Charcoal-Making in a Home, and the Utilization for Activated Carbon*

By

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家庭製炭と活性炭への利用

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Contents

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1. Introduction

In Japan, charcoal together with firewood was important energy source in home until 30 years ago. Namely, charcoal was 22%, firewood 12% of the fuel and light expenses a home in 1955.[1] And also, in the total energy supply, that is 56×10^{13} kcal in 1955, firewood occupied 5.4% charcoal 2.6% respectively.[2] But now, the ratio of woody fuel in the supply is only 0.1%.[2] Actually, the amount of charcoal has decreased from 2,170,000 tons in 1957 to 35,000 tons in 1982.[2]

But petroleum, the replacer of them, has some problems that comprise the shortage in future and the steep rise in prices, caused by the "Oil Shocks" that happened in 1973 and 1978. So, the wooden fuel has been noticed again.[3]

Charcoal is necessary and favorite for high grade cooking, tea ceremony, mutton dish named Jinghis Khan and barbecue on the field. Therefore, a simple carbonization in a home to get a small amount of charcoal was planned and practiced in a stove for wooden fuel. There has been reported only one study on stove charcoal by FUKUYAMA and SATONAKA.[4]

This time, the woods of 19 tree species, a *Sasa* bamboo and a densified sawdust fuel (Ogalite) in Hokkaido were carbonized in the laboratory. Next, various activated carbons were prepared by steam activation method which occupies the mainstream in the nowaday industry. The adsorptivity was tested with methylene blue and NSSC spent liquor. As the NSSC spent liquor has lower content of combustible matter, the technical combustion method for the treatment of the spent liquor is expensive.

Now, a paper factory under the strict regulation of effiuent quality is practicing the adsorption method with activated carbon.[5,6] With the progress of such regulation, more factories may adopt the same method.

Thanks should be expressed to Miss Yuriko SEZAKI for her much assistance.

2. Experimental

2.1 Raw material

The woods of 19 tree species shown in Table 1 were cut out from Tomakomai Experiment Forest. Nemagaridake, *Sasa kurilensis* was cut out from Uryu Experiment Forest of Hokkaido University. A densified sawdust fuel, Ogalite was purchased from a commerical shop at the price of ¥ 650 a pack of 14 pieces in October of 1980. And one pack of oak charcoal produced in Iwate Prefecture was also purchased at the price of ¥ 3600/15 kg in August of 1981. This charcoal was used as a standard raw material for activated carbon.

Table 1. Raw material used for experiment

Species	Botanical name	D. B. H. (cm)	Height (m)
Todomatsu	*Abies sachalinensis*	10	13.0
Karamatsu	*Larix kaempferi*	10	13.0
		8	9.8
		8	10.7
Shirakanba	*Betula platyphylla* var. *japonica*	11	10.9
Sawashiba	*Carpinus cordata*	8	7.4
Asada	*Ostrya japonica*	10	9.6
Mizunara	*Quercus mongolica* var. *grosseserrata*	10	9.3
Harunire	*Ulmus davidiana* var. *japonica*	6	8.0
Yamaguwa	*Morus bombycis*	7	6.0
Hounoki	*Magnolia obovata*	7	9.3
Noriutsugi	*Hydrangea paniculata*	—	—
Tsuruajisai	*Hydrangea petiolaris*	—	—
Ezoyamazakura	*Prunus sargentii*	13	19.0
Azukinashi	*Sorbus alnifolia*	8	8.7
Itayakaede	*Acer mono*	7	10.0
Yamamomiji	*Acer palmatum* var. *matsumurae*	12	10.3
Shinanoki	*Tilia japonica*	8	9.0
		6	6.7
Koshiabura	*Acanthopanax sciadophylloides*	10	10.4
Harigiri	*Kalopanax septemlobus*	10	8.4
Aodamo	*Fraxinus sieboldiana*	8	10.0

2.2 Preparation of material

At first, the wood was cut at the size of about 5 cm diameter, 8.5 cm long. Two diameters, the longest one, the right-angled one to that, and the two heights that depart from the ends of the longest diameter were measured. The average values were determined as the each diameter and height. The volume was calculated as a column. At that time, in order to obtain the diameter shrinkage

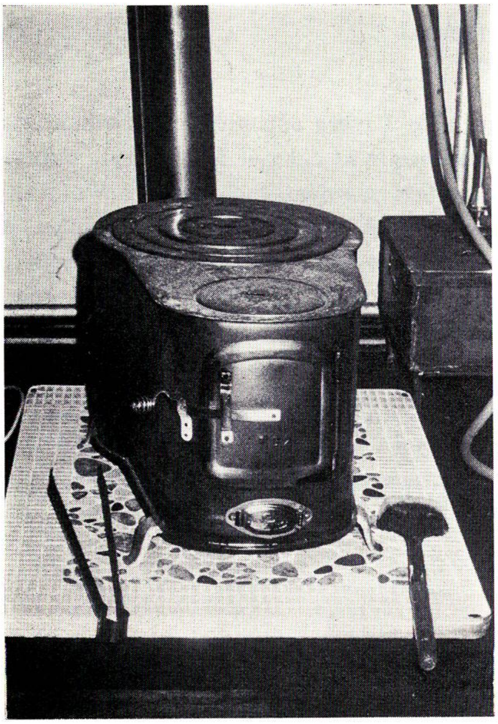

Photo 1. A conventional wood-fuel stove.

Photo 2. A vessel made of iron for carbonization.

Photo 3. Raw material (*Acer palmatum*) in the vessel.

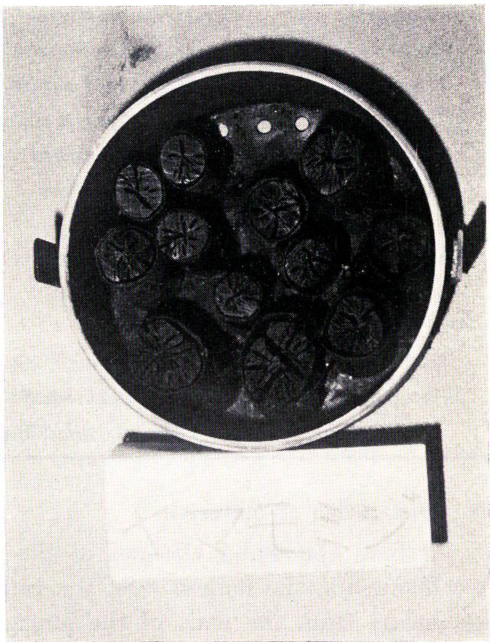

Photo 4. Charcoal made from *Acer palmatum*.

we hurt a little at an end of the longest diameter. Each specimen was weighed on an upper-dish balance with accuracy of 0.01 g.

2.3 Carbonization

An iron cylindrical lidded vessel in a conventional firewood stove was used. Size of the vessel is 20 cm diameter and 9,5 cm deep. There are three pores of 1 cm diameter through both the round side and the bottom. Through these pores, wood gas and pyroligneous liquor go out, and burn in the stove. This means the efficient utilization of the heat energy comparing with the common charcoal making.

Prepared materials were put into the vessel, the average number in a vessel was 9.7 pieces except *Sasa* bamboo. The lid was put on the vessel, and it was placed in the rear part of the stove, in which a trivet of 10-cm height was put already. With this structure, the heat is transmitted through all of the vessel surface. The combustion of fuel is begun by the ignition of some little pieces of Ogalite. Fuel used was four pieces of Ogalite and the time needed was 3~4 hours. After that, the stove containing charcoals was left through a night. Next morning, the size, volume, weight and moisture content of various charcoals prepared were determined.

2.4 Activation with steam

The charcoals and a commercial charcoal made from oak wood in Iwate Prefecture were crushed and sieved. Each 10~20 mesh fraction was activated with water vapor.

The apparatus for activation is illustrated in Fig. 1. The cylindrical reactor is 5.5 cm inner diameter and 80 cm high. There is a diffusion plate in the center of the reactor. The diffusion plate is tapered down to the center with 30° in angle. And the plate has 64 holes with 2 mm diameter. This electric furnace has the ability of 3.0 kW.

Conditions for activation[7] are as follows:

1) Weight of charcoal charged: OD 10 g
2) Activation temperature: 900°C
3) Activation time: 15 minutes
4) Flow rate of water vapor for activation: 1.5 g/min.
5) Flow rate of nitrogen gas for fluidization: 100 mℓ/min.

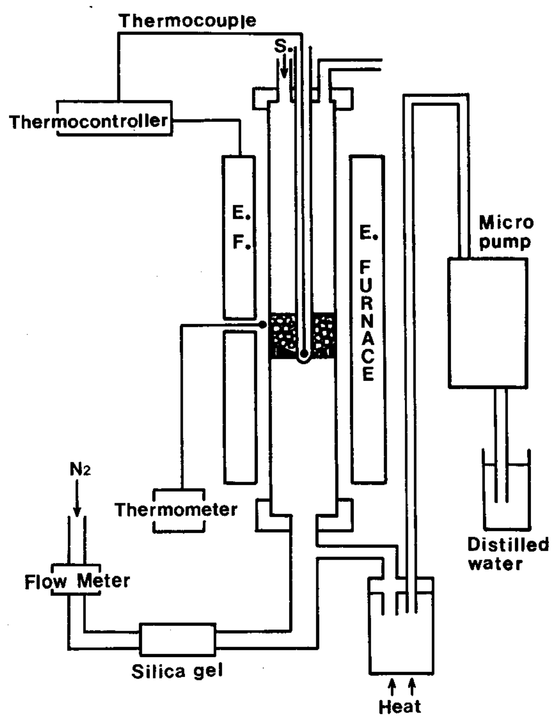

Fig. 1. Apparatus for activation.

As for the operation of activation, charcoal particles are poured into the reactor through the upper inlet of the reactor which is held at 900°C. After the restoration of the temperature, water vapor is sent with the stream of nitrogen.

After the activation, a tube which protects thermocouple is pulled up and activated carbon is dropped down, nitrogen gas is stopped, the lower lid is taken off and the resultant activated carbon is obtained.

2.5 Adsorptivity test

The ability of the activated carbons was tested twice on the same sample, by following methods.

2.5.1 Adsoptivity for methylene blue

This test was carried out according to the JIS K-1470.[8]

The specimen passed through a 100 mesh sieve was used. Oven-dry 0.1 g sample was taken in a 30-mℓ sample bottle, into which 20 mℓ of 0.3% methylene blue solution was poured. This test solution was prepared by dissolving 6 g equivalent methyene blue with distilled water into a 2000 mℓ quantitative flask. The bottle was shaken for 30 minutes at room temperature, and the content was filtered through a No. 5 C filter naturally. The filtrate was diluted to a 1/1000 solution with water. The maximum absorbance at about 665 nm was measured with a Hitachi visible and UV spectrophotometer.

Adsorbed amount was calculated according to the following formula.

$$\text{Adsorbed methylene blue (mg/g)} = 60^{*} \times \left(1 - \frac{\text{Absorbance of the specimen after adsorption}}{\text{Absorbance of the original methylene blue solution}}\right) \times \frac{1}{\text{Weight of activated carbon (g)}}$$

2.5.2 Adsorptivity for lignin in NSSC spent liquor

NSSC spent liquor was prepared according to the Textbook of Forest Products Chemistry by University of Tokyo.[9] Cooking conditions are as follows:

Concentration of cooking liquor: 40 g/ℓ (as Na_2CO_3)

$Na_2SO_3 : Na_2SO_3 = 7 : 1$

Liquor ratio: 4

Cooking temperature: 170°C

Rising time: 1 hour

Holding time: 2.5 hours

Raw material: Chips of *Betula maximowicziana*, OD 560 g equivalent.

The spent liquor was diluted to a 1/500 solution with water and the adsorption tests was carried out by the same way in the case of methylene blue.

The absorbance at 273 nm was observed and the adsorptivity was calculated as follows:

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* Weight of methylene blue in mg contained in 20 mℓ of the 0.3% solution.

Adsorptivity for lignin

$$= \left(1 - \frac{\text{Absorbance for the specimen}}{\text{Absorbance for the original spent liquor}}\right) \times \frac{0.1}{\text{Weight of specimen}} \times 100$$

2.6 Combustion test

Each charcoal was splitted to the size of 2~3 cm cubes and they were put on an asbestos-iron wire which had been set on a tripod. The charcoal particles were heated with a Teclue burner through the wire.

The smoking, ingnition and combustion states were observed.

3. Results and Discussion

3.1 Yield of charcoal

Yield of charcoal ranged from 25 to 35% and the average was 28% on basis of oven-dry raw materials.

Comparing the yields with that under various temperatures, they correspond

Table 2. Yield and properties of charcoal, and shrinkage during carbonization

	Yield (%)	Density		Moisture Content (%)	Shrinkage during carbonization in Radial, Longitudinal, Volume (%)			Adsorption of Methylene blue (mg/g)
		Charcoal	Wood		Radial	Longitudinal	Volume	
Ogalite	28	0.47	1.12	0.7	15.1	7.9	30	74
Caripnus	25	0.32	0.69	2.0	20.6	12.5	45	17
Acer p.	27	0.34	0.69	2.1	21.4	10.9	45	38
Fraxinus	26	0.33	0.68	1.8	20.7	11.8	45	45
Hydrangea pa.	25	0.31	0.68	3.1	20.5	12.6	45	31
Acer m.	27	0.31	0.66	1.5	18.5	11.7	41	30
Prunus	31	0.30	0.64	2.2	14.9	10.1	35	54
Sorbus	25	0.28	0.64	2.5	19.2	10.2	41	27
Morus	28	0.27	0.63	2.8	13.5	12.3	34	61
Hydrangea pe.	28	0.30	0.61	1.1	17.1	16.4	43	59
Ulmus	35	0.30	0.61	0.8	12.9	7.2	30	22
Ostrya	27	0.30	0.58	2.5	22.2	11.9	46	16
Quercus	30	0.26	0.58	1.8	10.9	10.1	29	54
Betula	25	0.25	0.58	1.0	18.1	12.7	42	11
Larix	28	0.20	0.54	1.2	11.5	11.6	22	47
Acanthopanax	27	0.21	0.49	1.6	13.8	10.7	34	27
Magnolia	26	0.19	0.46	2.4	17.5	9.5	38	25
Tilia	25	0.21	0.45	3.1	21.1	11.6	45	13
Abies	34	0.16	0.44	2.7	—	12.0	—	61
Kalopanax	33	0.19	0.43	1.8	10.0	9.9	26	29
Sasa	29	0.31	0.66	3.3	24.2	14.0	44	28
Commercial	—	0.46	—	—	—	—	—	25
Av.	28	0.29	0.61	2.0	17.2	11.3	38	36

to 1000~400°C,[10] and the 28% corresponds to 600°C,[10] which is the average temperature of carbonization for Kurozumi charcoal.

Then, the double and triple experiments showed the yield of 28 and 30% in larch, and 29, 30 and 34% in fir, respectively.

3.2 Density of charcoal

Density of charcoal ranged from 0.16 (Todomatsu fir) to 0.47 (Ogalite) and the average was 0.29. This value was fairly lower than 0.50, which is the average of kiln-made charcoals produced in Hokkaido.[10] The low density of these charcoals is similar to the charcoal made by dry distillation.[4]

To increase the density is a next important problem.

3.3 Moisture content of charcoal

The moisture content of charcoal taken out next moring ranged from 0.73 to 3.28% and the average was 2.0%.

The value increased to 4.6~6.5% and the average was 5.5% after the exposure in air for 1~2 months. The value 5.5% was lower than 7.6%[10] which is the average value of common kiln-made charcoal in Hokkaido. This fact may mean that the charcoal made by this way is at a lower level than common charcoal.

3.4 Shrinkage during carbonization

The shrinkage in radial direction was 10~24%, and the average was 17%. The shrinkage in longitudinal direction ranged from 7 to 16% and the average was 11%. The shrinkage in volume ranged from 22 to 46% and the average was 38%. These values correspond to the data of the charcoal carbonized at 400°C in bench scale.[10] But, these home-made charcoals must have been carbonized at the higher temperature and the shrinkage seems not to have progressed as a literature.[10] These phenomena may be derived from the faster carbonization than the usual one. As the fir wood charcoal showed obvious cracking, the shrinkage could not be measured.

3.5 Adsorption of methylene blue on the charcoal

The results ranged from 11 to 74 mg/g and the average was 36 mg/g. There are no references about these data, and they are too small to have the correct values.

Namely, in case of the activated carbon which shows the adsorptivity of more than 100 mg, the difference of 10 mg in duplicate experiment is less 10%. However, in case of the charcoal, the error sometimes amounts to near 50%.

3.6 Yield of activated carbon

The yield of activated carbon ranged from 23 to 65%, the average was 46% on basis of charcoal. But on basis of wood, it ranged from 7.5 to 18.2%, the average was 12.7%.

The yield of activated carbon from a tropical wood was 13.8% under the similar conditions.[7]

As the yield by steam activation is 30%[11] on basis of charcoal, the value 46%

Table 3. Yield of activated carbon and the adsorptivity

	Yeld of activated carbon charcoal base (%)	wood base (%)	Adsorption of methylene blue (mg/g)	Adsorption of lignin (%)
Ogalite	62	17	138	12
Carpinus	52	13	273	43
Acer p.	53	14	211	29
Fraxinus	41	11	222	50
Hydrangea pa.	47	12	127	26
Acer m.	52	14	215	36
Prunus	52	16	182	31
Sorbus	57	14	278	27
Morus	57	16	202	27
Hydrangea pe.	47	13	298	47
Ulmus	23	8	312	46
Ostrya	41	11	319	52
Quercus	46	14	223	33
Betula	43	11	251	50
Larix	65	18	115	29
Acanthopanax	41	11	175	33
Magnolia	40	10	235	55
Tilia	30	8	322	53
Abies	35	12	293	48
Kalopanax	23	8	345	61
Sasa	54	16	198	5
Commercial charcoal	55	—	219	43
Average	46	13	234	38
Commercial W			359	50
activated carbon K			230	81

of activated carbon prepared in our laboratory was fairly high.

3.7 Adsorption of methylene blue on the activated carbon

The adsorption of methylene blue on the activated carbons ranged from 115 to 345 mg/g and the average value was 234 mg/g. In comparison with commerical activated carbons, the top of them was a little inferior to an activated carbon of W Co. (359 mg/g), however, ten kinds of them were superior to an activated carbon of K Co. (230 mg/g).

3.8 Adsorption of lignin on the activated carbon

The adsorption of lignin on the activated carbons ranged from 5 to 61%, and the average was 38%. In comparison with commercial activated carbons, six kinds prepared in the laboratory were superior to a commercial one W. A commerical activated carbon K was very excellent, showing 81%.

The best result confirmed from the adsorption of lignin on an activated carbon prepared from NSSC waste liquor with phophoric acid was 36.2%.[12] The results such as 61, 55, 53% etc. obtained in this experiment were superior to the value.

3.9 Total evaluation of activated carbon

Total valency was calculated as "Yield of activated carbon on basis of wood × adsorptivity"

Table 4. Total evaluation of the activated carbon

Adsorptivity for methylene blue (mg/g)		Lignin (%)	
Sorbus	39.6	*Hydraugea pe.*	6.19
Hydraugea pe.	39.2	*Ostrya*	5.76
Carpinus	35.5	*Magnolia*	5.72
Ostrya	35.3	*Abies*	5.71
Abies	34.7	*Carpinus*	5.59
Morus	32.2	*Betula*	5.38
Sasa	31.0	*Fraxinus*	5.33
Quercus	30.8	*Larix*	5.28
Acer p.	30.2	*Acer m.*	5.05
Acer m.	30.2	*Prunus*	5.00
Prunus	29.3	*Kalopanax*	4.63
Betula	27.0	*Quercus*	4.55
Kalopanax	26.2	*Morus*	4.31
Ulmus	25.1	*Acer p.*	4.15
Magnolia	24.4	*Tilia*	3.98
Tilia	24.2	*Sorbus*	3.85
Ogalite	24.0	*Ulmus*	3.70
Fraxinus	23.7	*Acanthopanax*	3.65
Larix	20.9	*Hydrangea pa.*	3.06
Acanthopanax	19.4	Ogalite	2.08
Hydrangea pa.	14.9	*Sasa*	0.78

Table 5. Correlations of various properties on wood and charcoal

Property	Density of Wood	Density of Charcoal	Moisture Content of Wood	Moisture Content of Charcoal	Yield of Charcoal	Radial Shrin-kage	Volume Shrin-kage	Average Volume of used Material	Average Diameter of used Material
Density of Wood	—	0.946**	—	-0.307	-0.187	0.159	0.046	—	—
Density of Charcoal	21	—	-0.467*	-0.254	-0.203	0.321	0.248	-0.023	-0.284
Moisture Content of Wood	—	21	—	-0.271	0.002	-0.394	-0.215	—	—
Moisture Content of Charcoal	21	21	21	—	-0.177	0.523*	0.480*	-0.523*	-0.480*
Yield of Charcoal	21	21	21	21	—	-0.619**	-0.640**	0.147	0.106
Radial Shrinkage	20	20	20	20	20	—	0.928**	-0.575*	-0.602**
Volume Shrinkage	20	20	20	20	20	20	—	-0.578*	-0.490*
Av. Volume of Material	—	21	—	21	21	20	20	—	—
Av. Diameter of Material	—	21	—	21	21	20	20	—	—

N=20 RL (0.01)=0.591 RL (0.05)=0.450
N=21 RL (0.01)=0.576 RL (0.05)=0.438

As the results, in case of the adsorption of methylene blue, *Sorbus a*, *Hydrangea pe*. *Carpinus c*, *Ostrya j*. showed superior adsorptivity. In case of the adsorption of lignin, *Hydrangea pe*., *Ostrya j*., *Magnolia o*., *Abies s*. showed superior results. Considering both results, excellent activated carbons are obtained from *Hydrangea pe*. and *Ostrya j*.

3.10 Relationships between various properties

3.10.1 Density of wood and that of charcoal

The correlation between the density of wood and that of charcoal has been known. This time the correlation coefficient is 0.946 at 1% level, the graph is shown in Fig. 2.

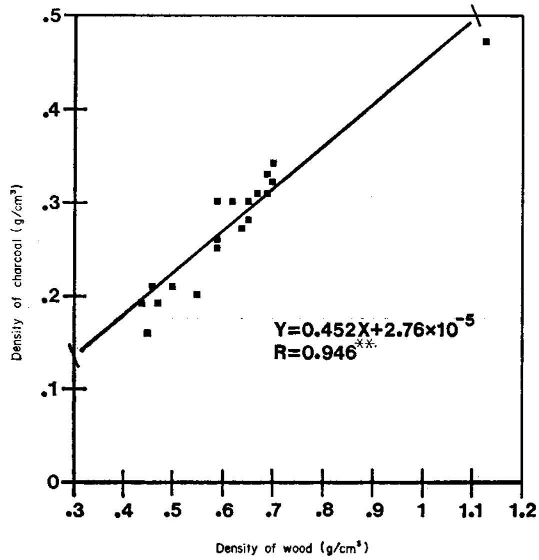

Fig. 2. Relation between density of wood and that of charcoal.

3.10.2 Moisture content of raw material and the density of charcoal

Relation between the moisture content of wood and the density of charcoal is recognized. The correlation coefficient is -0.467 at 5% level. This fact means that the higher the wood as raw material has moisture content, the lower the density of charcoal becomes. This is a contrary results from the past legend about conventional charcoal making.

This may have caused by the different way such as a home-made charcoal.

3.10.3 Moisture content of charcoal and the shrinkage during carbonization

The correlation between the moisture content of charcoal and the readial shrinkage is observed. The correlation coefficient is 0.523, which is significant at 5% level.

Then, the correlation between moisture content of charcoal and the volume shrinkage is seen. The correlation coefficient is 0.480 at 5% level. This means that the bigger the shrinkage progresses, the higher the moisture content of charcoal becomes. Namely, the further the carbonization progresses, the higher the adsorption of moisture becomes.

3.10.4 Yield of charcoal and the shrinkage

The correlation of yield of charcoal and the radial shrinkage is illustrated in Fig. 3. The coefficient is -0.619, which is significent at 1% level. Then, the correlation of yield of charcoal and the volume shrinkage is shown in Fig. 4. The coefficient is -0.640 at 1% level. The lower the yield of charcoal becomes, namely, the further the carbonization progresses, the more the shirnkage progresses.

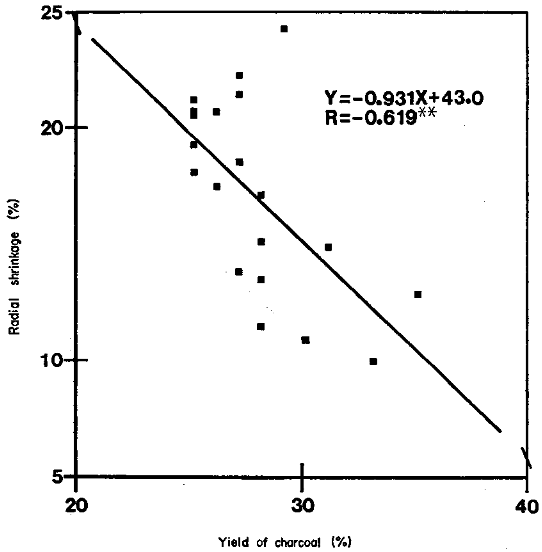

Fig. 3. Relation between yield of charcoal and radial shrinkage.

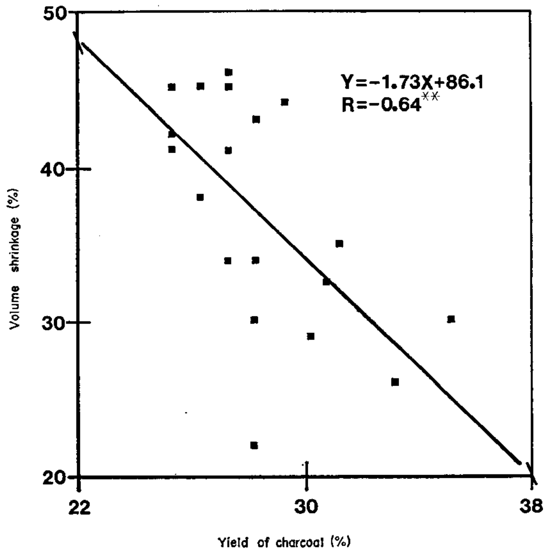

Fig. 4. Relation between yield of charcoal and volume shrinkage.

3.10.5 Size of raw material and the shrinkage

The relation between the size of used raw material that is the average volume and the radial shrinkage during the carbonization is observed. The correlation coefficient is −0.575, which is significant at 5% level. The relation between the size of used raw material and the volume shrinkage during carbonization is seen. The correlation coefficient is −0.578 at 5% level. The relation between the diameter of used raw material and the radial shrinkage during carbonization is observed. The correlation coefficient is −0.602, which is significant at 1% level. The relation between the diameter of used raw material and the volume shrinkage during carbonization is seen. The correlation coefficient is −0.490, which is significant at 5% level.

These coefficients are all minus values, and the smaller the size of used raw material is, the more the shrinkage progresses during carbonization. This means that in case of a small size raw material, the heat penetrates into the inner part easily, it is carbonized well and the shrinkage progresses.

3.10.6 Size of raw material and the moisture content of charcoal

Relation between the diameter of raw material and the moisture content of charcoal is seen. The correlation coefficient is −0.480 at 5% level. Relation between the volume of raw material and the moisture content of charcoal is also seen. The correlation coefficient is −0.523 at 5% level. These facts mean that the bigger raw material is hard to be carbonized and the bigger charcoal is hard to absorb moisture.

3.10.7 Yield of activated carbon and the density of raw material

The relation between the yield of activated carbon and the density of charcoal

Table 6. Correlations of various properties on activated carbon

Property	Density of Wood	Density of Charcoal	Yield of Activated Carbon	Adsorption of Methylene Blue	Adsorption of Lignin
Density of Wood	—	0.946**	0.581**	−0.471*	−0.624**
Density of Charcoal	21	—	0.479*	−0.303	−0.414
Yield of Activated Carbon	21	22	—	−0.707**	−0.720**
Adsorption of Methylene Blue	21	22	22	—	0.715**
Adsorption of Lignin	21	22	22	22	—

N=21 RL (0.01)=0.576 RL (0.05)=0.438
N=22 RL (0.01)=0.562 RL (0.05)=0.428

used for activation is observed. The correlation coefficient is 0.479, which is significant at 5% level. The relation between the yield of activated carbon and the density of woody raw material is recognized. The correlation coefficients is 0.581, which is significant at 1% level.

These facts mean that the heavy raw material is not evaporated easily in the high temperature treatment.

3.10.8 Yield of activated carbon and the adsorptivity

The relation between the yield of activated carbon and the adsorptivity for methylene blue is shown in Fig. 5. The correlation coefficient is −0.707, which is significant at 1% level. The relation between the yield of activated carbon and the adsorptivity for lignin is illustrated in Fig. 6. The correlation coefficient is −0.720, which is significant at 1% level.

These facts mean that with the progression of activation the suitable pore structures are developed, and the adsorptivity increases.

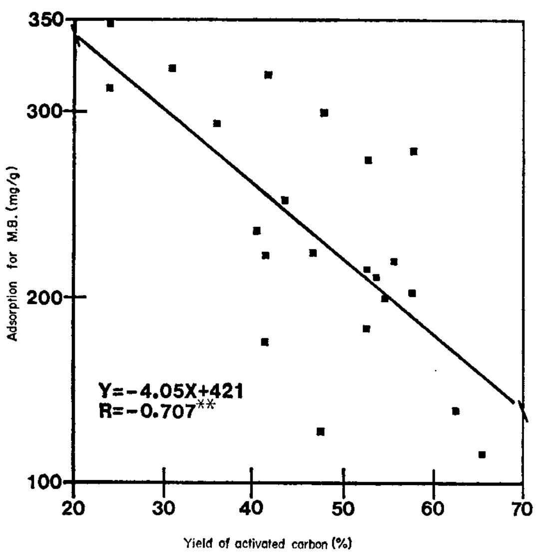

Fig. 5. Relation between yield of A.C. and adsorption for M.B.

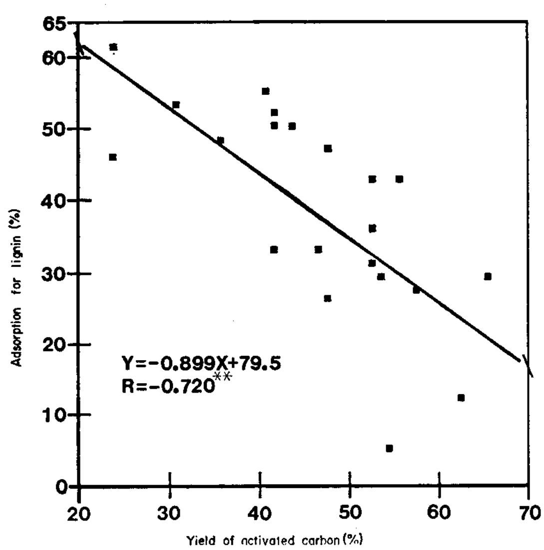

Fig. 6. Relation between yield of A.C. and adsorption for lignin.

As the characteristics of wood species, *Hydrangea paniculata* and *Acanthopanax sciadophylloides* showed lower adsorptivity in spite of their lower yields. However, *Carpinus cordata* showed higher adsorptivity in spite of the higher yield.

3.10.9 Adsorptivity of lignin and that of methylene blue

The relation between the adsorptivity of lignin and that of methylene blue is illustrated in Fig. 7. The correlation coefficient is 0.715, which is significant at 1% level. This fact means that an excellent activated carbon for an adsorbent is also excellent for the other adsorbent. However, in case of commercial activated carbon, W is superior to K for methylene blue, and K is superior to W for lignin. These facts indicate that these activated carbons are manufactured to have some characteristic distribution of pore size.

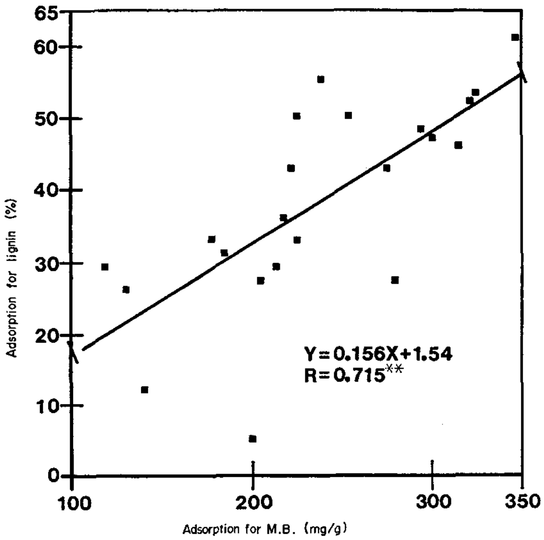

Fig. 7. Relation between adsorption for M. B. and that for lignin.

3.10.10 Density of raw material and the adsorptivity of activated carbon

The relation between the density of woody raw material used and the adsorptivity of methylene blue on the activated carbon is recognized. The correlation coefficient is −0.471, which is significant at 5% level. The relation between the density of used woody raw material and the adsorptivity of lignin on the activated carbon is also observed. The correlation coefficient is −0.624, which is significant at 1% level.

These facts mean that the raw material having low density are suitable for the manufacture of activated carbon.

3.11 Combustion test

All charcoals burnt in similar manner to commercial ones. The smoking was not observed. The ignition was easy, the combustion was fast. So, these charcoals are suitable for the cooking such as Jinghis Khan or barbecue.

4. Conclusion

With the progress of civilization, people need charcoal for nice cooking, pleasant recreation, chemical industry and the improvement of environments.

Small amount of charcoal could be obtained by use of a small vessel in conventional wood-fuel stove. The density of the charcoal and shrinkage during carbonization were somewhat lower than that of kiln-made ones. High yield charcoals were obtained from *Ulmus davidiana, Abies sachalinensis* and *Kalopanax septemlobus.* Rigid and high density charcoals from Ogalite (densified sawdust fuel), *Acer palmatum* and *Fraxinus sieboldiana* were obtained.

Various activated carbons were prepared from the charcoals by a steam method. In comparison of adsorptivity with commercial activated carbons, there were 10 kinds of activated carbons which were superior to the commercial ones in the methylene blue adsorption test. And also, there were 6 kinds of activated carbons which were superior to the commercial one in the lignin adsorption test. Judging from the total evaluation, it can be said that the excellent activated carbons are produced from *Hydrangea petiolaris* and *Ostrya japonica.*

But, this time, because of the same treatment for all woody materials, the most suitable conditions for each raw material are not yet searched. A new research in future will be able to find the better raw material, charcoal and activated carbon.

5. Summary

People sometines need a small amount of charcoal for the fine dish such as Jinghis Khan or barbecue in a home. So, a convenient and simpler carbonizer which is composed of a vessel in a conventional wood-fuel stove was developed. Then, people also need an effective "worker" to improve environment, that must be an excellent activated carbon. Several kinds of activated carbon were manufactured by a steam method from the charcoals. The results are as follows:

1) Yield of the charcoal was 28% (min. 25~max. 38%) on basis of oven-dry material.

2) Density of charcoal was 0.29 (0.16 to 0.47), which was lower than 0.50 of kiln-made charcoal.

3) Moisture content of charcoal at the next morning was 2.0% (0.7 to 3.3%).

4) Shrinkage during carbonization was 17% (10 to 24%) in radial direction, 11% (7 to 16%) in longitudinal direction and 38% (22 to 46%) in volume. These data are lower than that in a literature.[10]

5) Adsorption of methylene blue on the charcoal was 36 mg/g (11 to 74 mg/g), these data include some error because of their low values.

6) Yield of activated carbon was 46% (23 to 65%) on basis of charcoal and 13% (8 to 18%) on basis of wood. These data are higher than that in a literature.[11]

7) Adsorption of methylene blue on the activated carbon was 234 mg/g (115 to 345 mg/g), which was a little inferior to a commercial W but was a little superior to commerical K.

8) Adsorption of lignin in NSSC spent liquor on the activated carbon was 38% (5 to 61%). Six kinds of them were superior to a commercial activated carbon W.

9) Total evaluation of activated carbon was calculated by the following way: (Yield of activated carbon on basis of oven-dry wood) × Adsorptivity. As the results,

some excellent activated carbons could be obtained from *Hydrangea petiolaris* and *Ostrya japonica.*

10) Positive and strenuous relation was recognized between the density of wood and that of the charcoal.

11) Negative correlation between the yield of charcoal and both radial and volume shrinkage during carbonization was observed.

12) Negative high correlations between the yield of activated carbon and both the adsorption of methylene blue and lignin were observed.

13) Positive and strong correlation was seen between the adsorption of methylene blue and lignin.

14) Negative correlation was seen between the adsorption of lignin on activated carbon and the density of wood which was used as raw material.

15) Practical combustion test of the charcoal showed the favorable properties such as easy ignition, fast combustion and no smoking.

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要　　約

家庭で，ジンギスカンまたはバーベキューをおこなう場合には，小量ではあるが，木炭を必要とするときがある。そこで，家庭用普通マキストーブの内部に小型容器を設置して，簡易炭化法により製炭をおこなった。本法は炭化のさいに発生する木ガス・木タールもすべて室内加温の熱エネルギー源として利用するもので，故福山伍郎教授の発案による。

環境改善と生活面においても，活性炭は必需品となっているので，上記木炭を原料として水蒸気賦活法により活性炭を製造した。おもな結果はつぎのとおりである。

1) 木炭の収率は絶乾原料基準で28% (最小25～最大38%) であった。

2) 木炭の比重は0.29 (最小0.16～最大0.47) で，炭窯製炭の木炭の0.50よりはかなり低かった。

3) 炭化後，翌朝の木炭の吸湿率は2.0% (0.7～3.3%) であった。

4) 炭化中における半径方向の収縮率は17% (10～24%)，繊維方向の収縮率は11% (7～16%)，容積収縮率は38% (22～46%) であった。これらのデータは，既往のデータより若干低かった。

5) 木炭へのメチレンブルーの吸着は36 mg/g (11～74 mg/g) であった。これらのデータは絶対値が低いため，若干の誤差をふくんでいる。

6) 活性炭の収率は，木炭ベースで46% (23～65%)，木材ベースで13% (8～18%) であった。これらのデータは，既往のデータより高かった。

7) 活性炭へのメチレンブルーの吸着は234 mg/g (115～345 mg/g) であり，それは市販活性炭W (359 mg/g) より少々劣っていたが，市販活性炭K (230 mg/g) よりも少々すぐれていた。

8) 活性炭へのNSSC廃液中のリグニンの吸着は38% (5～61%) であった。市販活性炭W (50%) よりも優れた吸着力の活性炭が6種あった。

9) 活性炭の総合力価が“木材ベースの活性炭の収率×吸着力”により計算された。その結果，すぐれた活性炭が，ツルアジサイとアサダから得られた。

10) 正の高い相関が，木材比重と木炭比重の間に再確認[10]された。

11) 木炭収率と炭化中における半径・容積の両収縮の間に，負の相関が観察された。

12) 活性炭の収率とメチレンブルー・リグニンの両吸着の間に，かなり高い負の相関が認められた。

13) メチレンブルーとリグニンの吸着の間には正の高い相関がみられた。

14) 活性炭のリグニン吸着と，その原料として用いられた木材の比重との間に，負の相関がみとめられた。

15) 木炭の実際燃焼テストは，容易な着火，速い燃焼，無煙燃焼の良い性能を示した。