Recycling of meat and bone meal for food safety and security

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Summary

Recently, meat and bone meal (MBM) has rapidly spread all over the world as an effective feed resource for daily or beef cattle. MBM is effective recycling of dead animals and slaughterhouse waste. It has been an efficient protein source due to the richness of undegradable proteins in rumen. However, Bovine Spongiform Encephalopathy (BSE) occurred due to an infectious prion contaminating the MBM, and its use became prohibited in Japan. Now, most MBM is incinerated as general garbage, and part is disposed of as a raw material of cement. A large amount of tax is spent for this process, and a useful resource is lost by incineration. The present study deals with a newly developed bone carbonization technology for a safe recycling process of MBM and dead animals with a low input of energy and high-added value compared to conventional methods. Carbonization of MBM was examined with a tubular furnace or a muffle which used a crucible under aerobic conditions. Control of temperature, oxidation and reduction in the carbonization process were examined concerning organic matter survivability, surface structure, surface element, and the surface functional group for safe carbonizing conditions and high additional value. In consequence, it was shown that chemically safe bone charcoal could be manufactured at 600°C for 1 hour, as well as the conventional charcoal manufacturing condition of 800°C for 8 hours. Subsequently, inactivation of transmittable prions in the present manufacturing process was confirmed by an infective bioassay in which the charcoal products of brains of transmissible prion-infected hamsters was inoculated into the brains of transgenic mice. The safety of the process was confirmed chemically at 600°C for 1 hour. However, observation for about one year should be necessary for a bioassay, and a conclusion of whether or not there is an infectious existence needs to wait for the results of bioassay. From the results of the present studies, the practical use of a carbonization system of 600°C for 1 hour can be proposed.

Keywords: meat and bone meal, BSE, bone charcoal, prion, recycling

Introduction

In the dairy and beef cattle industries there has been pressure on farmers to more efficiently produce milk or meat on limited land with a limited number of animals. Higher milk production or daily gain could be supported by the quality and quantity of amino acids absorbed in the small intestine. Protein sources have been the most expensive ingredients of dairy and beef cattle feed. Most plant origin protein sources are exposed to microbial degradation in the rumen of cattle. In consequence, a lot of protein consumed escapes from the rumen as ammonia except for when used in microbial protein syntheses or proteins avoiding microbial degradation. MBM has spread all over the world because it has been a recycled feed ingredient rich in undegradable proteins, and has efficiently increased milk

production and daily gain. Unfortunately, a part of MBM has been contaminated by transmissible prions which induce BSE, commonly known as "mad cow disease", a fatal brain disease that affects cattle.

Most diseased carcasses are disposed of by incineration after a BSE inspection in Japan. A part of the carcass is incinerated or used in making cement after processing to MBM applying a maximum government subsidy of 60 yen (0.53 US dollars) per kg. The reason is to have been put out a notification of prohibition of the use of MBM as a gradient for concentrate mixture from the government for BSE problems since incidence of BSE. The carbonization of MBM might be a recommendable procedure if its safety is guaranteed. However, past bone char manufacturing methods weren't able to raise enough added-values because carbonization at high temperature under an anaerobic atmosphere eliminated phosphorus and the characteristics of activated charcoal. Tentative guidelines for secure MBM processing are to process at 800°C for 8 hours. This process requires large-scale carbonization equipment and much energy. Nitrogen and phosphorus in the raw material were eliminated easily by heating. Phosphorus, especially, radiates in the form of hydride, and the content of phosphorus, after the anaerobic process of carbonization, is markedly less (Takahashi et al., 2003). Adsorption capacity was not achieved by carbonization processing under these manufacturing conditions. The density of phosphorus in carbonization directly affects its performance, though bone char can be used to remove fluorine in water (Kaya & Kuroda, 1988). The recycling process must be improved. The construction of a system which gives priority to environmental preservation and resource recycling becomes an important issue in livestock production as shown in laws concerning food recycling and animal effluent, etc. The movement to control carbon dioxide emissions tends to have already expanded not only energy recycling but also waste management of converting incineration processing to recycling with discretion. In addition, it has been an important issue that the balancing strategy in which excessive nitrogen, taken from atmospheric paired nitrogen into the hydrosphere and soil, is returned to the atmosphere and collecting and recycling systems for exhaustible resources such as phosphorus (Takahashi, 2004). The primary issue is to inactivate transmissible prions for completely preventing the risk of contamination. New usage should be developed for MBM due to its insufficient calories and calcium content for cement.

The present study deals with the manufacturing process of safe bone charcoal from MBM and carcasses at relatively lower temperatures to reduce input energy for carbonization. Simply put, the target temperature of carbonization was set to 600°C in the present study. Concurrently, advancing the pyrolysis of the materials was examined to achieve surface activation by introducing a part of direct combustion into the anaerobic carbonization without elimination of phosphorus. The construction of a carbonization system was examined by using a tubular furnace. Inactivation of transmittable prions according to the present manufacturing process was confirmed by the infective bioassay where in the charcoal products of the brains of transmissible prion infected hamsters was inoculated to the brains of transgenic mice.

Chemical confirmation of bone charcoal safety

For safe bone charcoal manufacturing, carbonizing at 800°C for 8 hours has been required as a tentative guideline according to the manufacturing process in circulation commodities. This process requires large-scale carbonization equipment and much energy. Thus, the improved carbonization of MBM and livestock carcasses requires a lower temperature with smaller energy input. However, Brown, a chief researcher on BSE at NIH in the USA, suggested the possibility of BSE infection in carbonization at 600°C from results of his infective bioassay in which hamsters' brains infected by BSE and carbonized at 600°C with a crucible in a muffle furnace were inoculated (Brown et al., 2000). Therefore, the new carbonizing technology

must be sure to eliminate transmissible prions in carbonized products.

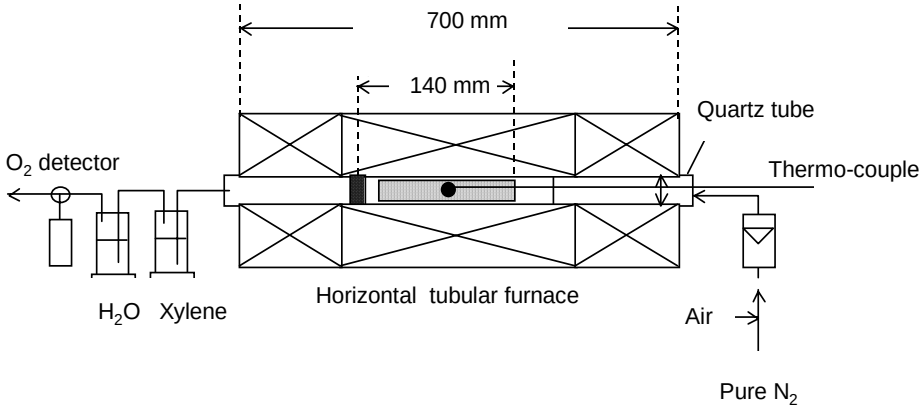


Figure 1. Carbonization test with a tubular furnace

Figure 1 shows a tubular furnace used in the carbonization experiment. An aerobic condition was achieved by inducing air to examine porous formation on the surface of bone charcoal. MBM is quite rich in protein, but its Ca and energy contents are too low for being used as a raw material of cement as an alternative way of MBM disposal (Table 1). Manufacturing conditions of bone charcoal with safe and high added value are eluted phosphorus and nitrogen retention and large surface area with a porous structure like activated carbon. These added values were improved by controlling O_2 concentration in the furnace. Figure 2 shows analyses of surface functional groups of bone charcoal with electron spectroscopy for chemical analysis (ESCA). The left figure shows the location of linkage energy in the wide scanning spectrum of bone charcoal. The right figure indicates the analysis of the peak. Carbonyl and carboxyl groups were identified in the complicated carbonized surface. The surface structure and distribution of activated phosphorus were detected by scanning electron microscopy and electron proves micro-analyses (EPMA) of anaerobically carbonized bone charcoal (Figure 3).

Table 1 Chemical composition and characteristics of MBM

N	1052	wt%
P	4.07	wt%
K	0.48	wt%
Ca	7	wt%
C	44.09	wt%
H	5.22	wt%
Crude fat	11.15	mg/kg
Solid	94.3	wt%
Ash	25.6	wt%
Heat production	16000	kJ/kg

* including meat, bone, skin and hair

The surface structure of bone charcoal became more complex and more distribution of activated phosphorus that indicated by yellow color by introducing oxygen. Remains of organic matter of carbonized MBM were inspected by gas chromatography-mass spectroscopy of n-hexane extracts. Some of them were estimated at 400°C carbonization, but

no organic matter was observed at 600°C carbonization. The remains of organic matter of carbonized MBM were detected when MBM was carbonized with a crucible in a muffle furnace according to the procedure reported by Brown et al. (2000). Thus, carbonization with a crucible at 600°C is insufficient and can not inactivate transmissible prions. Consequently, the BSE infectivity of carbonized products will not disappear when the materials are contaminated by transmissible prions.

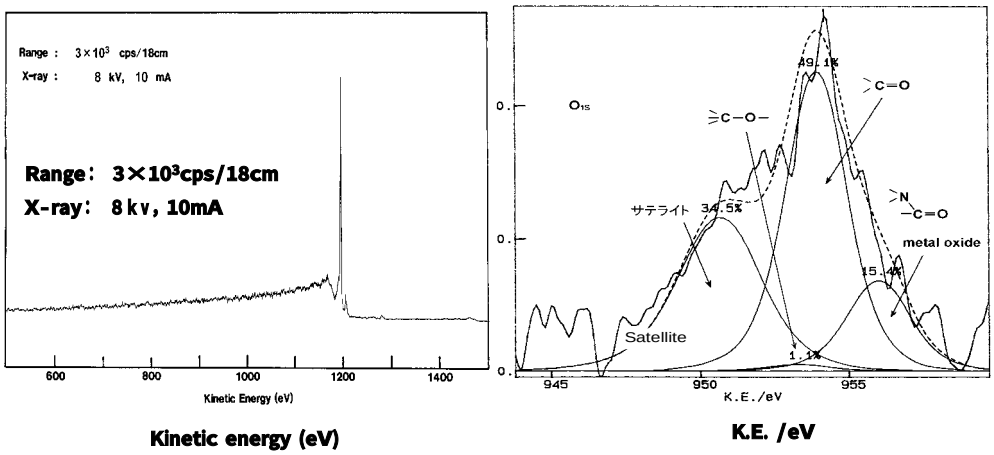


Figure 2. Functional groups of the surface of bone charcoal :Electron Spectroscopy for Chemical Analysis (ESCA)

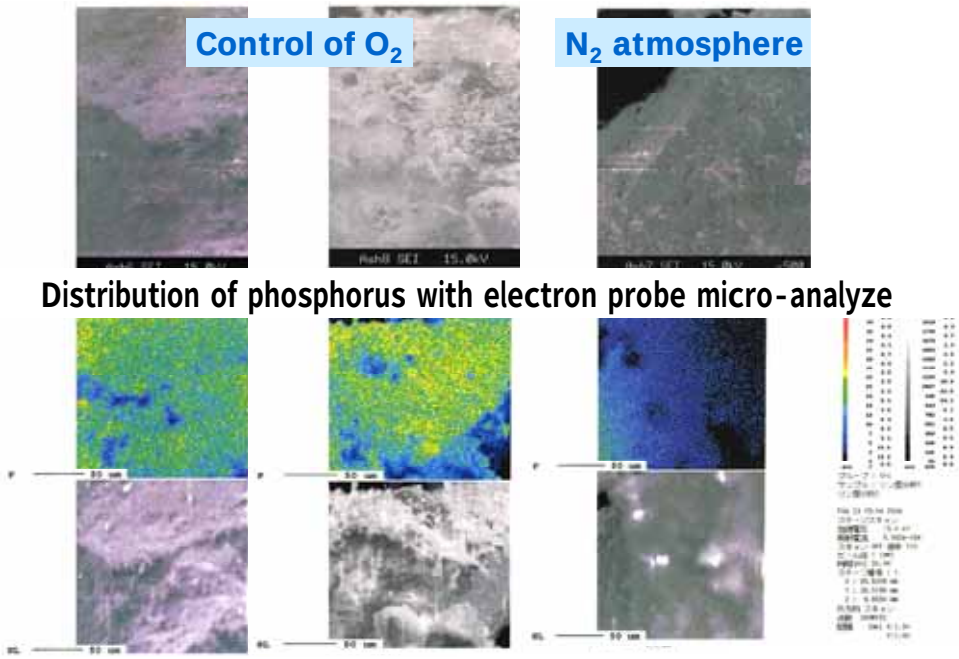


Figure 3. The surface structure and distribution of activated phosphorus with scanning electron microscopy and electron prove micro-analyses (EPMA) of anaerobically carbonized bone charcoal

From the results of carbonization of MBM, manufacturing secure bone charcoal could be confirmed at 600°C for 1 hour with an ordinary furnace. Additionally, the added value will be improved under aerobic conditions in the furnace.

Bioassay test confirming the safety of BSE

Subsequently, to confirm safety from contamination of transmissible prions, the BSE infected hamsters' brains (hamster prion strain Sc237) were carbonized with a tubular furnace or a crucible in a muffle furnace according to Paul Brown's procedure at P2 bio-hazard level. For an infectivity bioassay, the carbonized hamsters' brains were inoculated intracerebrally into transgenic mice (TgHaNSE) at P3 bio-hazard level. Figure 4 shows the surface structure of the BSE infected hamsters' brains carbonized with a tubular furnace or with a crucible in the muffle furnace at 600°C. Carbonization of brains was almost completed at 600°C and 800°C. However, carbonization was still ongoing at 400°C. Furthermore, fibrous tissues remained in the carbonized brains with a crucible in the muffle furnace at 600°C.

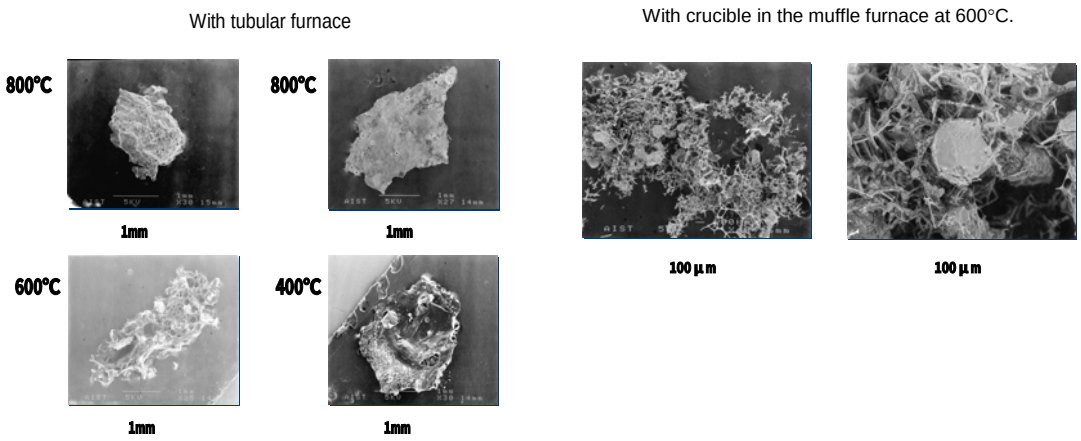


Figure 4. Carbonized brains in BSE infected hamsters using a tubular furnace or a crucible in the muffle furnace at 600℃

Figure 5 shows the spectra of the energy dispersive X-ray fluorescence spectrometer (EDX) for surface element analysis of BSE infected hamsters' brains carbonized with a tubular furnace or with a crucible under aerobic conditions of a muffle furnace at 600°C. The C/O peak ratios in EDX spectra of carbonized brains with a tubular furnace indicated low values at 600°C and 800°C carbonization with a tubular furnace. However, a relatively higher C/O peak ratio was observed at 400°C carbonization. This result indicated that carbonization was still ongoing at 400°C.

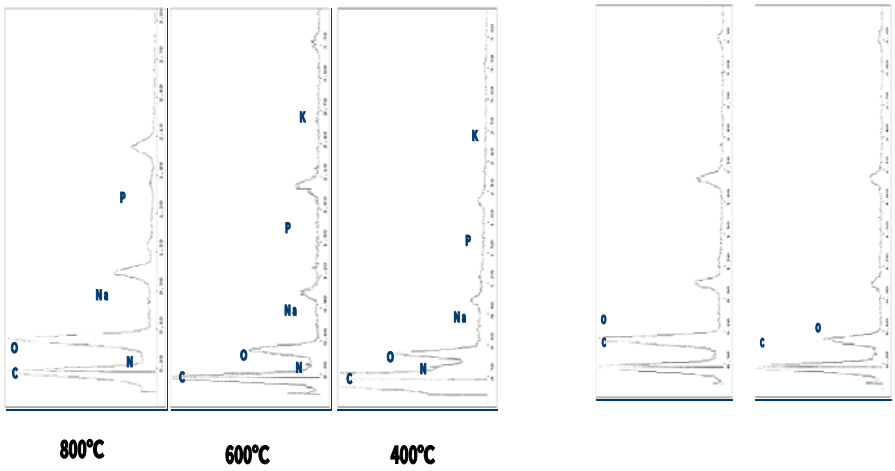


Figure 5. EDX spectra (energy dispersive X-ray fluorescence spectrometer) of carbonized brains in BSE infected hamsters with tubular furnace (left) and with a crucible in the muffle furnace at 600℃ (right)

The C/O peak ratio in the EDX spectrum of carbonized brains with a crucible under aerobic conditions of a muffle furnace at 600°C is similar to 600°C carbonization with a tubular furnace. This result indicates that only the surface of brains was carbonized under aerobic conditions with activate tissue remaining. Therefore, fibrous tissue was observed in scanning an electron microscopy. Figure 6 shows the spectra of the Fourier transform infrared spectrometer (FTIR) to identify the surface functional groups of BSE infected hamsters' brains carbonized with a tubular furnace or with a crucible under aerobic conditions of a muffle furnace at 600°C. In carbonization with a tubular furnace, the strong absorption band of aroma family ring appeared instead of small absorptions of the carboxyl group and the hydroxyl group at 800°C and 600°C carbonization. On the contrary, marked absorptions of the carboxyl group and the hydroxyl group were observed at 400°C carbonization.

For the brains carbonized with a crucible under aerobic conditions of a muffle furnace at 600°C, the spectrum indicated a medial profile between 400°C and 600°C carbonization with a tubular furnace.

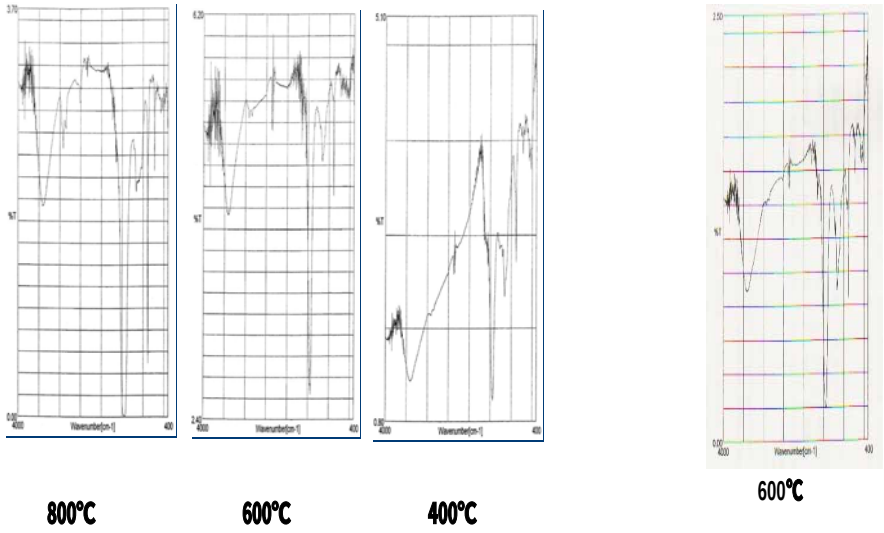
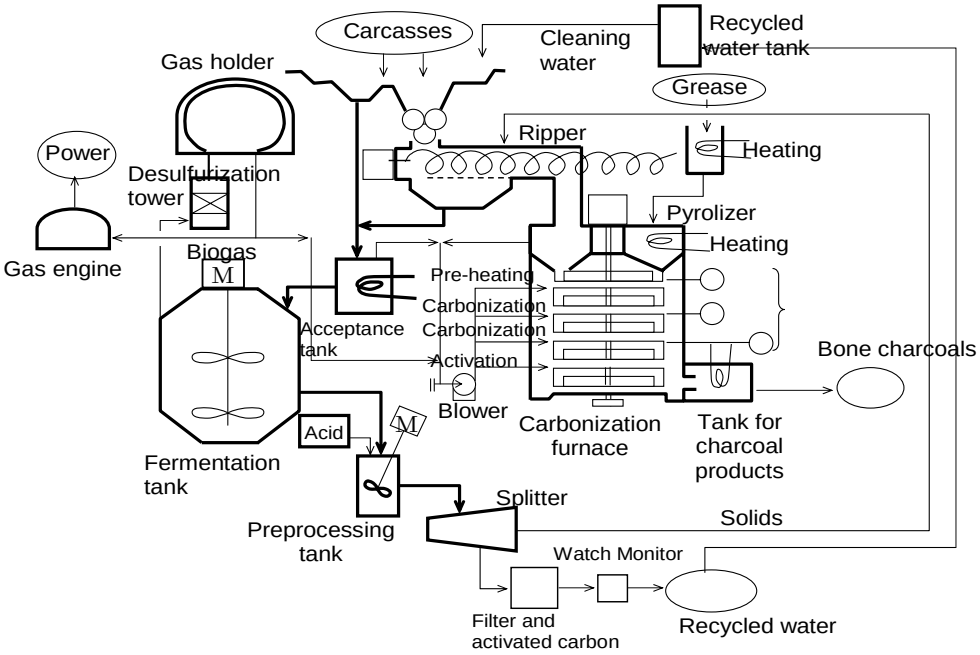


Figure 6. FTIR spectra (Fourier transform infrared spectrometer) of carbonized brains of BSE infected hamsters with a tubular furnace (left) or with a crucible in the muffle furnace at 600℃ (right)

From the results of EDX and FTIR spectra analysis, carbonization of brains was almost completed at 600°C and 800°C. However, carbonization was still ongoing at 400°C. In the present study, we double-checked Brown's report (2000) in which the risk of BSE infectivity remained at 600°C carbonization with a crucible. For the confirmation of BSE infectivity, we have to wait for the results of the bioassay, but it can be estimated that in the first place only the surface of brains will be carbonized and oxidized by a high concentration of oxygen in the crucible. In consequence, it is possible for the tissue without carbonization to still have the risk of BSE infectivity. For practical purposes, the advantage of carbonization at 600° C is to be able to use metal materials for the carbonizing furnace. Thus, a large-scale furnace can be constructed where uniform carbonization is enabled by finely controlling the atmosphere in the furnace. The control of the atmosphere in the furnace is the most important factor to produce added value in specific surface area and phosphorus content. The inactivation of BSE infectivity in carbonization at 600° C for 1 hour is expected to be confirmed by the results of the bioassay which is still ongoing.



Scheme 1. Production of high-quality bone charcoal from carcasses as a resourceful recycling system

Recent carbonization technology of organic waste as a biomass energy source has been required to produce added value by efficient energy input at lower temperatures. As shown in scheme 1, a carbonizing system for secure recycling of MBM and livestock carcasses can be proposed for practical use.

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