Transactions of the Materials Research Society of Japan 28 [4] 1059-1062 (2003)

Carbonization of Wood Chips with Wood Ash

Yoichi TOMIMURA and Yutaka MAEDA
Kyushu Research Center, Forestry and Forest Products Research Institute
4-11-16 Kurokami Kumamoto 860-0862 Japan
Fax: 81-096-344-5054, e-mail: tomimu@ffpri.affrc.go.jp

Wood ash contains alkaline metals such as potassium, calcium, magnesium etc. These alkaline metals could accelerate oxidative reaction during the carbonization of wood. In order to shorten the carbonization time and to obtain charcoal with higher adsorption quality, wood chips of Japanese cedar were carbonized in the presence of wood ash. Wood ash of pine was obtained from a pottery. After carbonization, the mixture was screened and separated into charcoal and ash. The charcoal was determined in its yield and in the iodine adsorption test. The presence of wood ash shortened the carbonization time and the resultant charcoal showed slightly higher iodine adsorption at 900℃. But there was no effect at 600℃. Higher temperature is required to get enough effect in using ash as additives. A lot of wood is usually burned in a pottery and wood ash is produced. A part of ash is used in glazing pottery, but large part of it is not used. To utilize wood completely even to its ash as a recycle use in a new field would be another way of saving forest resources.

Key words: woody waste materials, carbonization, wood chip, wood ash, adsorption test

1. INTRODUCTION

Charcoal has been used as fuels for a long time in the history of humans. However, charcoal is also a promised material to clarify water and air or to adjust the humidity of atmosphere. Among these properties adsorption of pollutants will be the most useful in the future as environmental problems become serious. On the other hand, wood waste materials from lumber mills and thinning wood left in the forest are not fully utilized. Manufacturing charcoal or active carbon from these unutilized wood resources and using them as adsorption agent will be great help in protecting environment and saving natural resources. In the course of manufacturing active carbons, high content of inorganic substances often reduce the yield of carbon and cause unfavorable effect on the resultant carbon. Some kind of inorganic materials such as alkaline metals accelerate the activation reaction too much and reduce the surface area of carbons [1-4]. Recently active carbons with quite high surface area have been manufactured by the activation using potassium hydroxide [5, 6]. However this method requires a lot of chemicals and the chemical is so corrosive and difficult to deal with [7]. Carbonization method with high cost chemicals is not suitable for treating woody waste materials. Wood itself contains a small amount of ash including alkaline metals such as potassium, magnesium, calcium etc. Among them potassium in wood ash has been used as inorganic fertilizer in traditional agriculture. This potassium in wood ash could be helpful in accelerating oxidative reaction during the carbonization. Nowadays it is difficult to obtain a lot of wood ash especially pure wood ash. Incineration centers for city trash produce a large quantity of ash but they often contain harmful substances such as dioxins and heavy metals. The most promising place to obtain pure wood ash is a pottery. Especially a traditional pottery uses only red pine wood as fuel to maintain high temperature. A part of resultant wood ash is used in glazing pottery. But large part of it is not utilized or at most used as inorganic fertilizer in rural areas. Red pine wood ash contains considerable amount of alkaline metals, so it could be used as a substitute of high cost chemicals for activation to some extent. If the ash works as a catalyst in carbonization of woody waste materials, carbonization time would be shortened and the adsorption property of resultant charcoal would increase. In this paper, wood chips were carbonized in the presence of wood ash and the resultant charcoal was examined as to the yield and its adsorption property.

2. EXPERIMENTAL

2.1 Carbonization of wood chip with ash

Japanese cedar wood chips were used as raw materials. The average size of a chip was 15mm x 15mm x 3mm. Wood ash was obtained from a pottery in Tsukuba area. Wood ash was screened with 60 mesh screen to remove ash lumps and alien substances. Mixing wood chips with wood ash was carried out in a small stainless steel box. The weight ratio of the chip and ash was approximately 1: 1. To make sure close contact of the ash to the surface of the chips, a small amount of water was added to the mixture and mixed thoroughly. The carbonization was carried out in a reactor as Fig. 1.

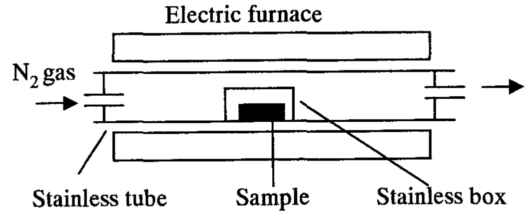

Fig. 1. Reactor used for carbonization of samples.

Each sample was set into a stainless steel box and inserted into a reactor made of stainless steel tube which was set in an electric furnace. The electric furnace used in this study was in the size of 35cm long, inner diameter 8cm with 4kw heater, 200V, 20A. The stainless tube was heated under the flow of nitrogen gas 1*l*/min. Carbonization temperature was set at 600℃ and 900℃. Carbonization time was determined after the temperature of the reactor reached 600℃ or 900℃. It took about 25 minutes from room temperature to 600℃and 40 minutes to 900℃. After the carbonization, the reactor was cooled down to the room temperature and the sample was taken out then sieved with 60 mesh screen to remove the ash fraction. As a control, wood chip without ash was carbonized in the same process under the same conditions.

2.2 Carbonization of wood chip with potassium hydroxide

To compare the difference of properties of charcoals from wood chip with ash and from wood chip with caustic alkaline chemicals, wood chip and potassium hydroxide were carbonized. In this case, three samples were prepared by mixing wood chip with 0%, 15%, 50% potassium hydroxide pellets of wood chip weight. After carbonization, these samples were successively washed with water, dilute hydrochloric acid, then with water again to remove chemicals. Dried samples were determined yield and adsorption properties.

2.3 Determination of charcoal property

The resultant charcoal fraction was washed with water to remove the fine particles of wood ash. Then oven dried charcoal was crushed, ground, sieved with the screen of aperture 150 μ m. After that the samples were subjected to the adsorption test according to JIS K1470. Specific surface was determined by the BET method using Belsorp 18 Plus-T.

3. RESULTS AND DISSCUSSION

3.1 Ash from red pine wood xylem

Table 1. Inorganic component of ash from red pine xylem. [8]

Component	K_2O	Na_2O	CaO	MgO
Content (%)	14.31	0.99	53.64	10.69

Fe_2O_3	Mn_3O_4	P_2O_5	SO_3	SiO_2
0.11	3.34	6.05	3.51	2.61

Table 1 shows the inorganic component of the ash from red pine wood xylem. In the ash of red pine wood, main alkaline metals are potassium oxide, sodium oxide, calcium oxide and magnesium oxide. Among them calcium oxide content is over 50%, and the content of potassium oxide, magnesium oxide are respectively over 10%. These compounds are amount to 80% of total ash weight. Especially calcium and potassium are useful alkaline metals to accelerate oxidative reactions during the carbonization process. In this work, at first water soluble fraction of the ash was used to treat wood chips but even hot water was used, soluble fraction of the ash was only about 5%, so small to cause enough effect on carbonization. There was no difference in the charcoal properties and yield between treated wood and the control. Therefore whole ash was used in mixing with wood chips. In the process of carbonization, at high temperature around 1000℃, even a part of solid ash gasify and could react wood chip surface.

3.2 Charcoal from wood chip and potassium hydroxide

Fig. 2 shows the relationship between carbonization time at 900℃ and iodine adsorption of the samples treated with potassium hydroxide. The yield of the samples decreased with the increase of carbonation time from about 20% to 12%. There was no significant difference in the yield of the samples between potassium hydroxide treated wood chip and the control. However iodine adsorption properties are quite different in these samples.

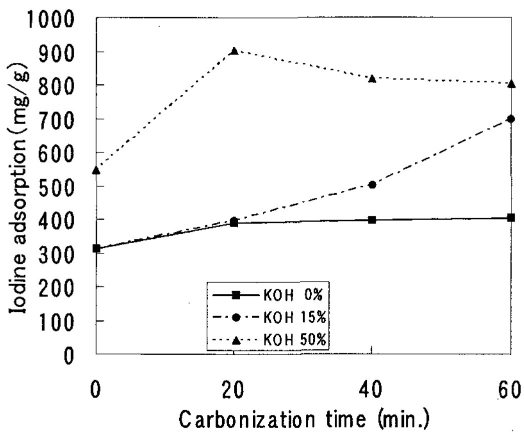

Fig. 2. Iodine adsorption and carbonization time of the charcoal from wood chips treated with potassium hydroxide carbonized at 900℃.

Samples from untreated wood chips showed constant about 400mg/g iodine adsorption from 20min to 60min at 900℃. Iodine adsorption of the samples from wood chips with 15% KOH increased gradually up to about 700mg/g in 60 min. Samples carbonized with 50% KOH showed high iodine adsorption all the time. Especially at 20min the maximum value about 900mg/g was obtained and gradually decreased with the increase of the reaction time. Specific surface determined by the BET method was 479, 739, 697, 555m^2/g at 0, 20, 40, 60min respectively. These samples showed maximum peak at 2nm in meso pore distribution. Potassium hydroxide is effective to increase the adsorption properties of the charcoal but at least 50% of the sample weigh should be added to obtain enough results. Using a lot of chemicals requires high cost in manufacturing charcoal from woody waste materials. Moreover potassium hydroxide is corrosive and in this work even stainless steel vessel was used, it was severely damaged after 2 or 3 times use in experiment. To remove chemicals after carbonization also requires additional processes. In the case of lower temperature at 600℃, carbonization was insufficient and even 50% KOH treated samples showed lower adsorption properties in comparison with the control.

3.3 Carbonization of wood chip with ash at 600℃

Instead of using chemicals, wood ash was added in the process of carbonization. Fig. 3 shows the yield of charcoal at 600℃. Ash added samples showed high yield from 35% to 40% but this was caused by insufficient carbonization. The ash layer around the wood chip surface insulated the heat from electric heater.

Fig. 4 shows iodine adsorption of the samples carbonized at 600℃. Charcoal from wood chip with ash showed lower iodine adsorption in comparison with the control at every point of carbonization time. This lower adsorption also indicated insufficient carbonization of the wood chip. Carbonization temperature at 600℃ was not enough to give sufficient heat to the wood chips with ash layer around their surface.

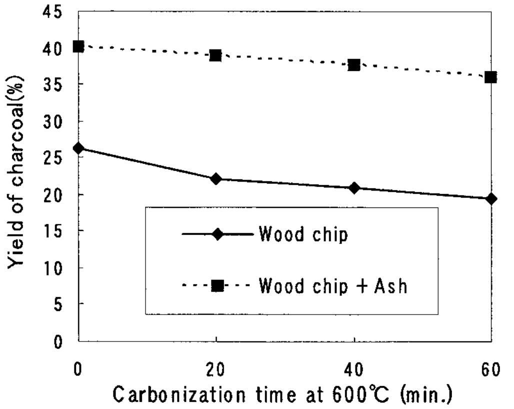

Fig. 3. Charcoal yield and carbonization time at 600℃.

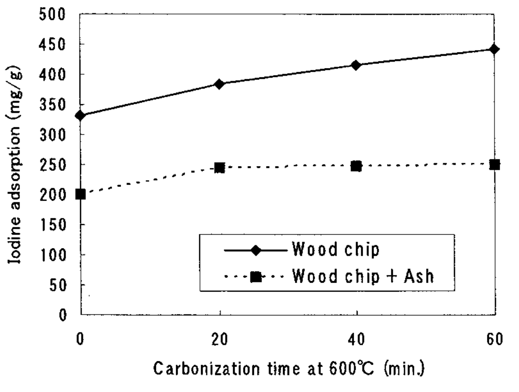

Fig. 4. Iodine adsorption and carbonization time at 600℃.

In both cases of wood ash and potassium hydroxide, carbonization temperature at 600℃ was not enough high to react wood chips with additives. Therefore, higher temperature was required for sufficient carbonization.

3.4 Carbonization of wood chip with ash at 900℃

Fig. 5 shows the charcoal yield of samples carbonized at 900℃. The yield of both samples from wood chip and wood chip with ash gradually decreased with the increase of carbonation time, but the yield of samples from wood chip with ash was higher all the time of reaction in comparison with the control. In the case of 600℃, the inner part of chips with ash was not carbonized yet, but at 900℃ the inside of the chips were fully carbonized. Therefore, high yield does not mean insufficient carbonization in this case. The main reason of high yield of charcoal from ash added chips could be the ash layer around the chip surface. This layer act as an insulation to heat at lower temperature 600℃, and prevent the carbonization of inside of the chip. However, at higher temperature 900℃, inside of chip was fully carbonized and even more the ash layer protect the charcoal surface from excess degradation by heat. And alkaline metals which are included in wood ash would serve as catalyst in oxidation of charcoal surface at higher temperature 900℃. The acceleration of oxidation of charcoal surface by alkaline metals in ash would increase the adsorption property.

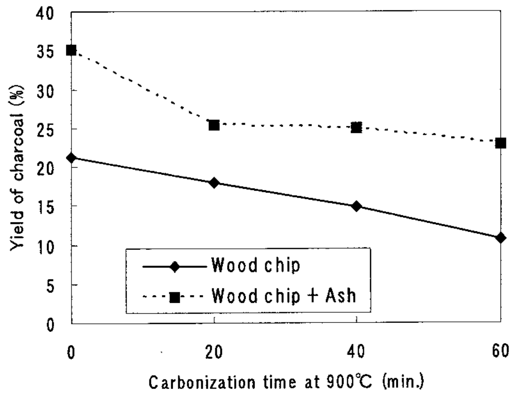

Fig. 5. Charcoal yield and carbonization time at 900℃.

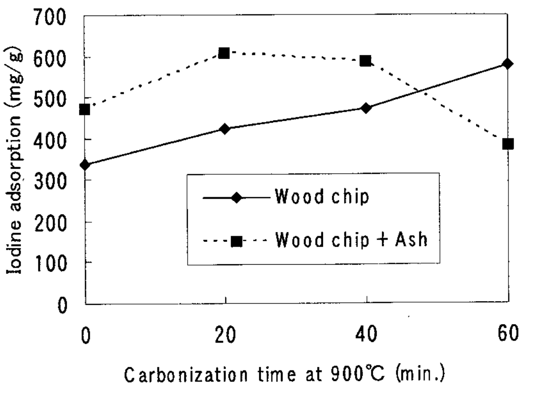

Fig. 6. Iodine adsorption and carbonization time at 900℃.

Fig. 6 shows the results of iodine adsorption of the samples carbonized at 900℃. In the carbonization time from 0 to 40min, samples from wood chip with ash showed higher adsorption than the control. However the adsorption value dropped sharply at 60min. and became lower than the control. Prolonged reaction time would deteriorate the charcoal surface and made them inactive. On the other hand, iodine adsorption from the control samples increased constantly all the time. It increased even after 40min to 60min. From these results, at 900℃, in the initial stage of carbonization especially 0 to 20min, mixing wood chip with ash was quite effective to obtain charcoal with high yield and high adsorption properties. Unlike caustic chemicals wood ash is not corrosive and easy to deal with and if it remains in charcoal it is not harmful to the health. Ash itself does not change so much in its property even after heating at high temperature repeatedly. Wood ash is also easily separated from the charcoal by sieving the mixture with screen. To use ash effectively, temperature and reaction time are important factors. Ordinary carbonization temperature such as 600℃ is insufficient. Higher temperature such as 900℃ s needed. There is a peak around 20min. in adsorption property. Specific surface area determined by the BET method was c.a. $450m^2/g$ at 20min. Meso pore distribution could not be detected by the machine used in this work. Although the effect of increase in adsorption is lower in comparison with potassium hydroxide treatment, using wood ash as additives can shorten the carbonization time and also increase the yield and adsorption of charcoal to some extent.

Acknowledgement

This work was supported in a part by a research program for development of technologies for establishment eco-system based on recycling in rural villages for the 21st century from the Ministry of Agriculture, Forestry and Fisheries.

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(Received December 20, 2002; Accepted Octorber 11, 2003)