

ARTICLE

Study on the Availability of Wheat Bran as a Raw Material for Charcoal

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<Abstract>

As a part of study to develop the utilization of wheat bran, an industrial by-product, the possibility of its carbonization was examined in this study. Generally, a calorific value for fuel charcoal of more than 7,000cal/g is said to be necessary, but according to the results of a differential scanning calorimetry analysis, wheat bran charcoal performs at almost this level, so this basic condition is met. It is also important that there are many fossulae as the surface area per unit weight must be big enough to absorb molecules of smell or color when it is used as an active carbon. Therefore after measuring the specific surface area of wheat bran charcoal, it showed a small value, particularly in comparison with general charcoal, indicating that its utilization as an active carbon is difficult. As a result of electron microscopy, the reason why the specific surface area of wheat bran charcoal was small was because there was no minute fiber structure such as is found in wood charcoal, and with the surface being smooth, the internal pores were blocked, presumably by carbonized starch or protein. The solidification technology of wheat bran charcoal must be developed in the future to maintain equal heat radiation with wood charcoal in order to develop its practical use as fuel charcoal. There are many problems that remain as to whether some form of solidification processing should be done before carbonization again, and what kind of binder should be used for solidification, or whether it should be carried out after carbonization.

Keywords: wheat bran, charcoal, industrial by-product

As a study to plan utilization of wheat bran which is an industrial by-product, the use to the culture medium for the microbe, an enzyme production raw material, the dietary fiber, the abrasives for finishing the steel sheet, the flooring of the pickle have been studied¹⁾. In addition, the examination on the microbe production of the P- γ -GA raw material is just what reported by the previous report²⁾. P- γ -GA is the functional ingredient of the food for specified health use. However, it is the present condition not to yet succeed in the use development in large quantities. In this study, wheat bran was examined with the goal

of getting basic knowledge to consider the possibility of its carbonization, aiming finally at the use development to fuel, manure, and an active carbon and a carbon fiber.

Wheat bran is an industrial by-product in the flour milling industry, and most of it is consumed as feed of the domestic animal such as cow, pig and cock. It occurs as wheat bran where about 23% (1,300,000t a year) are industrial by-products of the wheat as the flour milling raw materials. When cheap wheat bran flows in by the change of a sudden exchange rate from the foreign countries (such as United States, Canada and Australia), there is the

actual situation that the sales decrease amount of money of the minute when the price of the wheat bran fell just suppresses the profit of the company directly. Actually, it caused the bankruptcy of many small businesses whenever appreciation of the yen happened till now. Therefore, it could contribute to Japanese flour milling industry and the allied industrial stabilization if an added value besides a feed use could be given to wheat bran.

It is the most important that the condition required by charcoal for fuel has a big calorific value. A Japanese oak is suitable for general fuel lumber charcoal most in Japan, but a calorific value of the charcoal of the Japanese oak exceeds 7,000 cal/g. Therefore, in the use development to charcoal, a calorific value of this around 7,000 cal/g becomes the most important target. In addition, not jumping during combustion with the crackle or the thing that it maintains burning for a long time are properties required next to a calorific value when used for fuel. Furthermore, it becomes important that there are many fossulae that is that the surface area per unit weight is big to adsorb smell or color when used as an active carbon. Therefore, in this study, a carbonization condition was examined to get the ratio surface area that became effective as an active carbon again mainly to get a calorific value that was equal to charcoal. In addition, other properties of matter as charcoal were investigated.

MATERIALS AND METHODS

Samples and materials

Wheat bran which is isolated from the individual wheat brand were used, that is, ICW (No.1 Canada Western Red Spring Wheat). This wheat brand is the most generally used as bread flour of best quality in Japanese baking industry. As a control, oak chip was used, since it is widely used as a raw material of charcoal in Japan.

Thermogravimetric/Differential thermal analysis

Colorimetric characteristics of TG (thermogravimetric) and DTA (differential thermal analysis) were examined with TG/DTA220 (SII NanoTechnology Inc., Chiba, Japan) under the experimental condition as follows. Sample weight: spirit scaled 20mg, Temperature range: 30–700°C, Temperature increase: 5.00°C/min, Gas: N₂F or air at the flow rate of 80.0ml/min, Reference: N₂ at the flow rate of 200.0ml/min.

Carbonization

Spirit scaled 10g sample was taken into a melting pot and burnt at predetermined temperature and period in a muffle furnace under anaerobic condition.

Determination of specific surface area

The specific surface area of the charcoal sample was determined with Monosorb (Quantachrome instruments, Florida, USA) under the following experimental conditions. Surface area range : 0.01m²/g to 3,000m²/g, Adsorbate: nitrogen, Ads/Des cycle: automatic, Dewar elevator: automatic, Desorption: hot air blower, Calibration loop: icc, Analysis station: one, Preparation station: one, Degas temperature: room temperature to 350°C .

Determination of charcoal pH

The supernatant which was cooled down to room temperature was directly used for pH determination.

Determination of calorific value

Heat releasing capacity of the charcoal sample was determined with a differential scanning calorimetry X-DSC7000 (SII Nano Technology Inc., Chiba, Japan) according to JIS K 2279³⁾.

Scanning electron microscopy

Carbonated samples were examined using a scanning electron microscope (Hitach S-530, Tokyo, Japan) with the magnification of 1000

under 15KV. Vapor deposition of samples was conducted with Hitach Ion Sputter (E101 ION SPUTTER) for 2 min according to the conventional method.

RESULTS AND DISCUSSION

Thermodynamic characteristics of wheat bran

The mass of wheat bran is monitored against time and temperature under both aerobic and anaerobic atmosphere according to thermogravimetric analysis as shown in Figure 1. The change of the TG% between two atmospheric conditions was very little which is similar to the wood of usual charcoal raw material. Differential thermal analysis under aerobic condition showed that bran starts to burn around 490°C. This fact indicates that wheat bran progresses the ashing and the yield of charcoal will decrease as the temperature rises to more than 490°C under aerobic carbonizing condition. Therefore, it becomes necessary to burn wheat bran under anoxia in the same way as wood charcoal when it is carbonized.

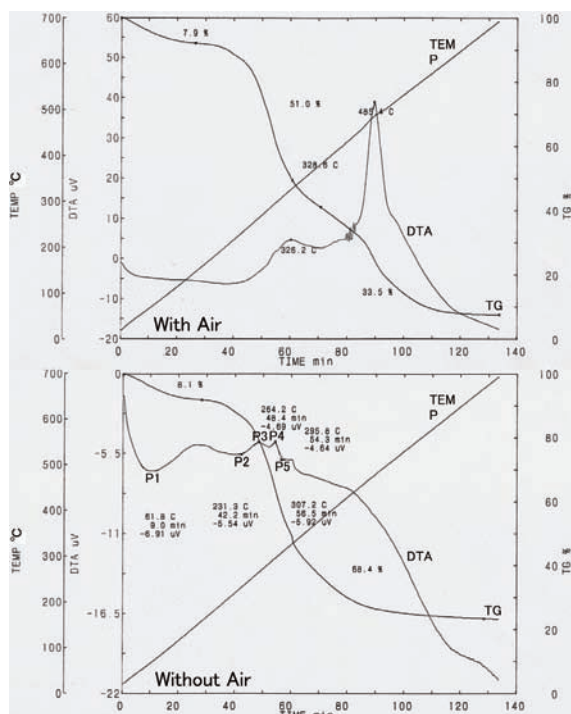


Figure 1. TG/DTA analysis on wheat bran with air and without air.

On the other hand, differential thermal analysis under anaerobic condition showed several peaks of both endothermic and exothermic reaction. Characteristics of the five distinguished peaks shown as P1-P5 in Figure 1, are summarized in Table 1. The peak 1 is the endothermic peak of water evaporation. Other peaks are considered to be the major component of wheat bran, such as cellulose, hemicellulose, lignin and so on. It is from these data, and which peak cannot judge which component.

Table 1. Characteristics of 5 peaks obtained from DTA analysis

| Peak No. | Temperature (°C) | Elapsed Time (min) | DTA (μV) |
|----------|------------------|--------------------|----------|
| P1 | 61.8 | 9.0 | -6.91 |
| P2 | 231.3 | 42.2 | -5.54 |
| P3 | 264.2 | 48.4 | -4.69 |
| P4 | 295.8 | 54.3 | -4.64 |
| P5 | 307.2 | 56.5 | -5.92 |

General properties of wheat bran charcoal

Wheat bran was heated at various combustion temperatures against time under anaerobic atmosphere to prepare the wheat bran charcoal. As physical characteristics to control a property of the fuel charcoal, charcoal yield (%), specific surface area (m^2/g), and pH were determined and the results are as shown in Table 2. Carbonization progressed at the combustion condition of more than 400°C and 20 min. Charcoal yield was decreased as combustion temperature increased and as combustion time increased. Also, the specific surface area increased as combustion temperature increased. pH tends to become basic according to the higher temperature and the longer combustion time. Moisture content had no relation to both the combustion temperature and time. These results approximately correspond to the results carried out of wood except that the specific surface area of wheat bran charcoal is only approximately ten minutes around one compared to general wood charcoal^{4,5}. This fact means that it is difficult for wheat bran charcoal to use it as an active carbon.

Differential scanning calorimetry analysis

showed that wheat bran treated at 800°C, 30min has the heat releasing capacity of 6,500cal/g. As a control, oak was carbonized in a same way of wheat bran and it showed a heat releasing capacity of 7,970cal/g. Generally, a calorific value of fuel charcoal more than 7,000cal/g was said that it was necessary, but understood that met a basic condition as fuel charcoal because wheat bran charcoal showed near calorific value to it.

Table2. Difference of physical properties of wheat bran charcoal obtained by various carbonization condition

| Heat Temp. (°C) | Carbonization Time (min) | Charcoal Yield (%) | Specific Surface Area (m ² /g) | pH | Moisture(%) |
|-----------------|--------------------------|--------------------|---|-----|-------------|
| 400 | 10 | 74.1 | ND | 6.0 | 2.0 |
| | 20 | 33.1 | ND | 7.9 | 1.0 |
| | 30 | 32.2 | ND | 8.1 | 1.0 |
| 500 | 10 | 29.3 | 2.4 | 8.3 | 1.3 |
| | 20 | 27.1 | 5.9 | 8.3 | 1.7 |
| | 30 | 26.8 | 6.0 | 8.9 | 1.7 |
| 600 | 10 | 26.0 | 2.2 | 9.0 | 1.8 |
| | 20 | 24.7 | 37.1 | 8.6 | 1.8 |
| | 30 | 24.4 | 38.1 | 8.9 | 1.4 |
| 700 | 10 | 23.9 | 38.8 | 9.1 | 1.4 |
| | 20 | 23.5 | 44.0 | 8.5 | 1.2 |
| | 30 | 23.1 | 50.1 | 8.9 | 1.3 |
| 800 | 10 | 22.9 | 15.6 | 8.8 | 2.2 |
| | 20 | 21.4 | 24.2 | 8.5 | 1.8 |
| | 30 | 21.6 | 82.7 | 9.1 | 2.0 |

※ND: No Detected

Pore structure of wheat bran charcoal

A specific surface area of wheat bran charcoal was conspicuously smaller than that of wood charcoal. In order to examine the reason, micro pore structure was observed with a scanning electron microscope. Wheat bran charcoal was carbonized at 800°C, 30min and oak charcoal was prepared in a same manner as a control. Naked eye observation photograph of wheat bran charcoal is shown in Figure 2. The shape is form of small granule, and appropriate size understands that it is necessary to solidify it using a binder because in this situation heat radiation does not last for a long time to use it with fuel charcoal.

Figure 3 shows difference in several structural properties between wheat bran

charcoal and oak charcoal. The comparison of surface structure of A-1 with B-1 demonstrates the following fact. As for the surface of wheat bran charcoal, the surface of oak charcoal understands that thin fiber gets twisted up⁶⁾ and is comprised whereas it is smooth. Therefore, surface area of wheat bran charcoal becomes smaller than that of oak charcoal. When it compares the A-2 (wheat bran charcoal) with sectional B-2 (oak charcoal), the pore size is uneven than oak charcoal, and it understands wheat bran charcoal to cause blocking small. Probably it is guessed that starch granules and the protein that attached to wheat bran carbonized and cause blocking. According to these results, it is considered to be very difficult to increase a specific surface area of wheat bran charcoal.

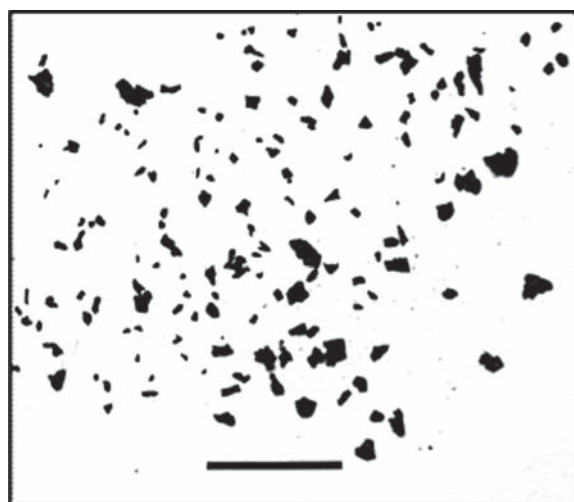


Figure 2. Photograph of wheat bran charcoal. Black bar indicates 10mm length.

CONCLUSION

Because wheat bran had a calorific value that was equal to charcoal, available possibility was provided as fuel charcoal. However, for a more value-added high active carbon, it was understood the thing that was less likely to be available for a characteristic of the surface and the internal fossula structure because a specific surface area was conspicuously small.

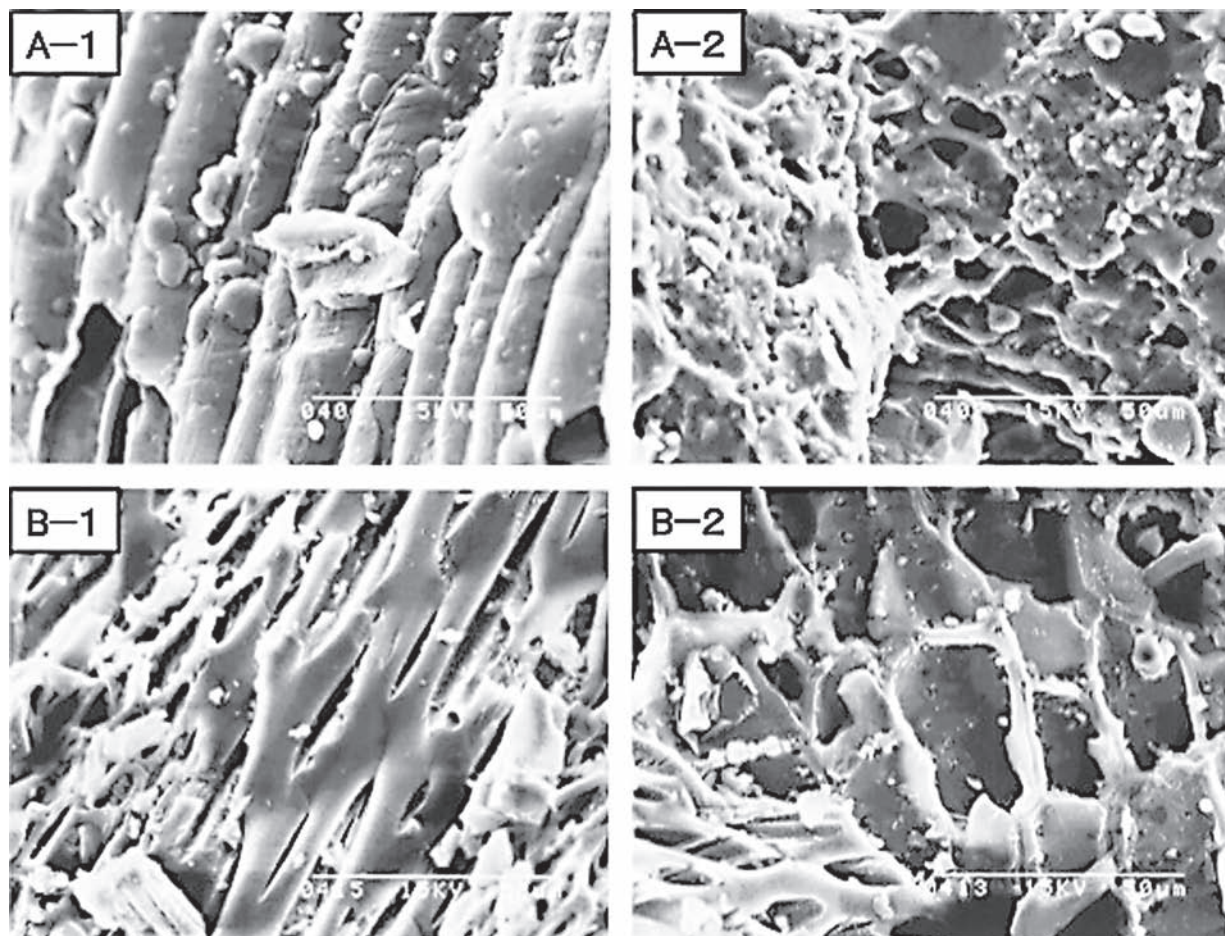


Figure 3. Scanning electron microscopy of charcoals. "A" and "B" indicates wheat bran and oak, and "1" and "2" means surface and cross section of each flat charcoal, individually. White bar shows 50 μ m length.

We must develop a solidification technology in future to maintain heat radiation with wood charcoal equally to develop practical use as fuel charcoal. There are many problems that there remained it whether solidification processing should be done before carbonization again what kind of binder should be used for solidification or should do it after carbonization.

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REFERENCES

- 1) The Wheat, edited and published by Japan Wheat Research Association, Tokyo, Japan. p537 (1994).
- 2) Kai, T. : Trial of isolating the high yield bacteria for producing poly- γ -glutamate with wheat bran a fermentation raw material. *Bulletin of Seinan Jo Gakuin University*. 16:89-95 (2012).
- 3) Japan Industrial Standard: Crude petroleum and petroleum products-determination and estimation of heat of combustion (1993).
- 4) Abe, I., Iwasaki, S., Iwata, Y., Kominami, H., and Kera, Y.: Relationship between production method and adsorption property of charcoal. *Carbon*, 185:277-284 (1998).

- 5) Mori, M., Saito, Y., Shida, S., and Arima, T.: Adsorption properties of charcoals from wood-based materials. *Mokuzai Gakkaishi*, 46:355-362 (2000).
- 6) Shimada, M., Iida, T., Kawarada, K., Okayama, T., and Fushitani, M.: Pore structure and adsorption properties of carbonized material prepared from waste paper. *Journal of Material Cycles and Waste Management* 3:135-143 (2001).

原 著

小麦ふすまの炭の原料としての利用可能性に関する研究

甲斐 達男

<要 旨>

産業副産物である小麦ふすまの有効利用を図るための研究の一環として、本研究では、炭化の可能性を検討した。一般に燃料炭の発熱量は7000cal/gを超える必要があるとされているが、小麦ふすま炭は、示差走査熱量測定（DSC）の結果、それに近い発熱量を示したので燃料炭としての基本的条件を満たすことが判った。活性炭として利用する場合は、匂いや色などの分子を吸着するための小孔が多いこと、つまり単位重量あたりの表面積が大きいことが重要となる。そこで、小麦ふすま炭の比表面積を測定したところ、一般の木炭に比べ顕著に小さく活性炭としての利用が困難であることが判った。電顕観察の結果、小麦ふすま炭の比表面積が小さい理由は、木炭のような微細な繊維構造がなく表面が滑らかであること、さらに、内部の小孔がおそらくは澱粉やタンパク質などの炭化物によって目詰まりしているためであることが判った。今後、燃料炭としての実用化を図って行くためには、放熱の維持を木炭と同等にするために小麦ふすま炭の固形化技術を開発しなければならない。固形化にどのようなバインダーを使用するのか、また、固形化処理を炭化の前にやるべきか炭化後にやるべきかなど、多くの検討課題が残されている。

キーワード：小麦ふすま、炭、産業副産物