences of the trunks are virtually identical. This means that the



A : Radial distribution of the longitudinal growth stress. On the vertical axis, (+) is tension and (−) is compression stress.
B : Sometimes, spiral grain is formed in the tree tsunk. This spiral structure reinforce the tree trunk.
C : Compression stress act in the circumferential direction of trunk like putting a hoop on a barrel.

Fig. 3. Schematic diagram of growth stress in the tree trunk[4].

shorter is the diameter of the log, the greater is the distortion of the timber.

A large growth stress is several hundred kilograms per square centimeter. In the case of tropical woods, when a board that shows sawing crook due to growth stresses is to be made straight, a large load of ten tons may be needed. When a tree of 1 to 2 meters in diameter is cut down, if such large growth stresses are released, the log may be split from one cut end over ten and some meters longitudinally.

Such large growth stresses are generated by groups of cells, of which length is several millimeters and width is from ten and some microns to several tens of microns. The major chemical components of these cells are cellulose, lignin and hemicellulose. Cellulose forms the framework. Lignin is shapeless matrix and serves as a cement. Hemicellulose binds cellulose and lignin together. The respective cells are formed by these components, and distortions generated by the individual cells are integrated to appear as growth stress of the entire tress.

We have been working hard to find an effective way of controlling the growth stresses of trees. Smoke drying of woods and bamboos attempts to control this growth stress by controlling the very root, namely, the distortions that are generated in the individual cells. Cell walls of plant cells of woods and bamboos are made of cellulose, lignin and hemicellulose. Cellulose gather in the form of fibers to form a framework of cell walls. This framework has the same role as the rebars in reinforced concrete. Lignin surrounds the framework of cellulose. Lignin plays the role of concrete. Hemicellulose works as a binder that makes cellulose and lignin compatible with each other. When these cell walls are formed, forms that originate various distortions are made by cellulose fibers. Lignin deposits around the fibers to fix these distortions. As a result, the individual cells have a variety of internal stresses. The magnitude of stress is proportional to the magnitude of distortion. When this fixed distortion is eliminated or moderated, the stress will be reduced.

Lignin, that fixes this distortion, is found to have an interesting property. When glass is heated, glass will eventually became soft in a certain temperature range. This temperature range is called thermal softening point. Components of woods and bamboos have their thermal softening points. When wood and bamboo are dry, the thermal softening point of lignin is in a range of 134°C to 235°C. However, when wood and bamboo have much moisture, like greenwood, the thermal softening point of lignin drops to a range of 77°C to 108°C. Smoke drying of woods and bamboos uses this effectively to regulate distortions at low temperatures.

3. Bamboo Charcoal Production Technology and Functions of Bamboo Charcoal

In Japan, after World War II, the production of charcoal, which mean wood charcoal, increased rapidly with the postwar rehabilitation. In the 1940s, it attained the highest production in history. However, due to the high economic growth policy of the subsequent period and the fuel revolution resulting from the use of fossil fuels, charcoal rapidly disappeared from the world of fuels.

New merits of wood and bamboo charcoal were discovered in early 1980s when environmental pollution by industrial waste became conspicuous. The adsorbing and reducing functions of wood and bamboo charcoal were found to be effective in improving the soil that was exhausted by chemical fertilizers and agricultural chemicals, purifying rivers, and improving living environment. In this way, charcoal was not used as an energy source. Great importance was given to charcoal's functions that reduce and purify the environment oxidized by carbon dioxide, nitrogen oxides, sulfur oxides and the like.

With such an environment as the background, bamboo, that was almost neglected, was rediscovered and bamboo charcoal production became active.

As it is well known, bamboos grow quickly. In the temperate zone, they grow within about 60 days. In the tropical zone like Myanmar, they grow in a period of three to five months, between May when the rainy season begins, and October when the rainy season ends. The annual increment in stock of bamboos is comparable to or greater than that of woods. When bamboos cut systematically every year, they will be harvested just like agricultural products, without destructing the environment. Bamboos are precious wood resources.

Moreover, we are beginning to know that the productivity can be improved greatly by carbonizing bamboos to produce charcoal and effectively utilizing the distillate, being a by product, in the field of agricultural production. In Myanmar, we are planning to introduce chemical fertilizers to raise the productivity of rice. Their effects are remarkable but only in short term. Their effects will not continue for ten years. After that, the soil will be exhausted, and the productivity will drop rapidly. Then we will need much more chemical fertilizers and agricultural chemicals to compensate for the drop in productivity. The costs relative to the production will increase, giving greater burdens on the producers.

The production cost of the Japanese agriculture has increased by more than 200 percent in the last fifty years. With such a constitution, the Japanese agriculture can not win in the international competition of agricultural products. Energy - intensive production increases the cost of production. In addition to it, a huge investment will be needed in future to lessen the burdens accumulated on the environment by chemical fertilizers and agricultural chemicals. Japan and other industrially advanced countries are shifting unmarketable chemical fertilizers and agricultural chemicals to the developing countries. There is no need for Myanmar to repeat the same mistake as the Japanese agriculture.

In the case of Myanmar, bamboo charcoal will also have an important role as fuel.

Carbonization of woods and bamboos can be roughly divided into two types; charcoal burning and dry distillation. As both processes produces charcoal as their main product, the distinction between charcoal burning and dry distillation is not very clear. However, in general, charcoal burning uses green wood as the raw material and a charcoal kiln. Dry distillation uses air - dried wood as the raw material and a retort. Both processes give a byproduct, distillate. Moisture in the raw material for charcoal is 30 to 35 percent of the original weight of the raw material in charcoal burning. It is 20 percent in dry distillation. As for bamboo charcoal, moisture content of 20 to 25 percent is claimed to be

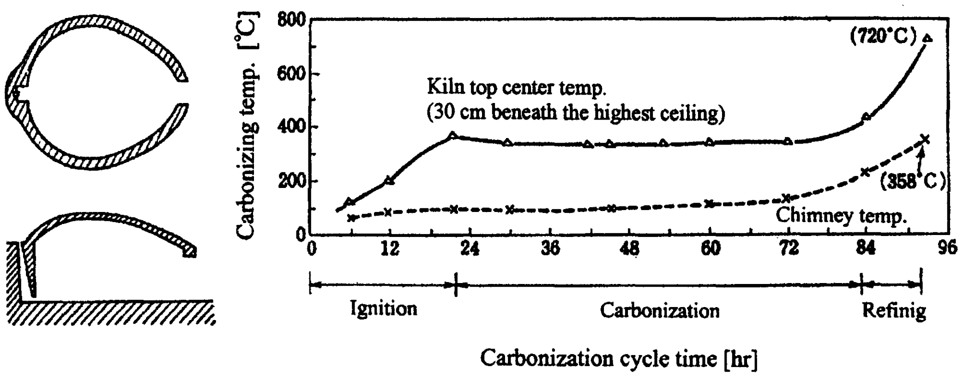


Fig. 4. Kurosumi kiln (Miura standard kiln) and its carbonizing temperature curves[5].

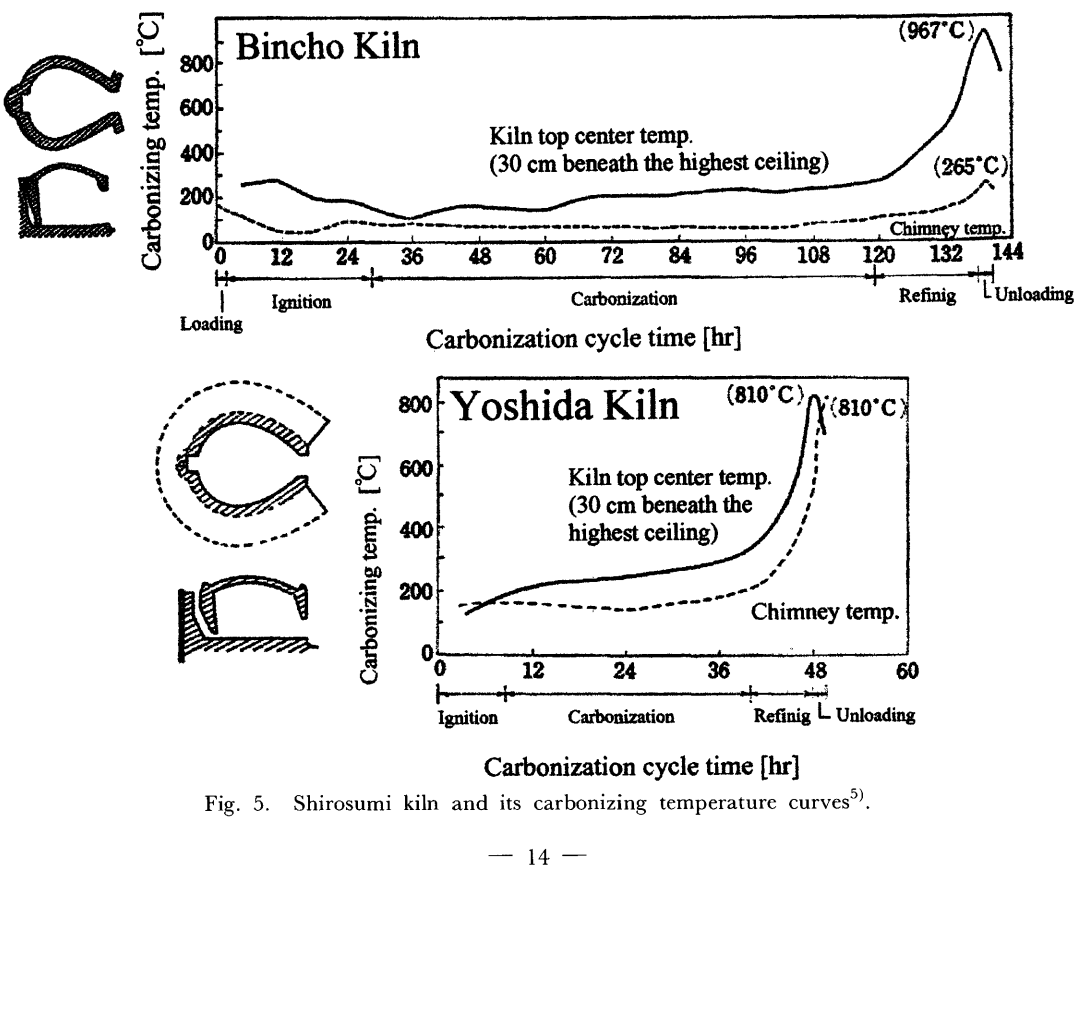


Fig. 5. Shirosumi kiln and its carbonizing temperature curves[5].

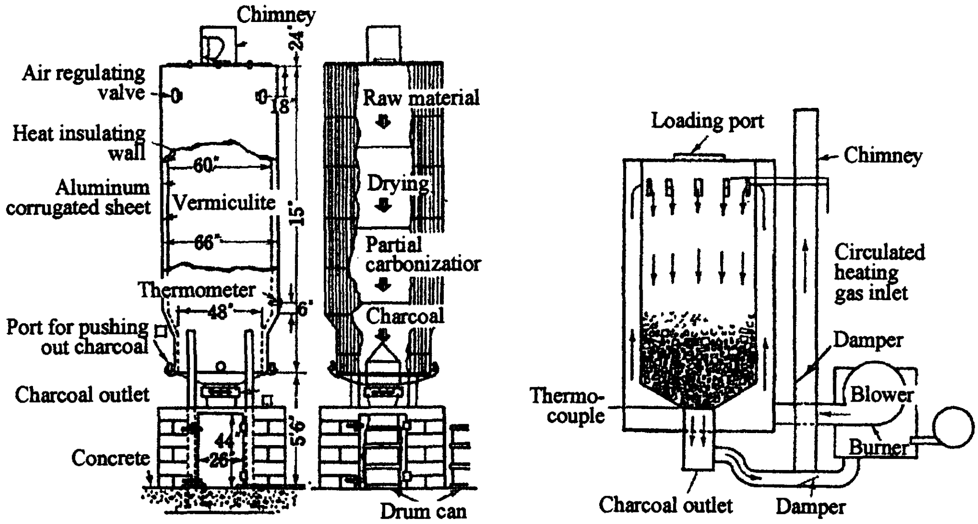


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Fig. 6. Typical plants of dry distillation[5].

adequate in charcoal burning.

The representative kilns of charcoal burning in Japan are "kurosumi kiln" and "shirosumi kiln" as shown in Fig. 4, 5[5]. "Kurosumi" is black charcoal, and "shirosumi" is white charcoal. Let us examine the carbonizing temperature curves of the two kilns. In the case of black charcoal, it takes about 90 hours for the raw material to turn in to charcoal. In the case of white charcoal, it takes 140 hours. The highest carbonizing temperature is 500 to 700°C for black charcoal, and around 1,000°C for white charcoal. Charcoal produced by charcoal burning is relatively hard, and the yield is 15 to 20 percent relative to the raw material for black charcoal, and 10 to 15 percent for white charcoal. Charcoal burning produces charcoal of good quality.

The typical plants of dry distillation are shown in Fig. 6[5]. They are of batch type. The raw material is fed into the retort from the top, and a auxiliary fuel, such as kerosene or fuel oil, is burnt. The combustion gas is flown back to carbonize the material. Carbonization is effected normally at 400 to 500°C. As this temperature range is lower than that of charcoal burning, dry distillation can not produce charcoal of good quality. But as an auxiliary fuel is used, dry distillation is suited to produce a large volume of charcoal. This process has a demerit of high fuel cost, and the production cost of the retort is 30 times as high as that of charcoal kiln. This process is not a very good process.

Charcoal kiln is most suited to charcoal burning in Myanmar. Bamboo is preprocessed by smoke drying before it is subjected to charcoal burning. This smoke drying is a very important process that equalizing the distribution of moisture content in bamboo and reduces the moisture content down to 20 to 25 percent in a short time. This heat treatment also kills insects and spore of wood - decaying fungi and prevents degradation of the material due to insect and fungi damages. This is a very useful method, indeed.

If natural curing is used to reduce moisture content of bamboo to 20 to 25 percent, it will take four to six months in Japan. But smoke drying can attain the desired moisture content within a week. And the treated bamboo materials will hardly suffer any damages of insect and wood - decaying fungi even when the materials are stored over a long period. The establishment of this smoke drying method has eliminated mostly the problems of cracking, insect damage and decaying of bamboo. Moreover, smoke drying is an essential process as a pretreatment of the raw material before charcoal burning to produce charcoal of good quality. And, thanks to this smoke drying process, now charcoal can be produced throughout the year.

(A) Processing of Green Bamboo

Green bamboo has a better workability when it is used to produce baskets for daily use, braided furniture, screen, lamp shade and the like for interior decoration. When the finished products are subjected to smoke drying, they will be treated at the same time for insect proofing, fungus resistance and preserving.

(B), (C) Paper and Pulp

Production of paper and pulp may be divided into chemical pulp, that is produced industrially, and handmade paper. In the case of bamboo, most of the production has been chemical pulp up to the present. The disposal of pulp liquid waste that contains varied chemicals for chemically disintegrating bamboo fibers has been causing serious environmental pollution. On the other hand, among soil microorganisms, there exist lignin - degrading bacteria. The biopulping process uses these bacteria to produce bamboo pulp, although the scale of production is quite limited. This process can be practiced on a small scale in agricultural villages. This process does not cause environmental pollution with its pulp liquid waste. Moreover, the waste liquid can be utilized in agriculture as an agricultural chemical. Thus the process serves a double purpose.

To this end, first of all, you must find out the most effective lignin - degrading bacteria in Myanmar. When you succeed in it, you can produce paper of high quality. Because bamboo fibers are fine and can be tangled well

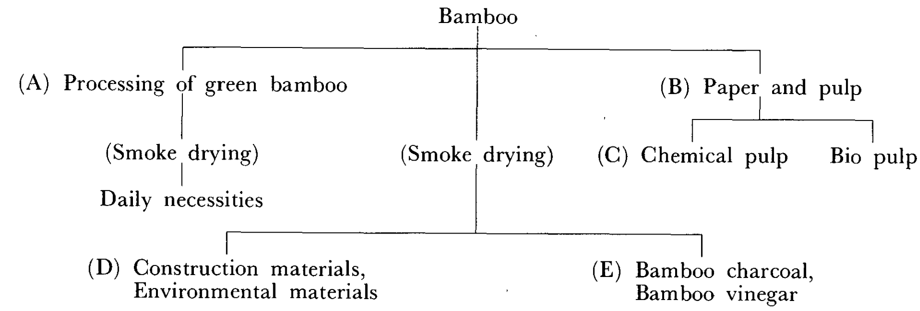

Fig. 7. Flow chart for process of bamboo utilization.

with each other, and this process does not damage fibers. Bamboo fibers produced by this process will be optimal as a raw material of unwoven fabrics.

(D) Construction Materials and Environmental Materials

In Asia where bamboo resources are abundant, bamboos have been used extensively as construction materials and environmental materials from ancient times. However, the uses of bamboos have been based on experience. In addition to this experience, if one can scientifically clarify the properties of bamboos and combine the scientific findings and experience - based wisdom, the scope of application of bamboos will be extended significantly, and new functions will be developed.

Smoke drying is an essential process for protecting bamboo materials from physical and biological degradations when bamboo materials are used as construction and environmental materials. When this preprocessing is made completely, then the quality of exported bamboo wares will be guaranteed, and these bamboo products will be accepted as reliable products.

(E) Bamboo Charcoal and Bamboo Vinegar

In this field, bamboo has boundless potentials as a raw material for environment - coexistence type industries. The industrially advanced countries are now striving to build such environment - coexistence type industries. There are more than 90 species of bamboo in Myanmar. If you can do charcoal burning that fully utilizes the features of the respective bamboos, bamboo charcoals for varied applications and having different characteristics will be produced. The byproduct of charcoal burning, the distillate or bamboo vinegar can be used in many fields. Bamboo charcoal and bamboo vinegar have not been utilized to fully exhibit their potential functions. The reason is that they are not suited as raw materials of the system of mass production and mass consumption. For such a system, one component must be provided by one raw material. When some components are required, they must be provided a combination of raw materials.

In future, however, natural materials, that do not give impacts to the natural environment, will be used in place of artificial materials.

In Japan, with the use of agricultural chemicals and varied products of chemical synthesis used as food additives, atopy patients are increasing ever. The number of atopy patients is said to be 20 million or 30 million persons. Bamboo vinegar is effective in treating this traumatic atopy. A simple calculation shows that the economic effects of bamboo vinegar amount to 200 billion to 300 billion kyats per year.

As for fishery, aquaculture is very active. A single culture farm operator spends as much as 3.6 million kyats a month for buying antibiotics. Now we are beginning to know that bamboo vinegar is effective as a substitute of antibiotics. Future applications and components of bamboo charcoal and bamboo vinegar are shown in Tables 3–6. As you can see, bamboo is, indeed, a large chemical plant created by nature.

The use of these technologies spreads all over the world. The people of Myanmar have been developing their

Table 3. Applications of wood and bamboo charcoal to materials in gaseous phase[5].

Catalyst carrier	Synthesis of Vinyl chloride and vinyl acetate, production of Freon, polymerization of ethylene and propylene, and synthesis of acrylonitrile.
Catalyst	Production of phosgene, and chlorination of ethylene and acetylene.
Recovery of solvent	Carbon disulfide, acetone, alcohol, ether, benzene, methylene chloride, toluene, ester, naphtha, hexane, benzine, methyl ethyl ketone, and trichlen.
Purification of gas	Hydrogen, helium, chlorine, hydrogen chloride, carbon dioxide, acetylene, ethylene, water gas, combustion gas, cracked gas, air for fermentation reactor, air for food and chemical industries, instrument air, plant exhaust gas, nuclear reactor exhaust gas, automobile exhaust gas, air for general purposes, miscellaneous (gas mask, getter of vacuum equipment, refrigerator, deodorization of toilet).
Separation and collection of gas	Benzene, gasoline, LPG, LMG, hydrogen, nitrogen, carbon monoxide, acetylene, ethylene, propylene, methane, ethane, propane, butane, pentane, alcohol, acetone, etc. from coal carbonization gas, natural gas, petroleum gas, cracked kas, synthesis gas, fermentation gas, etc. Radioactive materials from nuclear reactor exhaust gas, etc. Cyclo hexane, toluene, methylcyclohexane, ethylene oxide, propylene oxide, acetic acid, prussic acid, nitrogen oxide, titanium tetrachloride, titanium dioxide, and sulfurous acid gas from waste gases of chemical industry. Partition of components by gas chromatograph.

Table 4. Applications of wood and bamboo charcoal to materials in liquid phase[5].

Food industry	Decoloration and refining of refined -sugar- related products, thick malt syrup and sugar derivatives. Decoloration and refining of mono-sodium glutamate and liquid seasoning. Decoloration and aroma and taste adjustment of sake, fruit wine, beer, whiskey, alcohol, shoyu and vinegar. Decoloration and deodorization of high-grade edible oil. Purification of organic acid food additives such as citric acid.
Chemical industry	Separation, concentration and purification of medicines such as antibacterial materials, vitamin, hormone and alkaloid. Purification of dye intermediate, raw materials of synthetic fiber, intermediate, and various, inductrial chemicals. Decoloration and refinning of glycerol, fatty acid, hardened oil and margarine. Decoloration and refining of surfactant, plasticizer, oily medicine, castor oil and mineral oil. Desulfurization, deodorization and refining of petroleum products and LPG. Refining and regeneration of gas and absorbent of petrochemical industry. Regeneration of recovered acid, recovered salt and waste oil. Treatment of liquid waste and recovery of precious metal. Collection of iodo from brine. Carrier of catalyst.
Miscellaneous	Regeneration of dry cleaning solvent. Refining and regeneration of electroplating bath liquid. Medicinal charcoal (detoxicant). Prevention of side effects of agricultural chemicals. Water purification (Refining of raw water of water works). Dechlorination and removal of taste of city water. Purification and regeneration of industrial water. Removal of phenol, sterilizer, surfactant, mercury compound, etc. from waste-water.

Table 5. Components of wood vinegar and wood tar[5].

Organic acid	Formic acid, acetic acid, propionic acid, isobutyric acid, butyric acid, isovaleric acid, valeric acid, crotonic acid, isocaproic acid, tiglic acid, enanthic acid, and levulinic acid.
Phenol	Carbolic acid, *o*-, *m*- and *p*-cresol, 2, 4-xylenol, 3, 5-xylenol, 4-ethylphenol, 4-propylphenol, guaiacol, 4-methylguaiacol (creosol), 4-ethylguaiacol, 4-propylguaiacol, pyrogallol-1, 3-dimethylether, 5-methyl-pyrogallol-1, 3-dimethylether, 5-ethylpyrogallol-1, 3-dimethylether, 5-propylpyrogallol-1, 3-dimethylether, catechol, 4-methylcatechol, 4-ethylcatechol, and 4-propylcatechol.
Carbonyl	Formaldehyde, acetaldehyde, propionaldehyde, isobutyraldehyde, butyraldehyde, isovaleraldehyde, valeraldehyde, glyoxal, acrolein, crotonaldehyde, furfural, 5-hydroxymethylfurfural, acetone, methyl ethyl ketone, methyl propyl betone, methyl isopropyl ketone, methyl butyl ketone, diacetyl, methylcyclopentenone, and methylcyclopentenorone.
Alcohol	Methyl alcohol, etyl alcohol, isopropyl alcohol, propyl alcohol, allyl alcohol, isobutyl alcohol, and isoamyl alcohol.
Other neutral compoent	Levoglucosane, acetol, maltol, methylether of organic acid, veratrole, 4-methylveratrole, 4-ethylveratrole, 4-propylveratrole, 3, 4-benzopyrene, 1, 2, 5, 6-dibenzanthracene, 20-methylcholanthrene, and α-hydroxi-γ-valerolactone.
Base	Ammonia, methylamine, dimethylamine, pyridine, methylpyridine, dimethylpyridine, and trimethylamine.

Table 6. Applications of wood vinegar and wood tar[5].

Wood vinegar	
Soil disinfection	When 7–8 liters of 10-times-diluted wood vinegar is sprayed per 1 square meter one week before seeding hinoki, Japanese red pine, Japanese larch, keyaki, etc., wood vinegar will prevent damping-off. When used for eggplant, tomato, Japanese radish, beet, cucumber, etc., it has similar effects. In this case, it prevents germination of weed.
Compost, night soil	Addition of wood vinegar to compost and night soil will be effective in disinfection, insect proofing, and deodorization. It also promotes fermentation and increases the effests of fertilizer. Nitrifying bacteria and root nodule bacteria will survive.
Deodorization	Deodorization, disinfection and insect profing of toilet, night soil treatment plant, livestock, livestock barn, fishing boat, fish market, etc.
Coagulation	Coagulation of rubber latex and casein.
Dyeing and coating	Iron oxide of wood vinegar is used as mordant and black coating.
Distilled wood vigenar	
Food processing	Used by application, spraying, immersion, mixing, coating, addition, etc. When processing fish meat, mutton, whale meat, making ham, sausage, etc. It keeps freshness of fish meat, meat, fowl, etc.
Miscellaneous	Treatment of burns and cuts. Removal of ache. Removal of odor of sweat, blood, foul breath. Raw material of deodorant.

country slowly, always keeping compatibility with their natural environment. I would like to ask all of you to carefully examine the failures the industrially advanced countries experienced, and carefully introduce some scientific technologies, that can coexist with natural environment, into your traditional approach to the development. In this way, I believe, your approach to the national development will become the model of other countries in the 21st century. With this, I would like to conclude my presentation.

Acknowledgment

I would like to express my deep gratitude to the people of the Government of Myanmar, who kindly gave me this special opportunity, and the people of Mitsui Group of Japan, who generously cooperated with us in preparing for this presentation. I hope Myanmar and Japan will promote friendly relations more and more. And I hope you, the people of Myanmar, will contribute, as the principal leaders, to the construction of a society where not only the human kind but all creatures on earth live together in harmony.

Thank you very much.

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