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Analyzing a Simple Biochar Production Process and the Cultivation and Assessment of "Cool" Cabbages in Kameoka City, Japan

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Introduction

Reducing GHG on a global scale is needed and carbon sequestration with biochar has the potential to continuously sequester carbon if it is part of a sustainable, regional socio-economic system. Of particular importance is the redevelopment of agriculture to incorporate biochar, especially in marginalized rural areas. Our project focuses on applying biochar to agricultural land and proposes a social scheme based on an eco-branding strategy with biochar-cultivated vegetables named "Cool Vegetables" in a rural area of Japan (Kameoka City, Kyoto Prefecture).

The "Carbon Minus Project" (Figure 1) was launched by a partnership between the Kameoka City Government, Ritsumeikan University, and a local farming cooperative in 2008.

The socio-economic system proposed in this social scheme can function best when biochar is produced efficiently and cheaply. Adopting a modified-pit process enables the producer to convey equipment easily to the biomass site, helping reduce carbon emissions and supporting carbon minus LCA. We utilized bamboo from overgrown stands, which are abundant in Japan, as feedstock.

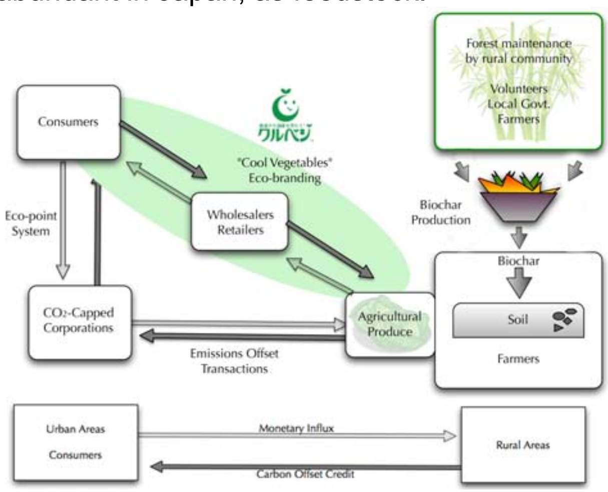

Figure 1. "Carbon Minus Project" Scheme

Biochar produced from this process was then used in a series of experiments to investigate the growth effects of biochar on agricultural products (cabbages).

This paper presents data from these two processes.

Results and Discussion

(1) Examining charring and economic efficiency in the simple carbonization process

Bamboo was carbonized in round, steel, open kilns by MOKI Manufacturing Co. Ltd. as shown in Photos 1 and 2. We are calling this process a "modified pit method."

Table 1 shows the capacity of carbonization. Over the course of a five day period, 3391kg of bamboo (1798kg of dry weight) was charred and doused with water to produce 1318kg of biochar (423.7kg dry weight). Moisture content was measured twice and averaged 67.84% due to dousing. Carbonized ratio (wet/wet) was 38.86% and (dry/dry) was 23.53%.

Photo 1. Carbonization of bamboo

Photo 2. Biochar produced

Table 1. Capacity of carbonization

Date of experiment (2009)	Jul.9	Jul.16		Aug.17		Jan.31		May.11		Total	Ave
Number of batchs	1st-2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd		
Input of biomass (kg)[A]	818.0	291.7	447.5	140.0	334.1	206.8	334.2	395.2	423.3	3391	
Biochar yield(kg) [B]	410.2	113.5	141.6	88.1	118.5	74.9	65.8	140.5	164.4	1318	
Non-carbonized matter	exist	exist	exist	exist	exist	exist	exist	exist	exist		
Moisture content of biomass(%)											46.98
Moisture content of biochar (%)											67.84
Dried biochar yield (kg)[C]	131.9	36.5	45.5	28.3	38.1	24.1	21.2	45.2	52.9	424	
Charring ratio (including moisture) (%) [B/A]	50.15	38.91	31.64	62.93	35.47	36.22	19.69	35.55	38.84		43.82
Dried biochar yield/Input of biomass (%) [C/A]	16.13	12.51	10.18	20.24	11.41	11.65	6.33	11.43	12.49		14.00
Ratio of carbon(%)	81.53	86.87									
Carbonizing time (minute)	398	108	167	58	115	85	325	258	193	1707	

Table 2. Costs for producing the biochar

Item	Unit price (JPN)	Unit	Quantity					Total	Total cost
			Jul.9	Jul.16	Aug.17	Jan.31	May.11		
Material for biochar	0	kg	818	739	474	541	819	3391	¥0
Carbonization instrument	¥1,627	piece/day	1	1	1	1	1	5	¥8,133
Labor cost 1	¥1,000	hour	8.1	6.1	4.4	8.3	9.0	36	¥36,000
Labor cost 2	¥1,000	hour	8.1	6.1	4.4	8.3	9.0	36	¥36,000
Chain saw	¥700	piece/day	1	1	1	1	1	5	¥3,500
Fuels, gloves and tools etc.	¥4,000	day	1	1	1	1	1	5	¥20,000
								Total	¥103,633

The ratio of carbon was measured from three biochar samples each of July 9th and July 18th and averaged 84%. These results indicate highly efficient charring because normal carbon ratios for bamboo charcoal range from 79% to 82% [1].

From an economic standpoint, the initial cost for producing biochar doused with water was 79 yen ($0.91US) per kg and 245 yen ($2.83US) per kg as a dry product (see Table 2 for breakdown of costs). Comparatively, inquiry into the cost of producing commercially available bamboo charcoal for gardening found an average price of 443 yen ($5.12US) per kg. Our biochar costs were equivalent or less than commercially available sources, but feedstock conveyance costs were not considered in these calculations.

(2) Examining the growth effects of biochar with varying treatments on cabbage

“Cool” cabbages were cultivated under three variables--- biochar application rate, presence of compost, and presence of chemical fertilizer-- over a range of treatments. The experimental treatments are shown in Table 3. Photo 3 gives a visual of the cabbages measured.

From these experiments, statistical analysis was performed on: (1) The difference between T-1:CM-4,-5,-6 (no biochar vs. biochar and chemical fertilizer). No significant difference was found between T-1 and CM-4,-5,-6 (P(0.05); (2) The difference between CM-1:CM-2,3 (no biochar vs biochar with no chemical fertilizer).

Table 3. Experimental treatments

Plot	CM-6	CM-5	CM-4	CM-3	CM-2	CM-1	T-1
Biochar	○	○	○	○	○	×	×
volume/0.1ha	4.3M3	2.1M3	1.0M3	4.3M3	2.1M3	0.0M3	0.0M3
carbon weight (ton-C/0.1ha)	3.0t	1.5t	0.8t	3.0t	1.5t	0.0t	0.0t
Compost 5 M^3/0.1ha	○	○	○	○	○	○	○
Chemical Fertilizer 120kg/0.1ha	○	○	○	×	×	×	○

Photo 3. Measured cabbages (L to R: CM=6 to T=1)

Table 4. Measured result

Section number	Above-ground part (kg) Total weight	Edible part	height(cm)	diameter(cm)	circumference (cm)
CM=1	1.75±0.07	0.79±0.05	12.5±0.41	15.8±0.40	50.6±1.12
CM=3	2.29±0.10	1.21±0.07	14.6±0.37	18.0±0.35	57.9±1.07
P-number	0.11	0.04＊	0.25	0.28	0.27

There was significant difference between CM-1 and CM-3 ($P \leq 0.05$) in the edible portion (Table 4); (3) No significant difference was found between CM-2:CM-5 and CM-3:CM-6 (biochar without chemical fertilizer vs. biochar with chemical fertilizer) ($P \leq 0.05$).

In addition, empirical analysis showed that the amount of lateral root and root hair growth was greater for biochar-cultivated cabbages.

Further experimentation taking into account more technical (feedstock and biochar production characteristics) and environmental factors (regional characteristics in climate and soil) is recommended.

Conclusions

The results of these experiments suggest that biochar production from a simple method is economically viable and among the cases of cabbages with varying treatments, no highly significant differences were found.

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[1] Ikejima, Y. 1999. *Takezumi & Tikusakueki no Tsukurikata to Tsukaikata. (Production Methods and Use of Bamboo Charcoal and Bamboo Wood Vinegar)* Tokyo: Nobunkyou, p.141.