

Properties of Charcoal Board Manufactured from Domestic Wood Waste¹

In Su Seo², Hwa Hyoung Lee^{2†}

SUMMARY

This research was carried out to examine the properties of black charcoal board, in order to find the proper manufacturing condition for the black charcoal-board made of the charcoal. The charcoal in this study was distilled from domestic wood waste, and it were also the purpose of this study to see if the black charcoal-board has the advantageous properties of charcoal as a well-being building material against the sick house problem. Domestic wood waste was consisted of MDF 40%, PB 30%, plywood 15% and wood 15%, respectively. Black charcoal board was produced by hot pressing with following conditions; temperature 170 °C, three stage pressing cycle of 40-10-40 kgf/cm²(1min.-2.5min.-5min.) and non formaldehyde adhesives [P15%+M5%:MDI(M), poly vinyl acetate emulsion(P). Fine mixed particle size [#6-12(16.9%), #12-18(16.7%), #12-40(47.2%), #40-60(9.5%), #60-100(5.9%), less than #100(3.8%)] gave better results than larger particle size [over #6(33.8%), #12-18(17.7%), #12-40(37.7%), #40-60(6.4%), #60-100(2.6%), less than #100(1.8%)] . Final moisture content of the mat was best at 36%. Black charcoal-board showed less MOR and IB(internal bond), more WA(water absorption) than that of white charcoal-board. Black charcoal board showed not only the same gas adsorption and dimensional stability as white charcoal board but also good cutting, nailing and drilling for indoor environment systems.

Keywords: charcoal board, final mat moisture content, charcoal particle size, hot pressing cycle, domestic wood waste

1. INTRODUCTION

Charcoal is the blackish residue consisting of mainly impure carbon obtained by partial burning or destructive distillation of organic material. It is usually produced by heating wood in the absence of oxygen. The charcoal shows soft, brittle, lightweight, black, and porous properties. And it is composed of 50% to 95% carbon with the remainders of volatile chemicals and ash. Charcoal, being almost pure carbon, yields a larger amount of heat in proportion to its volume rather than a corresponding quantity of wood; as a fuel it has the further advantage of being smokeless. Generally, the charcoal which has higher carbonization temperature shows the higher ignition temperature. When the charcoal has the higher remainders of volatile chemicals in it, the charcoal shows the lower ignition temperature. (Shin et al, 1983). An increase of C content as well as a decrease of H

Received for publication: Feb 7, 2010 ; Reviewed: March 6, 2010 ; Accepted: May 15, 2010

1) This study was supported by Technology Development Program of the Ministry of Agriculture and Forestry, Republic of Korea.

2) College of Agriculture and Life Science, Chungnam National University, Daejeon 305-764, Korea

† Corresponding author: Hwa Hyoung Lee(E-mail: hhlee@cnu.ac.kr)

content was observed up to about 600 °C with increasing the carbonization temperature. The changes in the ratio of atoms became stable at above 600 °C (Jo et al 2009, Krzesinska and Zachariasz. 2007). In the modern method, wood is raised to a high temperature in an iron retort, and industrially important byproducts, e.g., wood alcohol, acetone, and acetic acid, are saved by condensing them to their liquid form. Recently, charcoal has attracted a lot of attention not only by its environmentally friendliness but also by its unique functional characteristics, such as catalysis, moisture absorption, soil conditioning, filtering, deodorization, purification, far-infra red emission, and electromagnetic shielding effects. (Chung 1975, Kong and Kim 2002, Jo, Ahn and Choi 2005, Lee et al. 2001, Lee et al. 2003, 2005, Jo et al. 2009, Lee and Kim 2002, Kim and Lee 2006, Shin et al 1983, Shin and Kim 2006, Wang and Hung 2003). Charcoal could be activated to increase its effectiveness as a filter. Activated charcoal readily adsorbs a wide range of organic compounds dissolved or suspended in gases and liquids. Charcoal is often used as filter materials to remove bacteria and undesired tastes in air or water. Historically, charcoal has been used in great quantities for industrial fuel. Charcoal was consumed in the past as dietary supplement for gastric problems in the form of charcoal biscuits. Now it can be consumed in tablet, capsule or powder form for the digestive benefits. Charcoal absorbs gases and toxins to help heartburn, flatulence or indigestion. (Rolland 2006, Braithwaite 1856).

Indoor air quality could affect health and comfort of building occupants. The more people are increasingly interested in home air purification because of a lot of pollutants of indoor air quality and sick house syndrome. Moreover, recent findings have demonstrated that indoor air is often more polluted than outdoor air. For improving the quality of indoor air, basket and container filled with a lot of lump of charcoal were placed beside television and computer, in the wardrobe, and in the shoe closet. However, these kind application of charcoal would not be the best way in terms of aesthetic beauty and efficiency. Reclamation of charcoal under the building site gives higher electric potential, higher anion emission, and better environment condition for human body such as the inhibition of oxidization, air purification, gas absorption, humidity control and far-infra red emission. Recently, non-woven fabric sack filled with charcoal powder is placed under floor and living room, and non-woven fabric sheet with charcoal powder is installed in the wall for removing toxic gas and smell. Especially, volatile organic compounds and formaldehyde are regulated in indoor air environment. Since people spend most of their time today at home or in an office, long-term exposure to VOCs in the indoor environment can contribute to sick building syndrome. Many building materials such as paints, adhesives, wall boards, and ceiling tiles emit formaldehyde, can occur to the mucous membranes and can make a person irritated and uncomfortable. There are also many sources of VOCs in office buildings, which include new furnishings, wall coverings, and office equipments such as photocopy machines which can emit VOCs into the air. 『The indoor air quality control law of multiplex use facility etc.』 has been revised and enforced from on May 30th, 2004 (Lee 2006). Proposition of this indoor air quality control law which has concerned introducing a quality-certification process of the wood panel products for the production, imports, circulation and the use(Article 13 and Article 14) has given lawmaking notice on May, 2009 and this law will be put into force from 2012.

Lee et al (2004, 2005) has attempted to use the advantage properties of charcoal board for promoting a pleasant residential environment through the improving indoor air quality. Lee et al (2006) developed the new method for the fast making the charcoal board and charcoal board composite with excellent properties such as dimensional safety, gas absorption, and far-infra red emission for building interior material. Park et al (2009) also invented manufacturing techniques of

crack-free carbonized board from fiberboard. Wood-ceramics are developed from woody waste as a new porous carbon materials obtained by carbonizing woody material impregnated with thermosetting resin, such as phenol resin, in a vacuum furnace at high temperatures(Fan et al 2001, Hirose et al 2001 2002, Iizuka et al 1996, Kano et al 1997, Lee and Kim 2002, Oh and Okabe 2002, Okabe and Saito 1996). But these wood-ceramics have been focused to special use and have a lot of problems awaiting solutions such as mass production process of large scaled carbonization and easier process for cutting, nailing and drilling for indoor environment systems.

The aim of this study was to deeply examine the properties of black charcoal board, to characterize the properties of the black charcoal board manufactured from domestic wood waste which has caused problems for waste disposal, and to see if it has the advantageous functional properties of charcoal as a well-being building material for indoor environment.

2. EXPERIMENT

2-1 Materials

2-1-1 Domestic wood waste

Domestic wood waste was obtained from Seyong Co. a charcoal manufacturing company. Domestic wood waste was collected in Seoul. It was composed of MDF 40%, PB 30%, plywood 15% and wood 15% approximately. Domestic wood waste was crushed into the particle size of 10 mm

2-1-2 Charcoal

Black charcoal was made by continuous dry distilled retort from municipal wood waste in 20 minutes of 700-800 °C. To evaluate the influence of the charcoal particle size on the board properties, two kinds of charcoal particle size were applied in this study; the one is original size of over #6(33.8%), #6-12 (17.7%), #12-40(37.7%), #40-60(6.5%), #60-100(2.5%) and below #100 (1.8%) , the other size is crushed type of #6-12 (16.9%), #12-40(63.9%), #40-60(9.5%), #60-100(5.8%) and below #100 (3.9%).

2-1-3 Adhesives

Dipenylmethanediisocyanate(MDI) and poly vinyl acetate emulsion(PVA) were used as a non formaldehyde adhesive.

2-2 Methods

2-2-1 Industrial analysis of charcoal

Industrial analysis for moisture content, ash, volatile content, and fixed carbon of 60 mesh charcoal were measured according to KS M 1802(Test methods of activated charcoal) .

2-2-2 Manufacturing of charcoal board

Excellent functional charcoal-board manufacture process was developed by Lee(2005) with the proper condition of high moisture content of final charcoal particle mat(MC 36%), non formaldehyde adhesives(MDI, poly vinyl acetate emulsion) and three stage pressing cycle of 40-10-40 kgf/cm²(1min.-2.5min.-5min.). Final charcoal particle mat was pressed by hot press at

170°C. All boards were manufactured to 20cm×20cm×1cm in dimension and were made with 4 replications.

2-2-3 Physical- and mechanical- properties of charcoal-fiberboards.

The physical and mechanical properties of a charcoal board were measured according to KS F 3200(1997). Internal bond (IB) tests were carried out with specimens of 50 by 50 mm. Bending strength and internal bond were measured by an UTM (Universal testing machine, HS-50K, Hounsfield, England).

2-2-4 Thermal conductivity and electric conductivity

Thermal conductivity was determined by QTM 500(Kyoto Electronics, Japan) from specimens of 50 by 150 mm and electric conductivity was calculated with 601 Multimeter (Hongchang, Korea).

2-2-5 Far infra-red emissivity

Far infra red emissivity was calculated by FT-IR (M2410-C, MIDAC, USA)

2-2-6 Ethylene gas adsorption

Ethylene gas adsorption of charcoal board was carried out by a Gas chromatography(GC-14B, Shimazu, Japan).



(A) Domestic Wood Waste (B) Crushed Raw Material (C) Continuous Dry Distilled Retort

Fig1. Domestic wood waste, crushed raw material and continuous dry distilled retort



(A) Original Type (B) Crushed Fine Type

Fig2. Black charcoal-board depending on the charcoal particle size

3. RESULTS AND DISCUSSION

3-1 Industrial analysis of black charcoal

Properties of black charcoal made from domestic wood waste depend upon the carbonization process, and the type and the size of raw materials. Industrial analysis of this black charcoal is shown in table1. Fixed carbon values of wood based panel products including LPM overlaid products such as particleboard, MDF and plywood showed 80.15-88.78% by Kong and Kim(2000). As shown in Table 1, the contents of ingredient in the charcoal of this study showed lower value of the fixed carbon and slight higher in volatile content and ash than those of the charcoal of other study(Kong an Kim, 2000). This difference might be come from the different charcoal manufacturing methods.

Table 1. Industrial analysis of charcoal

Ingredient	Content (%)
Moisture content	6.05
Volatile content	16.55
Ash	15.54
Fixed carbon	61.86

3-2 The physical properties of black charcoal board

The Fig 3 shows the physical properties according to the charcoal particle size and the final mat moisture content of charcoal board. White charcoal board gave excellent results in dimensional stability, gas adsorption and far-infrared emission. The smaller particle size, the final mat moisture content (FMC) of 36-60% and the three stage pressing cycle showed the best result for the manufacture of white charcoal board (Lee,2005). Therefore with help of this Lee’s result, we compared crushed fine mixed charcoal particle size with original charcoal particle size. There are no differences between two types in density, moisture content and thickness swelling but water adsorption. Thickness swelling of below 2% showed best dimensional stability. The moisture content of charcoal-board showed around 7%. Such results satisfied the Korean standards of 5-13%. The water absorption of the smaller charcoal particle was showed a little increase. The final mat moisture content of 36% gave the highest water absorption value 82%. Park(2009) reported 0.47-0.76g/cm³, density of crack-free carbonized board from fiberboard and said that this density depended upon carbonization temperature and MDF thickness. In this study, the density showed same tendency in spite of different carbonization method and manufacturing process of charcoal board.

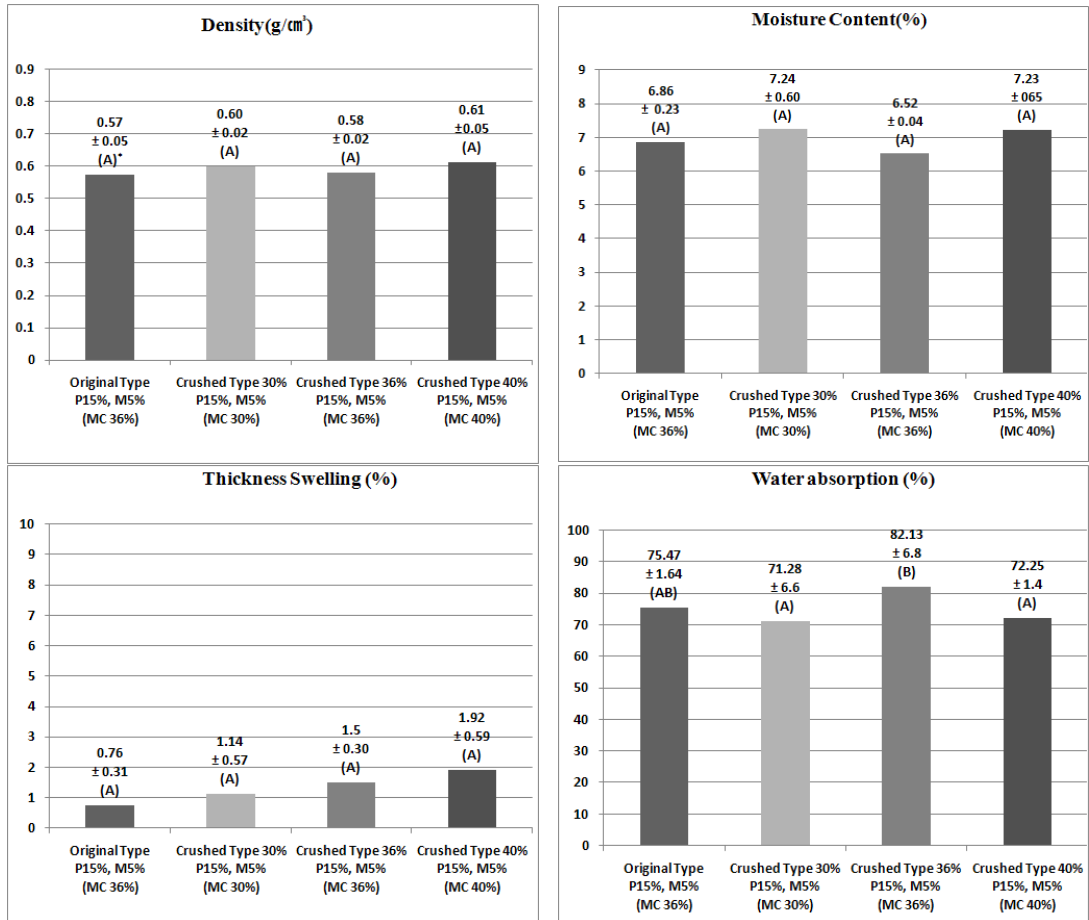


Fig 3. Physical properties of charcoal board according to the charcoal particle size and final mat moisture contents (* Duncan multiple test)

3-3 Mechanical properties of charcoal-board

The mechanical properties of black charcoal board were shown in Fig 4. The board made of crushed fine particle size gave the better bending strength (MOR). Same tendency was shown in MOE and IB. Lee et al (2005) had reported MOR of the white charcoal board was 43kgf/cm² at the same condition. Comparing with white charcoal board, black charcoal board showed lower bending strength, only 17kgf/cm² which was best at final moisture content 36%.

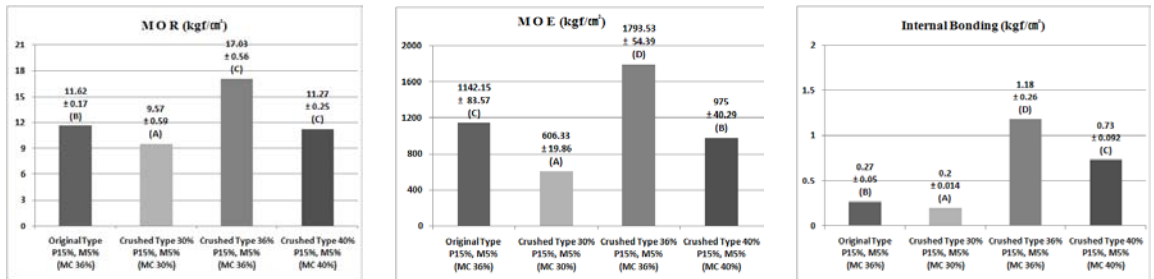


Fig 4. Mechanical properties of charcoal board according to the charcoal particle size and final mat moisture content

3-4 Nail withdrawal resistance of black charcoal board

Fig 6 shows the nail withdrawal resistance perpendicularly to the board surface (Fig 5). There was no difference statistically in the nail withdrawal resistance between original type and crushed fine type of final mat MC 36%, but inappropriate type of final mat moisture content such as crushed-30% and crushed-40%, showed lower value in the nail withdrawal resistance. Black charcoal board was nailed and sawed easily. The nail withdrawal resistance of black charcoal board was above 3 N/mm which was one fifth of *Pinus densiflora* (Lee 2002).



Fig 5. Specimen of nail withdrawal test

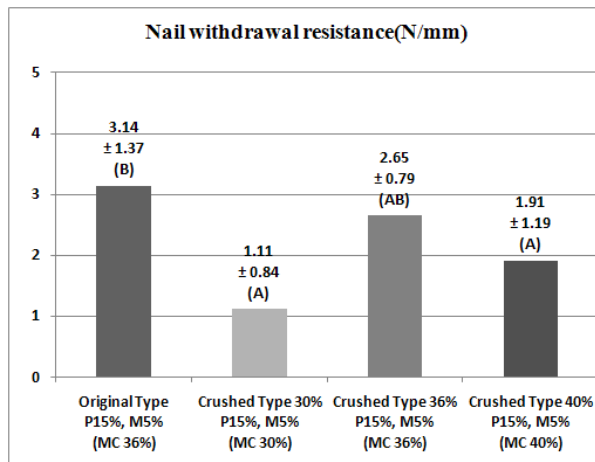


Fig 6. Nail withdrawal resistance of black charcoal board

3-5 Thermal conductivity, electric conductivity and Far infra red emissivity

The thermal conductivity and the electric conductivity of the charcoal board samples are shown in Fig 7. Thermal conductivity of softwood lumber at 12% moisture content was in the range of 0.1-to 1.4W/(m. °K)(USDA,FPL 1999) compared with 216 for aluminum, 0.9 for concrete, 0.036 for mineral wool and 0.138 for black charcoal board. This charcoal board showed good insulation properties. The electric conductivity of wood varies greatly with moisture content, especially below the fiber saturation point. Resistivity is about 10^{14} to $10^{16}\Omega$ -m for oven-dry wood and 10^3 to 10^4 for wood at fiber saturation (USDA,FPL 1999). But the electric conductivity of charcoal increases along with increased carbonization temperature (Lee et al 2001). The electric conductivity of air dried black charcoal board showed about 13-16 Ω -m. Far infra red emissivity of black charcoal board showed 92%, the same emission as white charcoal board and higher than that of woodceramics (Okabe et al. 1996).

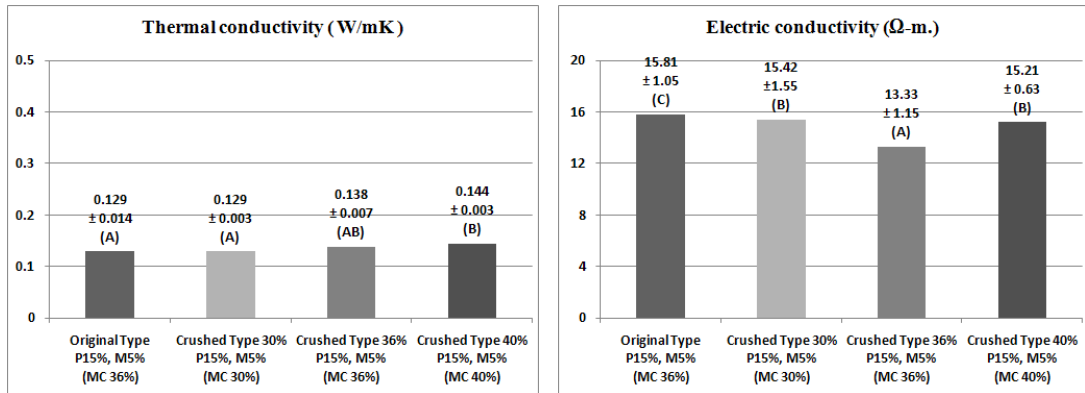


Fig 7. Thermal conductivity and electric conductivity

Table 6. Far infra-red emissivity of black charcoal board

	Far infrared emissivity(%)	Emission power
White charcoal board	92.9	4.31 X 100
Black charcoal board	92.2	3.72 X 100

Temperature at test: 40 °C, Wave length at test : 5-20 μ m

3-6 Ethylene gas adsorption

The ethylene gas adsorption of black charcoal board from domestic wood waste is shown in Fig 8. Ethylene gas adsorption of black charcoal board gave good adsorption capacity and showed the same adsorption capacity as that of the white charcoal board.

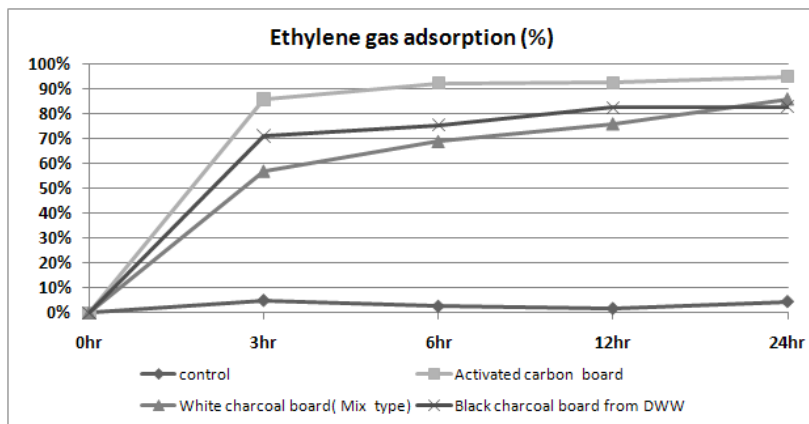


Fig 8. Ethylene gas adsorption of black charcoal board from domestic wood waste

4. CONCLUSION

This research was carried out to find the properties of black charcoal-board using the charcoal carbonized from domestic wood waste, and to see if it has the advantageous properties of charcoal as a well-being building material against the sick house problem. The black charcoal board was produced with following hot pressing condition; press temperature of 170 °C, three stage pressing cycles of 30-10-30 kgf/ cm² (1min.-2.5min.-6min.) and non formaldehyde adhesives [P15%+M5%:MDI(M), polyvinyl acetate emulsion(P). Crushed fine mixed particle size [#6-12(16.9%), #12-18(16.7%), #12-40(47.2%), #40-60(9.5%), #60-100(5.9%), less than #100(3.8%)] gave better results than original larger particle size [over #6(33.8%), #12-18(17.7%), #12-40(37.7%), #40-60(6.4%), #60-100(2.6%), smaller than #100(1.8%). Black charcoal-board showed less MOR and IB, more WA (water absorption) than that of white charcoal-board. Black charcoal board showed not only same gas adsorption and dimensional stability as white charcoal board but also good cutting, nailing and drilling for indoor environment systems.

Since the black charcoal board showed equivalent or better functional properties than those of conventional white charcoal board, the black charcoal board in this study could be widely used as a interior construction material.

5. REFERENCE

- Braithwaite, J. 1856. *The Retrospect of Practical Medicine and Surgery*. W. A. Townsend Publishing Co. p 292.
- Chung, D.K. 1975. *Forest Products*. Jin Myung Pub.Co. p 255-256
- Fan, T. X., T. Hirose., T. Okabe. and D. Zhang. 2001. Surface area characteristics of wood ceramics. *Journal of Porous Materials*. 8(3):211-217.
- Hirose, T., T. X. Fan., T. Okabe. and M. Yoshimura. 2001. Effect of carbonization temperature on the basic properties of woodceramics impregnated with liquefied wood. *Journal of Materials Science*. 36(17):4145-4149.

- Hirose, T., B. Zhao., T. Okabe. and M. Yoshimura. 2002. Effect of carbonization temperature on the basic properties of wood ceramics made from carbonized bamboo fiber and liquefied wood. *Journal of Materials Science*. 37(16):3453-3458.
- Iizuka, H., M. Fushitani., M. Ohtsuka., T. Okabe., K. Saito. and K. Hokkirigawa. 1996. Mechanical properties of porous carbon materials: Woodceramics. *Journal of Materials Science Letters*. 15(20):1770-1772
- Jo, T.S. B. J. Ahn. and D.H. Choi. 2005. Changes of adsorption properties of woody charcoals prepared by different carbonizing temperatures. *Mokchae Konghak* 33(3):45-52
- Jo, T.S. et al. 2009. Changes of chemical bond in woody charcoal from different carbonization temperatures. *Mokchae Konghak* 37(1):87-93
- Kano, M., M. Michihiko., T. Okabe. and K. Saito.1997. Specific heat capacity of new porous carbon materials: Woodceramics. *Thermochimica Acta*. 292(1/2):175-177.
- J.P Lee and B.R Kim 2006. Studies on utilization of bark by carbonization. *Mokchae Konghak* 34(1):40-51
- Kong, S.W. and B.R Kim. 2000. Development of carbonization technology and application of unutilized wood wasdtes(II) *Mokchae Konghak* 28(2):57-65
- Kong, S.W. and B.R Kim. 2002. Adsorption characteristics of charcoals of major Korean wood species and wood based materials. *Mokchae Konghak* 30(4):33-40
- Krzesinska M., and J. Zachariasz. 2007. Correlation between the carbonization temperature and the physical parameters of porous derived from *Yucca flaccida* III International seminar on Physics and Chemistry of Solids. *Journal of Physics: Conference Series* 79(2007)012012, IOP Publishing
- Korean Standard Association. 1993. KS M 1802. Test methods activatied carbon.
- Korean Standard Association. 1997. KS F 3200. Fiberboard.
- Lee, D.W. and B.R. Kim 2002. Effect of carbonized wastewoods on purification of wastewater. *Mokchae Konghak* 30(1):34-39
- Lee, J.Y. et al. 2001. Charcoal and Wood Vinegar.. pp23, Dae Yang Pub. Co. in Korea.
- Lee, H.H. and G. E. Kim. 2002. Physical and mechanical properties of clay-woodceramics from 3 layers-clay- wood particleboard. 2002 Proceedings of the Korean Society of Wood Science and Technology fall meeting. 62-67.
- Lee, H. H. and G. E.Kim. 2002. Nail & screw withdrawal resistance of OSB made from domestic bamboo. *J. of Korean Society of Furniiture Tech.* 13(3):1-6
- Lee, H. H. and G. E. Kim. 2003. Ethylene gas adsorption capacity and preserving effect of fruit freshness of charcoal-fiberboard by wet forming process. *J. of Korean Society of Furniture Tech.* 14(1):1-9
- Lee, H. H., Y. M. Cho and H.S Park. 2005. Manufacture and properties of white charcoal board in relation with final mat moisture content and charcoal particle size. *Mokchae Konghak* 33(3):22-29
- Lee, H. H. et al. 2004. Development of charcoal containing new materials for produce packing, agricultural supplies, and building composies. Ministry of Agriculture and Forestry. 190p
- Lee, H. H., S. S. Jang and J. S. Lee. 2006. Eco-Woodbased Environmental Science. NURI Academy of Ecocity Program.p345
- Lee, H. H., Y. M. Cho, and H. S. Park. 2006. The manufacture of charcoal board and charcoal board composite with excellent properties such as dimensional safety, gas absorption, and far-infrared emission for building interior material. Republic of Korea, Patent No. 10-0572591

- Oh, S. W. and T. Okabe. 2002. Properties of wood ceramics made from MDF. *Mokchae Konghak*. 30(2):115-120
- Okabe, T., K. Saito and K. Hokkirigawa. 1996b. The effect of burning temperature on the structural changes of woodceramics. *J. of Porous Materials* 2:215- 223
- Okabe, T., K. Saito and K. Hokkirigawa. 1996a. New porous carbon materials wood ceramics. Pp167
- Park, S. B., S. M. Lee, J. Y. Park, and S.H. Lee. 2009. Manufacture of crack-free carbonized board from fiberboard. *Mokchae Konghak* 37(4):293-299
- Rolland, J. L. 2006. *The Food Encyclopedia: Over 8,000 Ingredients, Tools, Techniques and People*. Robert Rose. pp. p. 148. ISBN 0778801500.
- Shin, C. S. and B.R. Kim 2006. Effect of carbonized wastewoods on soil improvement(2). *Mokchae Konghak* 34(6):21-28
- Shin, D. S. et al. 1994. *Forest product chemistry*. Hyungmoon Publishing Co. Pp362-372
- USDA FPL. 1999. *Wood Handbook*. FPS catalogue no. 7269:3-15, 3-21
- Wang, S.Y. and C.P. Hung. 2003. Electromagnetic shielding efficiency of the electric field of charcoal from six wood species. *Journal of wood science* 49(5):450-454, Springer Japan.