Economic Benefits Analysis of Barbecue Bamboo Charcoal Plants at Different Production Scales in the Fujian Province of China

Tao Zhang,# Hongzhong Xiang,# Fang Liang, Wanhe Hu, Xiaomeng Yang, Bingbing Mi, Ge Wang, Benhua Fei, and Zhijia Liu *

Financial data of barbecue bamboo charcoal plants located in the Fujian province, China with annual productions of 1000 MT, 2000 MT, and 3000 MT was investigated to compare the economic benefits. The project was evaluated based on the time of purchasing bamboo processing residues as the starting point and the sale of barbecue bamboo charcoal as the end point. Calculations of the net present value (NPV), dynamic investment pay-back period (PBP), internal rate of return (IRR), and break-even point (BEP), and a sensitivity analysis were performed. The plant with an annual production of 3000 MT had good economic benefits with an NPV of 3.1 million USD and PBP of 2.89 years. The IRR and BEP of the plant were 44.4% and 63.8%, respectively, indicating that the plant had a good ability to adapt to market changes and resist risks. The sales prices had a greater impact on the sensitivity than the plant operating costs. Thus, high-quality barbecue bamboo charcoal should be produced to increased the price of the product for better economic benefits, even though all of the plants had good market prospects. A large-scale plant should be designed for better economic benefits if there are adequate raw materials.

Keywords: Bamboo residue; Barbecue charcoal; Economic benefits; Deterministic analysis; Uncertainty and risk analysis

*Contact information: International Centre for Bamboo and Rattan, Beijing, 100102, China; #: Co-authors: Hongzhong Xiang, equal contributor as first author; *Corresponding author: Liuzj@icbr.ac.cn*

INTRODUCTION

As one of the most important forestry resources in China, bamboo has some superior attributes, such as a fast growth rate, numerous applications, and high economic value. Bamboo is widely distributed in China, and the over 6.01 million ha in China account for approximately 30% of the total global bamboo area (Li *et al*. 2017). The bamboo industry is also one of the most important economic entities in southern China, especially in Fujian province (Wang *et al*. 2008). Fujian province has become the main production location for the bamboo processing industry because it has the most abundant bamboo resources in China (Wang 2017).

Additionally, a lot of bamboo residue is generated during processing because of the unique hollow structure of bamboo. With the introduction of a series of new environmental protection policies and sustainable development requirements, effective utilization of these bamboo residues is an urgent problem that needs to be solved. Direct-fired power generation, compression molding, biological fermentation, pyrolysis gasification, and liquefaction are considered to be potential ways to utilize bamboo residue (Gu *et al*. 2016). However, considering direct-fired power generation, the energy density of bamboo residue is low, and thus only large-scale utilization can produce good economic benefits (Pang *et* *al*. 2013). Investments in pyrolysis gasification processes are relatively high and have a long pay-back period, so they often cannot meet investment demands (Han and Kim 2008). The liquefaction process of bamboo residue is strictly controlled by the heating rate, reaction temperature, and catalyst content under anaerobic conditions. Furthermore, the high cost of purification and utilization of pyrolysis products limit the industrialization of the process (Du *et al*. 2007). Liu *et al*. (2013) reported that compression molding can improve the bulk density and energy density of biomass residue. However, there are still pollution emissions during the combustion process. Dirner *et al*. (2014) found that pollutant emissions were lower after the biomass was carbonized. Compared with these technologies, bamboo charcoal is the most effective and economic way to utilize bamboo residue in China. A machine for the small-scale production of biochar has been successfully fabricated and is used around the world (Odesola and Owoseni 2010). For example, Gladstone *et al*. (2014) studied briquetting charcoal as an alternative fuel source in Tanzania. In the Indonesian region, bamboo processing residue have been carbonized to use as commercial briquetted charcoal (Roliadi and Pari 2006). In Ethiopia, sesame stalk has been used to profitably produce more than 150000 MT/year of briquetting charcoal (Gebresas *et al*. 2015). Presently, bamboo charcoal is mainly used as a fuel for barbecues in China (Xiong *et al*. 2014). To the knowledge of the authors, there is a lack of sufficient economic analyses of Chinese barbecue bamboo charcoal manufacturing plants.

In this research, financial data from three barbecue bamboo charcoal plants in Fujian province, China were investigated, including the production scales, fixed investments, operating costs, cash inflows, and project cycles. Based on the financial data, a deterministic analysis (net present value (NPV), dynamic investment pay-back period (PBP), and internal rate of return (IRR)) was conducted to understand the economic benefits, while an uncertainty analysis (break-even point and sensitivity analysis) was used to understand the ability of the plants to resist risk (Comans *et al*. 2013; Arora *et al*. 2018). Through the evaluation of the economic benefits of the barbecue bamboo charcoal project, the investment direction and the impact of uncertain factors on economic benefits were clarified, which has guiding significance for the investment and construction of the plant.

BARBECUE BAMBOO CHARCOAL PRODUCTION PROCESS

The time for purchasing bamboo processing residue was taken as the starting point, and the economic benefit of the entire project was evaluated by taking the time of sale of barbecue bamboo charcoal as the end point. Therefore, the production process of barbecue bamboo charcoal needs to be understood, which is conducive to investigation and statistics of financial data in the production process. The production process of barbecue bamboo charcoal includes briquetting and pyrolysis. Bamboo processing residue is screened to remove impurities, such as metals, soil, *etc*. They are often stored in a factory for 30 d to 60 d. Before briquetting, the residue must be broken down and dried because their moisture content and particle size are important factors that affect the briquetting process (Oladeji 2015). Then, bamboo briquettes are manufactured in a briquetting mill. These bamboo briquettes are placed into brick kilns and pyrolyzed to produce barbecue charcoal. During the pyrolysis process, some gases and liquids are released (Demirbas 2009; Uzun and Kanmaz 2013). These gases and liquids are often burned to provide the heat energy needed for the drying or pyrolysis processes (Santos *et al*. 2017). The production process is shown in Fig. 1.

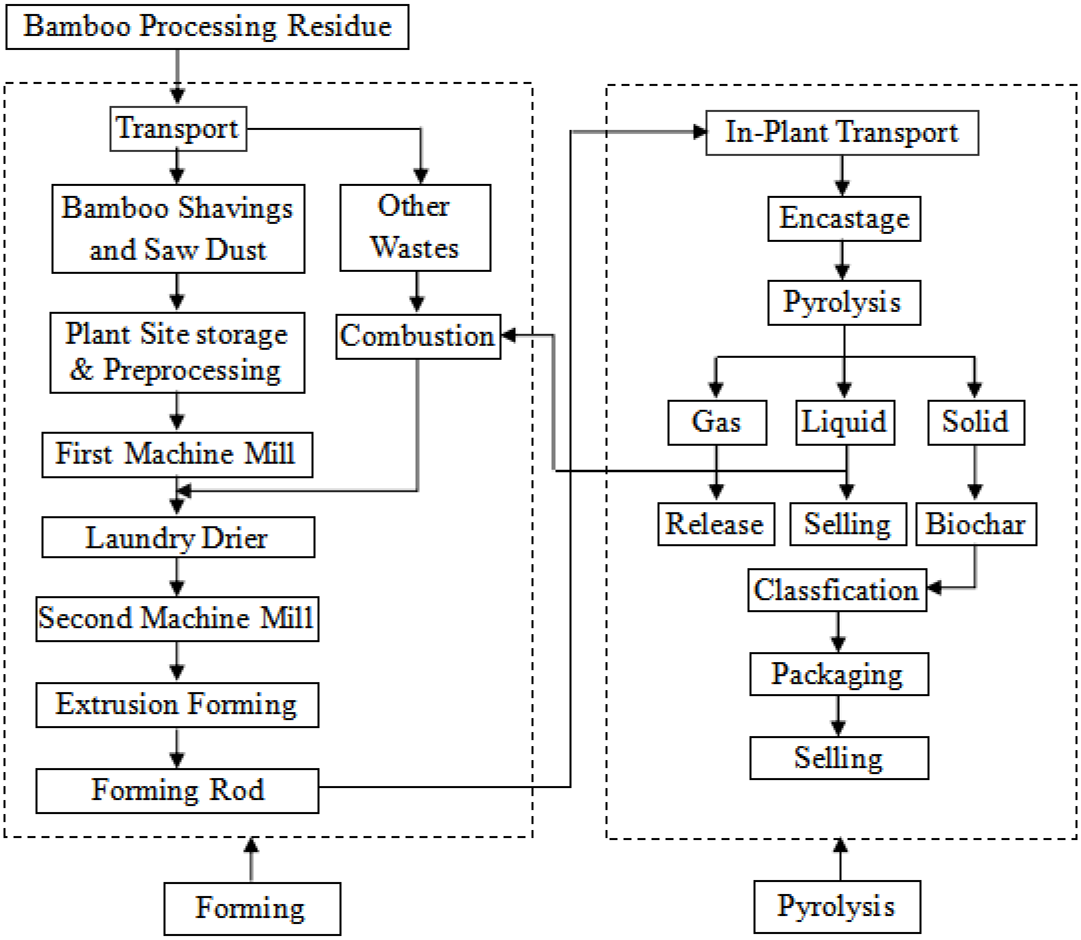

Fig. 1. Production process for barbecue bamboo charcoal

ECONOMIC BENEFIT ANALYSIS

Financial Data

The financial data of three barbecue bamboo charcoal plants (A-plant, B-plant, and C-plant) in Fujian province, China that have different production scales were investigated. According to the survey data (Table 1), the bamboo-char plant investment costs included fixed investment and operational costs (Chattopadhyay *et al*. 1995). The fixed investment was mainly comprised of civil engineering, equipment, and installation engineering costs, depending on the production scale of the barbecue bamboo charcoal mills. According to survey data, the fixed investment of A-plant, B-plant, and C-plant with annual productions of 1000 MT, 2000 MT, and 3000 MT, respectively, were 377640 USD, 604230 USD, and 1057400 USD, respectively. The operating costs included the costs of the raw materials, fuel and power, salaries and wages, repairs and maintenance, packaging, taxes, *etc*. The main factors affecting the costs of barbecue bamboo charcoal mills at different production scales was the raw materials (Consonni and Viganò 2011). The raw materials are mainly obtained from bamboo processing factories. Therefore, the location of a barbecue bamboo charcoal plant directly affects the production scale. A series of national policies were also enacted that require the use of forestry processing residue. The value added tax (VAT) of barbecue bamboo charcoal is instantly returned after paying (Finance and Tax [2006] No. 102 2006). The effect of the VAT was not considered in the following analysis. The current market price and the revenue from the sale of barbecue bamboo charcoal were used as the cash inflows for the current year. The estimated project cycle of the fixed assets of a plant was 20 years.

Table 1. Project Investment Parameters for Barbecue Bamboo Charcoal

Financial Data		A-plant	B-plant	C-plant
Production Scale (MT)	Annual Production	1000	2000	3000
Fixed Investment (USD thousands)	Fixed Asset	377.64	604.23	1057.4
Operating Costs (USD/MT)	Raw Material Costs	166.16	199.40	191.09
	Fuel and Power Costs	41.54	45.32	52.87
	Salaries and Wages	67.98	75.53	45.32
	Repairs and Maintenance	15.11	2.27	1.96
	Packaging Costs	30.21	32.18	37.76
Cash Inflow (USD/MT)	Current Market Price	513.60	498.49	513.60
Project Cycle (years)	Equipment Renovation	20	20	20

Deterministic Analysis

The economic benefit analysis for evaluating investment returns is mainly divided into static and dynamic evaluation indicators. Static evaluation indicators do not take into account the time value of the funds. Therefore, it does not correctly identify the advantages of a project. This study used dynamic evaluation indicators, including the NPV, IRR, and PBP, which consider the time value of the funds and economic status of a project throughout its life cycle.

The net income of a project can be expressed directly in monetary terms and can explain the relationship between the project investment and cost of the funds. According to the industry survey of forestry products in China, the benchmark rate of return is 11%, and so that value was used as the discount rate (i_0) in this research. Based on the survey data in Table 1, the cash flow statements of A-plant, B-plant, and C-plant were calculated and are shown in Tables 2, 3, and 4, respectively.

Table 2. Cash Flow Statement of A-plant

Item	Year																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Annual Sales	0	256.8	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6	513.6
Construction Investment	377.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operating Costs	0	160.5	321	321	321	321	321	321	321	321	321	321	321	321	321	321	321	321	321	321	321
Net Cash Flow	-377.64	96.3	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6	192.6
Cumulative Net Cash Flow	-377.64	-281.34	-88.74	103.86	296.46	489.06	681.66	874.26	1066.86	1259.46	1452.06	1644.66	1837.26	2029.86	2222.46	2415.06	2607.66	2800.26	2992.86	3185.46	3378.06
Net Profit Present Value	-377.64	86.76	156.32	140.83	126.87	114.30	102.97	92.77	83.58	75.29	67.83	61.11	55.05	49.60	44.68	40.25	36.27	32.67	29.43	26.52	23.89
Net Present Value	-377.64	-290.88	-134.56	6.27	133.14	247.44	350.41	443.18	526.76	602.05	669.88	730.99	786.04	835.64	880.33	920.58	956.85	989.52	1018.95	1045.47	1069.36

Values are in USD thousands

Table 3. Cash Flow Statement of B-plant

Item	Year										
	0	1	2	3	4	5	6	7	8	9	10
Annual Sales	0	498.49	996.98	996.98	996.98	996.98	996.98	996.98	996.98	996.98	996.98
Construction Investment	604.23	0	0	0	0	0	0	0	0	0	0
Operating Costs	0	354.7	709.4	709.4	709.4	709.4	709.4	709.4	709.4	709.4	709.4
Net Cash Flow	-604.23	143.79	287.58	287.58	287.58	287.58	287.58	287.58	287.58	287.58	287.58
Cumulative Net Cash Flow	-604.23	-460.44	-172.86	114.72	402.3	689.88	977.46	1265.04	1552.62	1840.2	2127.78
Net Profit Present Value	-604.23	129.54	233.41	210.28	189.44	170.67	153.75	138.52	124.79	112.42	101.28
Net Present Value	-604.23	-474.69	-241.28	-31.00	158.44	329.11	482.86	621.38	746.17	858.59	959.88

Item	Year									
	11	12	13	14	15	16	17	18	19	20
Annual Sales	996.98	996.98	996.98	996.98	996.98	996.98	996.98	996.98	996.98	996.98
Construction Investment	0	0	0	0	0	0	0	0	0	0
Operating Costs	709.4	709.4	709.4	709.4	709.4	709.4	709.4	709.4	709.4	709.4
Net Cash Flow	287.58	287.58	287.58	287.58	287.58	287.58	287.58	287.58	287.58	287.58
Cumulative Net Cash Flow	2415.36	2702.94	2990.52	3278.1	3565.68	3853.26	4140.84	4428.42	4716	5003.58
Net Profit Present Value	91.25	82.20	74.06	66.72	60.11	54.15	48.78	43.95	39.59	35.67
Net Present Value	1051.12	1133.33	1207.38	1274.10	1334.21	1388.36	1437.14	1481.09	1520.68	1556.35

Values are in USD thousands

Table 4. Cash Flow Statement of C-plant

Item	Year										
	0	1	2	3	4	5	6	7	8	9	10
Annual Sales	0	770.4	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8
Construction Investment	1057.4	0	0	0	0	0	0	0	0	0	0
Operating Costs	0	493.5	987	987	987	987	987	987	987	987	987
Net Cash Flow	-1057.4	276.9	553.8	553.8	553.8	553.8	553.8	553.8	553.8	553.8	553.8
Cumulative Net Cash Flow	-1057.4	-780.5	-226.7	327.1	880.9	1434.7	1988.5	2542.3	3096.1	3649.9	4203.7
Net Profit Present Value	-1057.4	249.46	449.48	404.94	364.81	328.66	296.09	266.74	240.31	216.50	195.04
Net Present Value	-1057.4	-807.94	-358.46	46.48	411.28	739.94	1036.03	1302.77	1543.08	1759.58	1954.62

Item	Year									
	11	12	13	14	15	16	17	18	19	20
Annual Sales	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8	1540.8
Construction Investment	0	0	0	0	0	0	0	0	0	0
Operating Costs	987	987	987	987	987	987	987	987	987	987
Net Cash Flow	553.8	553.8	553.8	553.8	553.8	553.8	553.8	553.8	553.8	553.8
Cumulative Net Cash Flow	4757.5	5311.3	5865.1	6418.9	6972.7	7526.5	8080.3	8634.1	9187.9	9741.7
Net Profit Present Value	175.71	158.30	142.61	128.48	115.75	104.28	93.94	84.63	76.25	68.69
Net Present Value	2130.33	2288.63	2431.24	2559.72	2675.47	2779.75	2873.69	2958.33	3034.57	3103.26

Values are in USD thousands

PBP

The PBP refers to the number of years required to recoup the investment with the net income of a project. This indicator reflects not only the speed of the investment recovery, but also partially describes the risks of a project. In this research, the time point that was considered the PBP was when the present value of the net cash flow was zero. The PBP was calculated according to Eq. 1,

$$\sum_{t=0}^{PBP}\left(CI_t - CO_t\right)\left(1+i_0\right)^{-t} = 0 \;\Rightarrow\; PBP = \frac{-\lg\left(1-\dfrac{\left(CI_0 - CO_0\right)\times i_0}{CI_t - CO_t}\right)}{\lg\left(1+i_0\right)} \tag{1}$$

where CI_t is the annual cash inflows for a certain year (USD), CO_t is the annual cash outflows for a certain year (USD), CI_0 is the annual cash inflows for year 0 (USD), CO_0 is the annual cash outflows for year 0 (USD), i_0 is the benchmark rate of return (%), and t is a certain year.

In this research, the calculated PBPs of A-plant, B-plant, and C-plant were 2.96 years, 3.16 years, and 2.89 years, respectively. Shorter PBP indicate faster investment recoveries and lower risk projects (Chhim *et al*. 2014). Therefore, C-plant had the fastest investment recovery and was the lowest risk project. It is well known that the PBP indicates the speed of investment recovery as a metric for project evaluation, but it does not take into account the profitability of the project after the PBP. To accurately evaluate the economic benefits of a project, the PBP must be comprehensively analyzed in conjunction with the IRR and NPV.

IRR

The IRR refers to the discount rate at which the total present value of the cash inflows over the life cycle of the project become equal to the total present value of the cash outflows; it is the rate of return when the NPV is zero (Kai and Tiong 2008). The IRR is the average profitability of the funds invested by the project throughout the project life cycle and reflects the pure economic efficiency of the project. The IRR was calculated according to Eq. 2,

$$NPV = \sum_{t=0}^{n}\left(CI - CO\right)_t\left(1+IRR\right)^{-t} = 0 \tag{2}$$

where CI is the annual cash inflows (USD/year) and CO is the annual cash outflows (USD/year).

In technical and economic analysis, the IRR can be estimated by using a trial calculation and linear interpolation method to obtain two rates of return, i_1 and i_2 (%). These rates were used in Eqs. 3 and 4, respectively:

$$NPV_1 = \sum_{t=0}^{n}\left(CI - CO\right)_t\left(1+i_1\right)^{-t} > 0 \tag{3}$$

$$NPV_2 = \sum_{t=0}^{n}\left(CI - CO\right)_t\left(1+i_2\right)^{-t} < 0 \tag{4}$$

Using A-plant as an example, when i_1 was 40%, NPV_1 was 34499 US$. When i_2 was 45%, NPV_2 was -16307 USD. Equation 5 shows how the IRR can be obtained from these values:

$$IRR \;= i_1 + \frac{NPV_1}{NPV_1 + \left|NPV_2\right|}\left(i_2 - i_1\right) \tag{5}$$

Thus, according to the linear interpolation method, the IRR of A-plant was 43.40%, as was calculated with Eq. 5. Similarly, the IRR values of B-plant and C-plant were 40.74% and 44.40%, respectively. If the IRR is higher than the discount rate, a project can be considered profitable. If the IRR is equal to the discount rate, the project breaks even. However, if the IRR is lower than the discount rate, the project will incur losses (Balaram *et al*. 2015). The IRR values for all of the plants were higher than the benchmark IRR of the forestry industry in China (11%), which indicated that A-plant, B-plant, and C-plant were economically feasible. It was found that the IRR of C-plant was higher than that of A-plant and B-plant, which confirmed that C-plant had the best economic benefits.

NPV

The NPV is the difference between the present value of the cash inflows (PCI; USD) expected to be realized by a project and the present value of the cash outflows (PCO; USD) for the implementation of a plan (Tang and Tang 2003). The NPV was calculated according to Eq. 6:

$$NPV = PCI - PCO = \sum_{t=0}^{n} CI_t (1+i_0)^{-t} - \sum_{t=0}^{n} CO_t (1+i_0)^{-t} \tag{6}$$

where n is the operation period of a project (year).

It is well known that when an NPV is positive, a project not only can achieve the standard rate of return (i_0), but also it can generate a certain excess return. When the NPV is zero, it means that the project has reached the standard rate of return (i_0). When the NPV is negative, the expected rate of return for the i_0 will not be achieved and the project is not feasible (Burksaitiene 2009). According to Eq. 6, the NPVs of A-plant, B-plant, and C-plant were 1063360 USD, 1556350 USD, and 3103260 USD, respectively. This indicated that C-plant had the greatest economic benefits.

Uncertainty and Risk Analysis

Because of the change in the objective conditions and the limitation of subjective forecasting ability, the factual result of the investment plan may not necessarily conform to the original predictions and estimates. This phenomenon is referred to as the uncertainty and risk of a project (Chavas and Holt 1996).

BEP

The relationship between the cost, yield, and profit can be used to find the break-even point (BEP) of a project (Davis 1998). A lower BEP indicates that a project has a better ability to adapt to market changes and resist risks. Using a dynamic balance analysis that considers the time value of money, the BEP can be used to analyze the long-term risks of a project throughout its life cycle, with a wide range of practical value. The BEP was calculated with Eq. 7,

$$Q_e = \frac{OC_{ft} + (K_1 + K_2)(A/P, i_0, n) - S(A/F, i_0, n)}{P - C_v} \Rightarrow BEP = \frac{Q_e}{Q_0} \tag{7}$$

where OC_{ft} is the annual fixed operating costs (USD), K_1 is the fixed asset investment (USD), K_2 is the circulating fund (USD), S is the recovered circulating fund (USD), P is the selling price (USD), C_{v} is the variable costs (USD), Q_{e} is the annual production of the balance point (MT/year), Q_0 is the annual production capacity (MT/year), A/P, i_0 (%), and *n* (year) are the Uniform-series Capital-recovery coefficients, and *A*/*F*, i_0 (%), and *n* (year) are the Uniform-series Sinking-fund Deposit coefficients.

$$Q_e = \frac{83090 + (377640 + 513600)(A/P,11\%,20) - 513600(A/F,11\%,20)}{513.6 - 237.91} = 678.3 \quad (8)$$

A-plant, for example, was able to reach a dynamic equilibrium point when Q_e was 678.3 MT/year. The resulting BEP was 67.83%. Similarly, the Q_e values of B-plant and C-plant were 1539.5 MT/year and 1915.3 MT/year, respectively, and the BEP values were 76.98% and 63.84%, respectively. It was obvious that C-plant had the lowest balance point, which indicated that it had a better ability to adapt to market changes and resist risks.

SA

A sensitivity analysis (SA) is used to understand the economic impact if some uncertainty factors were to change (Zhao *et al*. 2016). In this research, the construction investment, liquidity, sales volume, and project cycle were considered to be deterministic factors. The operating costs and sale prices are dominated by the market, which could directly affect the cash inflows and outflows. They consequently affect the IRR of a barbecue bamboo charcoal project. The sensitivity to uncertainty was analyzed by comparing the influences of the operational costs and sale prices on the IRR.

Table 5. SA of the Operating Costs and Sales Prices

Operating Costs	IRR			Sale Prices	IRR		
	A-plant	B-plant	C-plant		A-plant	B-plant	C-plant
-20%	55.88%	58.13%	58.10%	-20%	21.40%	12.70%	20.82%
-15%	52.85%	53.88%	54.67%	-15%	27.30%	20.42%	27.22%
-10%	49.65%	49.54%	51.33%	-10%	32.85%	27.71%	33.17%
-5%	46.58%	45.14%	47.93%	-5%	38.20%	34.31%	38.85%
0	43.40%	40.74%	44.40%	0	43.40%	40.74%	44.40%
5%	40.02%	36.22%	40.83%	5%	48.48%	47.03%	49.76%
10%	36.87%	31.57%	37.30%	10%	53.46%	53.10%	55.06%
15%	33.51%	26.76%	33.60%	15%	58.35%	59.00%	60.29%
20%	29.92%	21.70%	29.71%	20%	63.17%	64.77%	65.43%

Using A-plant as an example, Table 5 shows that decreases in the operating costs of 5%, 10%, 15%, and 20% corresponded to IRR increases of 3.18%, 6.25%, 9.45%, and 12.48%, respectively. When the operating costs increased by 5%, 10%, 15%, and 20%, the IRR values decreased by 3.38%, 6.53%, 9.89%, and 13.48%, respectively. When the sale prices decreased by 5%, 10%, 15%, and 20%, the IRR values decreased by 5.2%, 10.6%, 16.1%, and 22.0%, respectively. When the sale prices increased by 5%, 10%, 15%, and 20%, the IRR values increased by 5.08%, 10.06%, 14.95%, and 19.77%, respectively. B-plant and C-plant had similar results to those of A-plant. It was confirmed that the influence of the sale prices on the IRR was greater than that of the operational costs for barbecue bamboo charcoal plants.

CONCLUSIONS

1. The plant with an annual production of 3000 MT had good economic benefits. An NPV of 3103260 USD and a PBP of 2.89 years showed that this plant had the fastest investment recovery. Furthermore, the IRR and BEP values were 44.4% and 63.8%, respectively, which indicated that this plant had a better ability to adapt to market changes and resist risks. A large-scale plant should be designed if there are adequate raw materials for good economic benefits.
2. For the plant with an annual production of 3000 MT, the IRR value increased by 21.0% when the sale prices increased by 20%. When the sale prices decreased by 20%, the IRR value decreased by 23.6%. However, when the operating costs increased by 20%, the IRR value decreased by 14.7%. When the operating costs decreased by 20%, the IRR value increased by 13.7%. The sale prices had a more obvious influence on the IRR compared with the operational costs. Therefore, high-quality barbecue bamboo charcoal should be produced to increased the price of the product for better economic benefits even though all of the plants had good market prospects.

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