# Search for Highly Value-Additive Utilization of Bamboo Grown in Damyang District Based on Physico-Mechanical Properties

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## Abstract

Representative bamboo species of Damyang district, 'the home of bamboo in Korea' are *Phyllostachys bambusoides, Phyllostachys nigra var. henonis*, and *Phyllostachys pubescens*. Bamboo culm wood of Damyang have been used mainly for making various bamboo craftworks with traditional technique by the artisan. These banal craftworks have been faced with several difficulties due to old-fashioned design and dull processing technology. Matured market which is governed by matured consumers' consciousness wants new product of high dignity and satisfactory quality. Based on the physical and mechanical properties, the proper raw material should be chosen to make highly value-additive bamboo craftworks.

According to the external and physical properties, *Phyllostachys pubescens* is not proper to make high quality craftworks. Besides the material characteristics, the bamboo craft designer must consider the consumers' behavior, the concept and mechanism of new products development and even processing facility.

Consequently, the bamboo craftworks industry of Damyang district should implement the quality assurance system in which scientific material selection, high dignity design, improved processing technology operate effectively and should investigate market circumstances to regain the fame of the past and to pull up regional economic development.

# 1. Introduction

The high value-additive utilization of bamboo became new issue among bamboo industry all around world and many researchers prepared physical and mechanical properties of bamboo(Teodoro 1925; Sekhar et al. 1962; Ueda 1980; Watanabe et al. 1980; Fangchun 1981; Lu et al. 1985; So et al. 1999). 10 mechanical properties of bamboo of worldwide researches which had been unknown to authors were summarized for utilization as the building material by Janssen(1991). He stressed that bamboo should become a completely normal building material, just as timber, steel or concrete.

Some new technologies to enhance the usage of bamboo in building industry were introduced mainly Eastern Asian countries for instance India, Philippine, and China and so on. Especially there is drastic need of bamboo utilization as building material in China under IPCC environment supported flattening technology and laminated bamboo(glubam). Unfortunately, there is almost no application of bamboo in building site except matrices of ocher wall member in old-fashioned buildings for rural residential house and the stables.

Damyang district consisting of 12 subdivisions has approximately 1,716 hectare bamboo forest and main bamboo species are *Phyllostachys bambusoides*(342 ha), *Phyllostachys nigra var. henonis*(759 ha), and *Phyllostachys pubescens*(61 ha). It has also large *Sasa borealis*(Gramineae) forest(414 ha), but *S. borealis* has soft culm of small diameter and is not proper for craftworks except bamboo luck strainer. Among three major bamboo species, *Phyllostachys pubescens* is recently used for food rather than for craftworks with infant sprout and therefore are called 'shoot bamboo'. Table 1 shows the present prevailing products in bamboo craft market in Korea which are randomly introduced to the market simply by force of habit of manufacturer or artisan without deep consideration. Prices of those goods except some musical instruments are somewhat low and low profit due to high direct cost. Value addition of manufactured products can be increased by lowering direct cost and by raising the market price.

In this study, the author suggest the necessity of developing new product made of bamboo grown in Damyang district which can perform high value-addition through the investigation of physico-mechanical properties of the bamboo and the consideration of concept and development of new products. This approach will help Damyang's bamboo craft industry regain the fame of the past and continuously develop as the representative industry of Damyang district.

Table 1. Typical bamboo craftworks products in Korean market+

| Size | Item | Price(US$) | Direct Cost, $(%) | Species |
|---|---|---|---|---|
| Large | bamboo mat | 500 | 350(70%) | mixed |
| | bamboo shelf | 60 | - | imported |
| | bamboo hanger | 50 | - | imported |
| Medium to small | bamboo screen | 20 | 18(90) | *P. nigra var. h.* |
| | bamboo wife | 50 | 45(90) | *P. nigra var. h.* |
| | bamboo cushion | 110 | 90(82) | *P. bambusoides* |
| | bamboo lamp | 150 | 130(87); - | mixed; imported |
| | b. tea table | 150 | 140(93) | mixed |
| | b. charcoal | 60 | 50(83) | *P. bambusoides* |
| | bamboo bowl | 30 | 25(83) | *P. nigra var. h.* |
| | b. luck strainer | 5 | 5(100) | *Sasa borealis*** |
| | bamboo comb | 6 | 5(83) | *P. bambusoides* |
| | bamboo tray | 15 | 13(87) | *P. nigra var. h.* |
| | bamboo basket | 30 | 27(90) | *P. nigra var. h.* |
| | bamboo scraper | 5 | 4(80) | *P. bambusoides* |
| | b. cutting block | 25 | 23(92) | *P. bambusoides* |
| | bamboo pillow | 30 | 27(90) | *P. bambusoides* |
| Musical instrument | large fife | 800 | 300(38) | mixed |
| | middle fife | 300 | 120(40) | mixed |
| | small fife | 250 | 100(40) | mixed |
| | six-holed flute | 300 | 110(37) | mixed |
| | short b. flute | 35 | 20(57) | mixed |

* mixed : *P. bambusoides, P. nigra var. henonis*
** Gramineae

# 2. Characteristics of Bamboo of Damyang for craftworks

So et. al(1999) performed the comprehensive study on the external, anatomical, physical, and mechanical properties of three main bamboo species grown in Damyang district in Korea as the part of research for the development of fascinating bamboo mat. In this study, the author reviewed the physico-mechanical properties to get the technical and scientific idea for the development new highly value-added bamboo products.

## 2.1 Anatomical and physical properties of bamboo

Table 2 shows the external configuration and major dimension at the breast height. Internodal length and thickness are considered to be important for the musical instruments design and in this point of view, *P. pubescens* is thought to be improper for the craftworks due to its short clear length and thick culm wall esp. for musical instrument as fife. As shown in Table 3, there is no significant difference among three bamboo species.

Table 2. Characteristics of sample bamboo grown in Damyang

| Species | Height(m) | Clear length(m) | Internodal* length(cm) | Diameter* (mm) | Thickness* (mm) |
|---|---|---|---|---|---|
| *P. bambusoides* | 16.2±0.6 | 7.2±1.0 | 27.8 | 87.6 | 8.5 |
| *P. nigra* var. *henonis* | 14.6±0.9 | 6.3±0.8 | 24.2 | 83.0 | 7.5 |
| *P. pubescens* | 13.4±0.4 | 4.4±0.6 | 20.7 | 98.3 | 11.1 |

Note:* ; data from breast height

Table 3. Anatomical characteristics of bamboo grown in Damyang

| Species | Epidermis | Hypodermis | Proto-phloem | Tylosis | Vessel type |
|---|---|---|---|---|---|
| *P. bambusoides* | 1 layer | 2~3 layer | present | present | reticulate |
| *P. nigra* var. *henonis* | 1 layer | 1~2 layer | present | present | reticulate |
| *P. pubescens* | 1 layer | 1~2 layer | present or absent | present | reticulate |

Moisture in bamboo tissue may give harmful effect to the appearance and therefore *P. nigra* var. *henonis* is regarded as suitable for making bamboo craftworks like bamboo accessories and various living tools. This species is also considered to be proper to make musical instrument due to its high specific gravity concerning sound radiation and transmission of wind instruments(Table 4).

Moisture contents were measured by Korean Industrial Standard KS F2201. Drying technology should be prepared for each bamboo species to guarantee the quality of final bamboo craftworks.

Table 4. Green moisture content and specific gravity of bamboo grown in Damyang

| Species | Green M.C. (%) | Specific gravity of internode (g/cm³) | | | Specific gravity of node (g/cm³) |
|---|---|---|---|---|---|
| | | Outer(1/3) | Inter(1/3) | total | |
| *P. bambusoides* | 86 | 0.78 | 0.45 | 0.61 | 0.69 |
| *P. nigra* var. *henonis* | 67 | 0.85 | 0.52 | 0.66 | 0.74 |
| *P. pubescens* | 110 | 0.70 | 0.50 | 0.58 | 0.67 |

Anisotropic shrinkages in three directions were tested by KS F 2203 using traveling microscope with 0.001 mm precision. Table 5 shows somewhat interesting data on the shrinkage of three bamboo species. Though its high specific gravity, *P. nigra* var. *henonis* shrinks somewhat low in both direction and *P. pubescens* shows twice T/R ratio compared with other 2 bamboo species. Designers and artisans have to consider the difference of this characteristics for the consumers' satisfaction.

Table 5. Shrinkage and water absorption of bamboos grown in Damyang

| Species | Total shrinkage (%) | | | | Water absorption(g/cm²) | | |
|---|---|---|---|---|---|---|---|
| | Radial direction | Tangential direction | Longitudi. direction | T/R ratio | Radial direction | Tangential direction | Longtitudi. direction |
| *P. bambusoides* | 7.94 | 6.06 | 0.09 | 0.76 | 0.071 | 0.041 | 0.582 |
| *P. nigra* var. *henonis* | 5.75 | 5.53 | 0.11 | 0.96 | 0.059 | 0.033 | 0.618 |
| *P. pubescens* | 6.45 | 5.81 | 0.20 | 0.90 | 0.059 | 0.031 | 0.301 |

## 2.2 Mechanical properties of bamboo

Mechanical properties are directly related to the workability and serviceability of bamboo craftworks according to the in-use condition and required performance.

Most of mechanical properties except cleavage strength are proportional to the specific gravity of bamboo. The designer also consider these properties in the selection of the cutting tool and in

designing of high performance products.

Table 6. Mechanical properties of bamboos grown in Damyang (1)

| Species | Compressive str. (kgf/cm²) | Tensile str. (kgf/cm²) | Bending str. (kgf/cm²) | Young's modulus (×10³kgf/cm²) | Shear str. (kgf/cm²) |
|---|---|---|---|---|---|
| *P. bambusoides* | 686 | 2,798 | 1,525 | 82.7 | 170 |
| *P. nigra* var. *henonis* | 734 | 2,854 | 1,719 | 108.3 | 190 |
| *P. pubescens* | 535 | 2,277 | 1,448 | 78.6 | 168 |

Table 7. Mechanical properties of bamboos grown in Damyang (2)

| Species | Cleavage str. (kgf/cm) | Impact str. (kgf · m/cm²) | Hardness (kgf/mm²) | | |
|---|---|---|---|---|---|
| | | | outer | core | inner |
| *P. bambusoides* | 93.9 | 1.94 | 2.67 | 1.38 | 1.45 |
| *P. nigra* var. *henonis* | 86.2 | 2.28 | 3.23 | 1.72 | 2.27 |
| *P. pubescens* | 97.5 | 2.15 | 2.42 | 1.01 | 2.05 |

# 3. Search for Highly Value-additive Utilization of Bamboo

## 3.1 Concept and sort of new products development

Consumers in market always want higher quality of goods for its price under the market maturation era these days in which the economic growth becomes blunt. Therefore, it is so important for an enterprise to recognize the consumers' evaluating method on the goods in market for the products strategy including new products development. In a viewpoint of consumers, new products should have new value which they have never seen. New products can be sorted as follows;

- A product having improved quality compared with existing product
- A product having new uses which never have been found
- A product having innovation in concept compared with existing product
- A product having related concept with existing product
- A product to be launched in new market
- A product to be rehandled which has never been handled
- A product appeared as good for the first time by an enterprise

• A product or a service made for sale for the first time by an enterprise

## 3.2 Consumer behavior and condition of new products

Main factor in market change is the maturation of consumer's consciousness. Matured era can be described as 'meaning' selling times, the period turning to 'wants' from needs, the age selling not goods but 'emotion', the time in which 'high tech' and 'high touch' coexist and so on. So we can specify consumers' behavior reflecting the structure of their consciousness in market matured era as follows;

a) Diversification of the consumers' sense of value

Every consumer pursues various style in foods, clothing, living tools, furniture and so on in these material richness times to represent his/her individuality.

b) Representation of individual sense of value

The trend of individual ownership expands the demand in market and reflects his/her preference in purchasing to show his/her own sense of value e.g. sincere living, joyful and healthy life, human relationship and convenience in life.

c) Change in the standard of value

A criterion in goods choice is changing from functional value to emotional value and finally semantic or informative value. This generates the complexity in purchasing such as value judgement in individual stand, intention to price or quality, necessary timing and quantity, and even the softness(urban-like sense and cultural taste).

## 3.3 Development of highly value-additive bamboo craftworks

Old-fashioned bamboo craftworks attract no more consumers' attention in the present market. As stated above, every consumer is ready to pay money to get high quality and value for the luxurious living and individuality representation in his/her life. Therefore manufacturer of bamboo craftworks must consider the requirement which consumer seek for in the purchased goods to get the high value-addition. Highly value-additive production is mainly concerned with manufacturer, who must consider the material characteristics, workability and design for the reasonable selection of raw material, effective production and satisfactory products in the consumers' view point.

Highly value-added bamboo craftworks can be sorted into three division i,e., personal or tool

adornments, tools for living of dignity and high quality musical instrument and the actual production of these goods can be implemented by the consideration of material characteristics, design of high dignity, and qualitative manufacturing technology.

a) Personal or tool adornments

- brooch
- hair pin
- keyboard ornament

b) Tools for living of dignity

- Cellular phone stand
- Jewelry case
- pen/pencil case
- small furniture

c) Musical instruments

- High quality wind instruments : fifes and flutes
- High quality stringed instruments : *Haegeum*(Korean violin)
- High quality percussion instruments : mallets

# 4. Conclusion and Suggestion

Highly value-additive bamboo products should be designed and developed for the regaining the Damyang's fame of the past and the pulling up the regional economy, because existing bamboo craftworks industry has been sluggish with old-fashioned design and banal technology. According to external and physical properties, *Phyllostachys bambusoides* and *Phyllostachys nigra var. henonis* are proper species for making the bamboo craftworks, but more detailed consideration of these characteristics is inevitable to select the most appropriate bamboo species for the satisfactory final products. Furthermore, the mechanical properties are also considered for the workability and serviceability in-use condition. The designer for bamboo craftworks must understand consumers' behavior and the concept and mechanism of new products development as well as the material characteristics of bamboo. Quality assurance system should be also implemented for the sustainable development of bamboo craft industry.

Administrative support of Damyang district for the development of design and technology and the improving of processing facility will help bamboo craft industry normalize and develop continuously under green growth era.

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