Research note

Review, Current Status, and Prospects of the Bamboo Industry in Taiwan

Yu-Jen Lin[1,2)]

【Summary】

Bamboo offers local people a variety of products for daily needs, and helps protect habitats in Taiwan. In the 1960~1980s, bamboo-related processing industries in Taiwan reached a maximum output value of US$ 44.7 million and greatly contributed to economic improvements for bamboo farmers, local communities, and governments. But these industries have been in decline for a long time due to surging labor costs and high competition from cheaper imported products from other Asian countries. For Taiwanese agricultural authorities, how to promote the amount of bamboo utilization to maintain the health of indigenous bamboo forest resources, and how to allow the bamboo processing industry and bamboo production to prosper again are important issues in making strategy. This paper first reviews the development history of the bamboo-processing industry in Taiwan, so that one can know the contributions and importance of the numerous ways that bamboo was utilized by local people in bygone years, then describes the current status of this industry and how programs for promoting bamboo utilization have been successfully carried out by the agricultural authorities. Finally, the paper mentions several beneficial coordinated programs in cooperation with other related governmental agencies to upgrade the bamboo industry in Taiwan and the prospects for the potential development of bamboo utilization including high value-added fine bamboo craft products, bamboo pyrolytic oil production, and bamboo pellet manufacture.

Key words: bamboo, bamboo utilization, bamboo-processing industry, pyrolytic oil.

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[1)] Forest Utilization Division, Taiwan Forestry Research Institute, 53 Nanhai Rd., Taipei 10066, Taiwan. 林業試驗所森林利用組，10066台北市南海路53號。

[2)] Corresponding author, e-mail:yujen@tfri.gov.tw 通訊作者。

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研究簡報

台灣竹產業之回顧、現況與展望

林裕仁[1,2)]

摘　要

竹子之多元化產品除提供台灣地區民眾每日生活材料所需外，竹林也擔負環境保護之功能。以竹材為原料之竹加工相關產業在1960~1980年間台灣經濟成長歷程中曾貢獻許多，改善竹農與農村經濟，為政府重要收入來源，賺取外匯曾高達年44.7百萬美元。然面對高漲之工資與自亞洲其他國家低廉進口產品之競爭，該產業已呈現長期衰退狀態。如何藉由提昇竹子利用以維護竹林資源及如何再次振興繁榮竹加工業，始終是農業主管部門在擬訂決策時必須面對之重要課題。為瞭解竹子多元化利用對早期先民生活之重要性，本報告先回顧台灣竹加工業之發展變遷，接著描述竹產業現況及目前農業主管部門為提昇竹材利用所執行之計畫，最後敘及政府相關部門為提昇木竹產業所制訂之多項計畫及概述竹工藝、竹裂解油及竹燃料顆粒等具潛力之竹材利用展望。

關鍵詞：竹子、竹材利用、竹加工業、裂解油。

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There are abundant bamboo resources accounting for 7.2% of the total forest area in Taiwan. The distribution of bamboo in Taiwan can be both natural and planted, and ranges from the flatlands to high-mountain areas (0~3000 m) with 85 species within 15 genera (Lü 2001). There are 6 main commercial bamboo species in Taiwan: Moso bamboo (*Phyllostachys pubescens*), Makino bamboo (*P. makinoi*), ma bamboo (*Dendrocalamus latiflorus*), thorny bamboo (*Bambusa stenostachya*), long-branch bamboo (*B. dolichoclada* Hayata), and green bamboo (*B. oldhamii*) (Lü 2001). Each species plays an important role in bamboo utilization and offers local people a variety of products for their daily needs and helps protect habitats.

Bamboo utilization has a long and turbulent history in Taiwan. In the 1960~1980s, bamboo-related industries significantly contributed to local economies, providing jobs and revenue to bamboo farmers, local communities, and the government. But the industry declined due to soaring labor costs and high competition by cheaper imported products. Consequently, most processing factories shifted to China and Southeast Asia since the 1980s on to reducing produce costs. For decades afterwards, the economic potential of bamboo was largely neglected.

However, in recent years, bamboo has enjoyed renewed attention because its rapid growth and high productivity make it an interesting option for biomass, especially as climate change concerns and energy costs soar (INBAR 2009, Windenoja 2007). Currently, for Taiwanese agricultural authorities, strategies for reviving the bamboo-processing industry and bamboo production so that bamboo is better utilized to maintain the health of indigenous bamboo forest resources are important issues.

Through collecting relative statistics and reviewing published articles that analyzed bamboo utilization and the bamboo-processing industry in Taiwan, this paper first

illustrates the historical development of the bamboo-processing industry in Taiwan, then describes the current status of this declined industry, and finally mentions several beneficial coordinated programs by related governmental agencies to upgrade the bamboo industry in Taiwan and provide the potential development of bamboo utilization from efforts of the Taiwanese agricultural authorities.

Development history of the bamboo industry in Taiwan

Because bamboo is easy to process by hand, since earlier times, bamboo utilization in Taiwan was commonly distributed in farm villages located in areas with abundant bamboo resources. Most bamboo products in earlier times were handmade using simple hand tools. All parts of the entire bamboo plant, including the roots, culm, branches, twigs, leaves, and shoots, can be utilized by humans (Liese 1987, Scurlock et al. 2000). Table 1 shows bamboo utilization and related products based on the parts of the plant. The greatest utilization is using the culm for agricultural and fishing tools, furniture, construction bridges, scaffolding, building house frames, walls, window frames, roofs, interior dividers, etc. Except for green bamboo, the other 5 main commercial bamboo species in Taiwan can provide the abovementioned functions.

Edible bamboo shoots among the 6 main commercial species are Moso, Makino, ma, and green bamboo. In addition, ma bamboo shoots are processed in a dried form for storage, while the 3 other kinds of shoots are cooked and eaten fresh. The market price of Moso bamboo shoots is highest due to its limited production time, hard harvesting, and unique delicious taste.

Based on the results of an island-wide bamboo resource survey of Taiwan by Tai et al. (1973) in 1971~1973, the total area in bamboo of Taiwan had reached 175,638 ha. Among the main commercial bamboo, ma bamboo occupied the greatest area at 51.73%, Makino bamboo was next at 24.92%, and thorny bamboo was third at 17.46%. Table 2 shows the bamboo resources of Taiwan in the 1970s.

The bamboo-processing industry was highly developed due to the progress of processing technology using machinery, especially the development of lamination technology. The historical development stages of the bamboo-processing industry in Taiwan based on the product of life cycle are described as follows (Lee et al. 1993).

Introduction stage: before 1969

Before 1960, bamboo was utilized to make various products for household goods and agriculture appliances, but the quantity of most products did not reach an economic scale because things were handmade. Since the 1960s, the bamboo-processing industries in Taiwan gradually developed because the Japanese bamboo industry shifted to Taiwan, due to Japan facing the problem of high production costs domestically. After that, Taiwanese bamboo products began to be exported abroad employing the advantages of abundant bamboo resources, low wages, and low production costs. At this stage in 1961~1969, the export value of Taiwanese bamboo products increased from US$ 523,000 to 2,453,000.

Growth stage: 1970~1975

In this stage, the export value consistently increased due to contributions of the shift of Japanese processing technologies, many innovations in domestic processing machinery, and several assistance construction projects that were completed with governmental policy support, such as the bamboo preservation factories, specific parks for the bamboo-

Table 1. Bamboo utilization and related products sorted by parts of the bamboo

Part of the bamboo	Related products
Branches and leaves	Brooms, pan brushes, bamboo hats, leaves for bamboo dumplings, etc.
Culm	Culm: materials for households, materials for building of gardens, scaffolding poles for buildings, furniture manufacturing, supplementary implements for agriculture and fishery. Strip making: joss sticks, knitting sticks, bamboo mats, birdcages, light ornaments, skewers, sushi roller mats, toothpicks, bamboo curtains, pan brushes, etc. Tools: rice spoons, bamboo swords, ear scratchers, bread clips, combs, chopsticks, etc. Sliver intertwines: tea plates, bamboo screens, bamboo ceilings, bamboo wall boards, furniture, vases, handbags, etc. Cylinders: pen tubes, deposit tubes, incense tubes, rice tubes, etc. Boards made from rotated cut bamboo veneer: coffee plates, tea plates, bamboo screens, bamboo composite floors, bamboo ceilings, furniture, etc. Cylinder furniture: chairs, tables, magazine shelves, flower stands, etc. Culm bound with string: screens, poles, fences, etc. Square slices: seat cushions, car cushions, etc. Handmade appliances: vases, handbags, baskets, etc. Artwork: using engraving skills to create ornaments and functional products.
Roots	Handles of handbags and other various ornaments.
Shoots	Food.

Source: Lin (2006).

Table 2. Area in cultivation (ha) of the main commercial bamboo species of Taiwan in the 1970s

Bamboo species	Ma	Thorny	Green	Moso	Makino	Others	Total
Pure bamboo forest	14,911	17,280	4434	3296	43,774	735	84,430
Mixed bamboo forest	75,954	13,378	25	-	-	1851	91,208
Total	90,865	30,658	4459	3296	43,774	2586	175,638
Percentage (%)	51.73	17.46	2.54	1.88	24.92	1.47	100.0

Source: Tai et al. (1973).

processing industry, and bamboo utilization becoming an integrated field. The export value increased from US$ 4.3 million in 1970 to 18.1 million in 1975.

Mature stage: 1976~1980

This stage was the golden time for the bamboo-processing industry in Taiwan. Besides the installation of various processing factories by the government, the government simultaneously provided financial support and capital credit to help purchase machinery and solve turnover problems of capital at this stage. In addition, in order to obtain more-skillful labor and promote processing technologies, the government carried out training programs though cooperation between educational institutions and processing factories.

Under these advantageous circumstances, the export value reached US$ 30.7 million, and the growth rate reached 70% in 1976 compared to 1975. The export value even promptly increased to US$ 44.7 million in 1978 (Fig. 1). However, in the last years of this stage, the Taiwanese bamboo-processing industry gradually lost its advantages owing to soaring labor costs and was replaced by China and Southeast Asian countries.

Declining stage: after 1982

The golden time of the Taiwanese bamboo-processing industry lasted only about 10 yrs and promptly declined after 1982 not only because of soaring labor costs, the lack of labor and high production costs, but also due to impacts from the mass importation of semi-finished and whole products, and the exodus of other related industries. In 1991, in contrast to the time of 10 yr earlier, the export value had decreased to only US$ 21.0 million, which was only around 50% of the previous level, and the import value increased to US$ 2.9 million, a growth of about 91%.

Table 3 was different categories based on decades to describe the main bamboo products in Taiwan. The kinds of products manufactured were usually based on the processing technologies developed at that time. The functions of the products before the 1960s were almost all handmade for household goods and agriculture appliances of low value. Products after the 1980s, even as the industry was declining, consisted of many laminated products, engraved articles, and fine artwork, simultaneously produced in great amounts, due to using a lot of advanced machinery and progressive lamination technology.

Figure 2 shows Taiwan's main export countries of bamboo products during 1971~1991. The greatest one among the main export countries in 1976 was the US with a value of around US$ 14.8 million, followed by Japan with a value of around US$ 11.2 million. Since 1981, Japan became the largest importer instead of the US and kept that position until 1990. In 1990, the export value of bamboo products to Korea approached the value of US$ 11.5 million, which for the first time exceeded that to Japan with a value of US$ 11.4 million. Since then, exports of bamboo products gradually increased to Korea and remained at an important position with Japan.

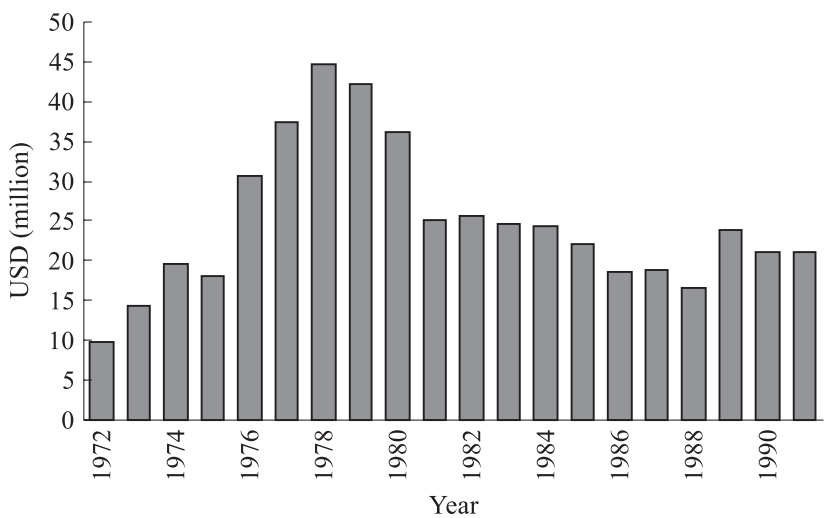

Fig. 1. Statistics of export value of bamboo products during 1972~1991 in Taiwan.

Current status of the bamboo industry in Taiwan

There were around 1200~1500 registered factories in Taiwan doing bamboo processing and related business during the mature stage (Lee et al. 1993). However, since 1982, the

Table 3. Time scale of bamboo product development in Taiwan

Time period	Main bamboo products
Before the 1950s	Building construction: bamboo booths, scaffolds, fences, etc. Agriculture tools: bamboo hats, dustpans, sieve plates, scoop wheels, etc. Fishery tools: rafts, fish baskets, fishing rods, etc. Food appliances: food steamers, chopsticks, rice spoons, etc. Wedding articles: palanquins, baskets for gifts, baskets for wares of needlework, etc. Articles for livelihood: tea plates, flower stands, baskets for vegetable transport, etc.
1950~1960s	Baskets from bamboo twigs, articles of bamboo weaving, etc.
1960~1970s	Bamboo curtains, skewers, bamboo plates, birdcages, teacup pads, jinrickshas, bamboo windbells, etc.
1970~1980s	Bamboo swords, bamboo furniture, coffee plates, bamboo curtains, etc.
1980~1990s	Bamboo lanterns, bamboo swords, laminated products, furniture with engraving, etc.
After the 1990s	Laminated products, engraving articles, fine artwork, etc.

Source: Lin (2004).

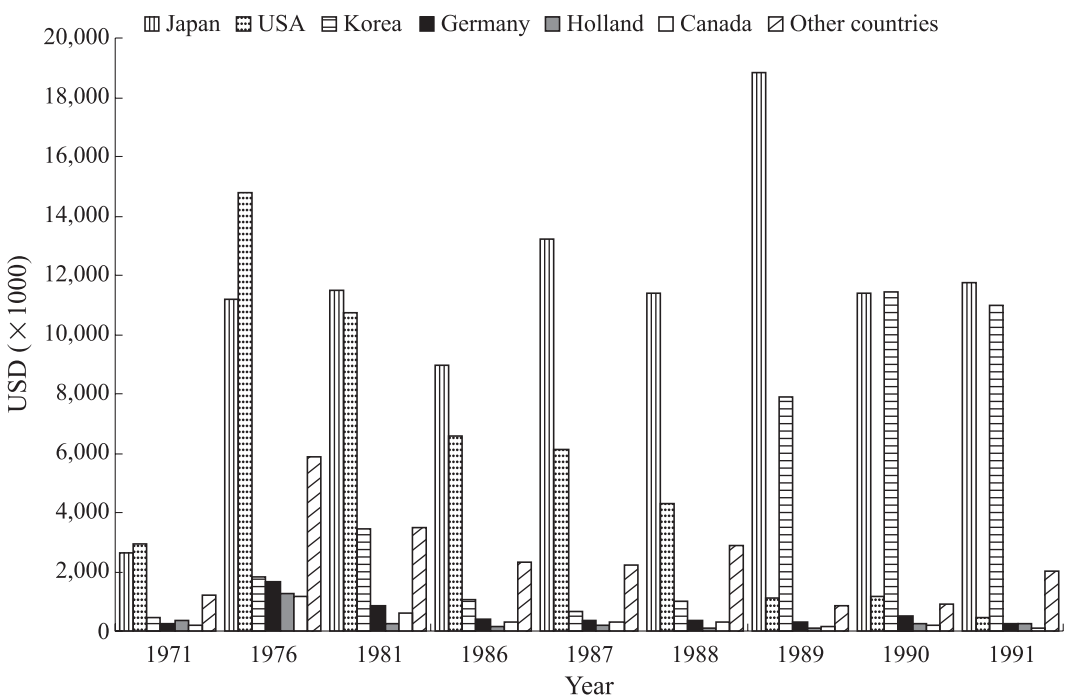

Fig. 2. Main export countries of bamboo products during 1971~1991 from Taiwan.

number of bamboo-processing factories rapidly declined year by year due to the loss of the advantage of lower labor costs. In 1993, the number of remaining factories was not even one-third compared to the mature stage. In 2004, there were fewer than 100 registered factories still in operation as small businesses in Taiwan. Most factories had shifted to China and Southeast Asia to seek cheaper labor and production costs. Therefore, bamboo harvesting slowly decreased due to reductions in the output value of the bamboo-processing industry, and amounts of relevant studies of the bamboo-processing industry and the statistical work of bamboo production were dropping off; even the official statistical data of bamboo harvesting by the Taiwan Forestry Bureau are hard to obtain since 2003. Figure 3 showed a continuous decreasing trend of the production value of bamboo (only culm,) from 1993 to 2002, at only around US$ 137,000 and 200,000 in 2001 and 2002, respectively.

Because it is in a different category, bamboo shoot production is not included in the bamboo-processing industry in Taiwan. Bamboo shoot production is one of the items among all bamboo products for which the production is stable regardless of whether for domestic or foreign markets. The total export value of frozen bamboo shoots overseas in the period of 1994~2003 was worth US$ 21 million, an average of US$ 2.1 million annually, and the export value was around US$ 180,000 in 2003. The main top 3 exporting countries for this product were Japan, the Netherlands, and the USA (Lin 2004).

In addition, despite the bamboo-processing industry having declined in Taiwan, there are still certain demands for bamboo products in the domestic markets for agricultural use and household goods. Amounts of imported bamboo products from China and Southeast Asian countries, such as Vietnam, Thailand and Indonesia, with cheaper prices are substituted for the domestic supply to fill market demand. Table 4 is the ranking of countries and output values of bamboo (canes, split skin, and roots) sorted by imports and exports during 1994~2003 in Taiwan. China accounted for 75.3% of the import value during 1994~2002 and reached 98.9% of the import value in 2003 (Lin 2004).

Undoubtedly, China has become the

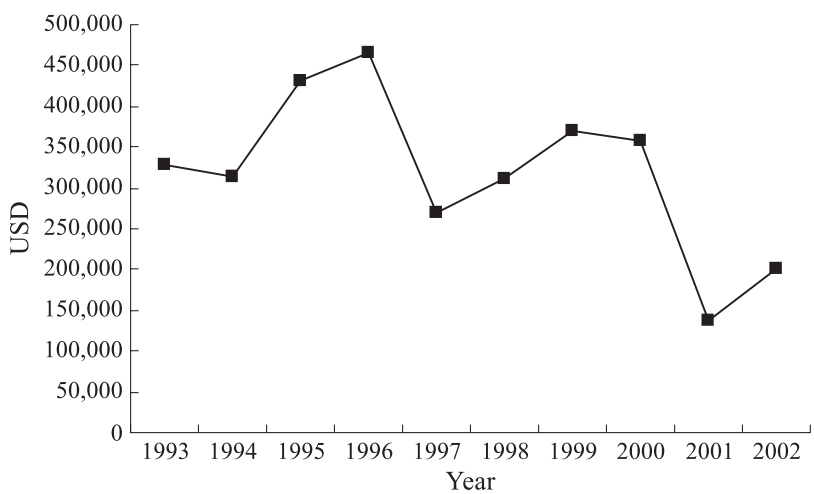

Fig. 3. Production value of bamboo during 1993~2002 in Taiwan.

Table 4. Ranking of countries and output value of bamboo (canes, split skin, and roots) sorted by the import and export value during 1994~2003 in Taiwan

	1994~2002				2003			
	Country	Rank	Value (USD)	Percentage (%)	Country	Rank	Value (USD)	Percentage (%)
Import	Overall		15,339,525	100.0	Overall		394,106	100.0
	China	1	11,553,842	75.3	China	1	389,751	98.9
	Vietnam	2	1,428,041	9.3	Vietnam	2	2,245	0.6
	Thailand	3	1,335,379	8.7	Japan	3	2,110	0.5
	Japan	4	527,802	3.4				
	Indonesia	5	354,714	2.3				
Export	Overall		19,663,838	100.0	Overall		1,413,035	100.0
	Japan	1	9,554,882	48.6	China	1	575,625	40.7
	Hong Kong	2	6,575,035	33.4	Hong Kong	2	404,551	28.6
	USA	3	1,233,096	6.3	Japan	3	198,270	14.0
	China	4	668,594	3.4	USA	4	124,406	8.7
	Germany	5	222,795	1.1	Mexico	5	85,206	6.0
	UK	6	203,986	1.0				
	Mexico	7	200,902	1.0				

Source: Lin (2004).

most important import country of bamboo products in Taiwan. With regard to the overall export value being higher than the import value, the reason is that the main import products are raw materials with lower value such as bamboo culm, branches, leaves, and roots, and most export products are processed products with higher value.

Bamboo grows fast, reproduces prolifically, and matures quickly within 4~5 yr, but the site productivity will rapidly degrade if the bamboo forest lacks suitable forest management for mature culm cutting. Unfortunately, nowadays large areas of unmanaged bamboo forests have formed due to the lack of bamboo cutting for the long term which is a serious waste of natural resources. Therefore, it is critical for the Taiwanese agricultural authorities to promote the amount of bamboo utilization and to restore the bamboo-processing industry and bamboo production once again, so that it can revive the economic activities in villages and recover the prosperity in farms and communities.

To achieve the abovementioned goals, the Taiwanese agricultural authorities have created a project called “Transforming and Reviving Plan of the Bamboo Industry” since 2002. Developing the local bamboo charcoal industry in abundant bamboo forest areas was a major part of the project. Adopting imported technology from Japan, many earthen kilns (a kiln structure is illustrated in Fig. 4.) for bamboo charcoal production have been built in many locations. The authorities simultaneously assigned experts, who are good at the production technology of bamboo charcoal, to teach bamboo farmers to produce the high-temperature carbonized bamboo charcoal for multi-functional usages.

Bamboo charcoal is made from mature bamboo of over 4 yr old, which is free from preservatives, termite-proof chemicals, glue, coatings, or other biochemical treatments.

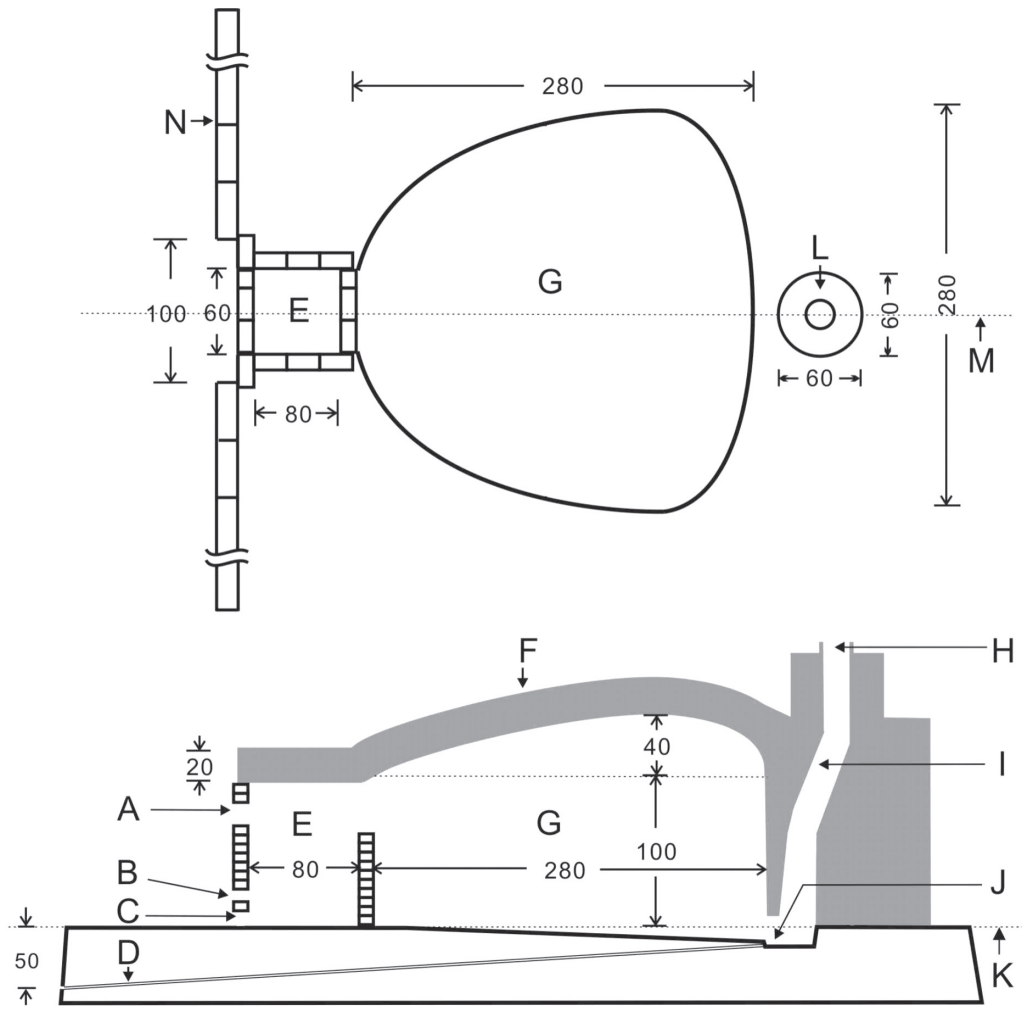

Fig. 4. Top and side views and dimensions of an earthen kiln. A, Fuel intake; B, air intake; C, ash exit; D, scupper; E, fuel chamber; F, kiln top; G, carbonization room; H, chimney; I, smoke channel; J, smoke exhaust hole; K, horizontal baseline; L, chimney skirt; M, central line; N, revetment. All dimensions are in centimeters (Lin et al. 2004).

High-temperature carbonized bamboo charcoal has powerful absorption/attachment capabilities due to its dense structure with many pores. Therefore, it can be used to regulate humidity levels and deodorize. Additionally, the specific property of far-infrared radiation emission, which is easily absorbed by the human body, is used to produce textile yarns as well to improve blood circulation and general health (CAS 2006). So, the main function of high-temperature carbonized bamboo charcoal is not to be burned for energy, which is only a kind of utilization of low value.

Using earthen kilns to produce bamboo charcoal requires only a little capital and easy operating technology, so it provides benefits for bamboo farmers. Consequently, the plan has performed well so far. In addition to

bamboo charcoal, bamboo farmers and manufacturers can obtain returns from selling the byproduct of "bamboo vinegar". Currently, there are around 40 kilns (including earthen and mechanized kilns) in Taiwan, and the production is estimated to be approximately 250 ton/yr^{-1}. In addition, to increase the competitive advantage in markets against cheaper imported bamboo charcoal and protect consumer safety, an official certification mechanism, called "CAS (Chinese Agricultural Standard)", to evaluate the bamboo charcoal quality of local manufacturers has been implemented for many years.

In the operation of the certification mechanism, several checkup items are thoroughly inspected and appraised during document reviews and on-site evaluations for applicants of the CAS certification. These checkup items include the environment of the operation area, facilities hardware, raw materials, manufacturing processes, quality, environmental hygiene, and warehouse management. In addition, the labeling must carry important information such as the index of refinement (electrical resistivity), fixed carbon content, BET value (the specific surface area), hardness, species and origin of the bamboo, manufacturing methods, shape, net weight, user instructions and important notices, production date, manufacturer, and vendor (CAS 2006).

Prospects for the bamboo industry

To promote and revitalize the bamboo industry, and to simultaneously operate in coordination with the strategy of the "Quality Agriculture Development Program", which is 1 of 6 key emerging industries (tourism, medicine and health care, biotechnology, green energy, culture and creation, and high-quality agriculture), what was proposed by Taiwan's highest government body, the Executive Yuan, to upgrade industrial competitiveness of Taiwan, Taiwanese agriculture authorities and other relevant authorities gathered together and drew up the following strategies and programs.

1. To continue developing bamboo charcoal production:
   To extend the production scale of bamboo charcoal, mechanized kilns will be increasingly produced. Activated bamboo charcoal will be developed and new uses will be created, such as in the fields of soil improvements, food additives, heavy metal absorbents, materials for bio-medicine, etc.
2. To organize cooperative associations of wood-bamboo industries:
   The government will assist owners of public and private timberland (including timber and bamboo) to organize local cooperative associations. Their objectives are to extend highly effective technologies for silviculture and harvesting, to integrate the supply chain of materials for forest farmers and forest product-processing sectors from up-, mid- and downstream so that a regional production system can be established, and to carry out research and development for domestic forest products with local characteristics.
3. To assist local manufacturers to obtain the quality certification mark "Smile MIT":
   To avoid the impacts of mass-produced cheaper products imported from China and Southeast Asia after the signing of the "Cross-Straits Economic Cooperation Framework Agreement: C-S ECFA", the Ministry of Economic Affairs (MOEA) has created a quality certification mark system called "Smile MIT" (made in Taiwan) for products that are made in Taiwan. The MOEA will assist most domestic manufacturers of wood-bamboo products to obtain the quality certification mark which can

help consumers clearly differentiate between locally made and imported products in markets, to ensure the competitiveness of local products, and prompt the production of value-added products.

4. To encourage the industries of wood-bamboo to apply for a "green building material label":
   New regulations for construction in Taiwan stipulate that the percentage of green building materials being used have to reach a 30% minimum to approach the goal of reducing carbon emissions. The percentage will be increased year by year in the future. Therefore, the Construction Institute, one of the agencies of the Ministry of the Interior (MOI), has created a system called "green building material label". To increase the utilization amount of wood and bamboo, the wood-bamboo industries will be encouraged to apply for this label to approach the concepts of "eco-green building materials", "health-green building materials", and "reuse-green building materials".
5. To create higher value-added fine bamboo craft products:
   To further increase value-added fine bamboo craft products, it is necessary to select better-quality bamboo and cooperate with bamboo artists to develop exquisite and highly beneficial products during processing. At present, exquisite bamboo furniture and bamboo swords still possess development potential among bamboo products. Most remaining factories of bamboo craft production are located in Chu-shan Township, Nantou County, in central Taiwan. A specific processing park for the bamboo industry is still in operation there. These factories can be retained because they possess the advantages of process rationalization in production management through years of accumulated experience (Chang 2005).
6. To develop the bamboo pyrolytic oil for bioenergy:
   Bamboo pyrolytic oil is produced by a rapid pyrolysis method, and this technology has moved beyond the laboratory scale. The potential contribution of pyrolytic oil production to substitute for fossil fuels as a part of boiler energy due to the abundance of raw materials has garnered more attention recently, and its development has been strengthened. This production is highly expected to enhance resource utilization of indigenous bamboo and make contributions in reducing emissions of carbon dioxide.
7. To develop bamboo pellets for bioenergy:
   Bamboo pellets are manufactured through a physical high-pressure treatment. The idea of bamboo pellets is derived from wood pellets. Because wood pellet manufacturing has advantages of less technical requirements, low capital investment, fewer environmental impacts, high market potential, and feasibility to develop local energy systems with pellet boilers, this product has high market potential in the world. Some studies showed that wood pellet consumption has grown from 2.7 million short tons in 2001 to 12.6 tons in 2008 on a global basis, which is an annual growth rate of about 25% (Lin 2009). European countries consumed over 75% of the pellets in 2008 what is driven by EU carbon and renewable energy policies. In Taiwan, there are few timber resources and waste woody materials with which produce wood pellets, because of the policy prohibiting cutting in natural forests since 1990, yet bamboo resources are abundant and could be substituted for woody materials. The benefits of developing bamboo pellet production and its utilization in energy are expected not only for the similar benefits as bamboo pyrolytic oil production, but also creating job

opportunities in farm communities. Therefore, to develop bamboo pellets instead of wood pellets will be an important aspect of bamboo utilization in Taiwan.

To conclude, bamboo is a significant forest product, and bamboo manufacturing is an essential traditional industry in Taiwan. However, the Taiwanese bamboo industry conspicuously declined as a result of changes in the industrial environment. To promote the amount of bamboo utilization, restore the bamboo-processing industry and bamboo production once again, revive the economic activities in villages, and recover the prosperity in farms and communities, Taiwanese agricultural authorities have successfully carried out a plan for bamboo charcoal production in abundant bamboo forest areas with an official certification mechanism of products. The related authorities have planned several beneficial projects as well. The prospects of reviving the bamboo industry in Taiwan can be expected if these projects are enhanced and continuously implemented in the coming decades.

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