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An activated carbon preparation device using traditional Chinese medicine waste residue as raw material

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Abstract: *In view of the serious waste of traditional Chinese medicine waste residue and the high energy consumption of traditional waste residue treatment, the device uses the characteristics of high water content of traditional Chinese medicine waste residue and easy to form pores, and designs the integrated structure of carbonization furnace and activation furnace to simplify the preparation of activated carbon from traditional Chinese medicine waste residue. The reaction rate can be accelerated by increasing the contact area between the rake and the annular steam pipe. At the same time, the connecting rod structure is applied to the material pushing to realize the simultaneous pushing and heating, which solves the influence of frequent state switching and has certain advantages. Increase the heating area and improve efficiency.*

Keywords: *carbonization, activation, Chinese medicine, integration, raw material*

1. Introduction

China is a big country of traditional Chinese medicine, which produces a large amount of traditional Chinese medicine waste residue every year and most of it is discharged arbitrarily. The "Ecological Environment Standards" published by the Ministry of Ecology and Environment of the People's Republic of China clearly points out that the production projects of apis that are difficult to achieve pollution control targets should be limited to prevent the expansion of low-level production capacity. On the one hand, the by-products produced by Chinese traditional medicine pharmaceutical reach more than 50 million tons per year, and the pollution is very serious. On the other hand, the preparation process of activated carbon using wood as raw materials has high energy consumption. Therefore, it is necessary to design an energy saving activated carbon preparation device for Chinese medicine residue. *Chinese medicine pharmaceutical industry water pollutant discharge standard* was published in Fig.1.

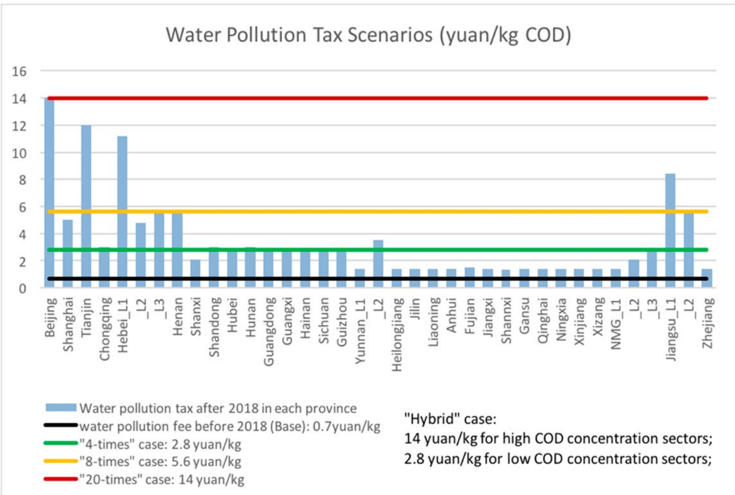

Figure 1: Chinese medicine pharmaceutical industry water pollutant discharge standard(GB 21906-2008)

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Under the call of the national policy, governments and enterprises all over the country began to pay attention to the activated carbon preparation and regeneration process, and with the call of environmental protection policies, enterprises continue to improve their research and development capabilities.

Among them, the biomass pyrolysis carbon solid technology, as a traditional production of activated carbon technology, is also recognized as one of the effective measures to solve the problem of climate change. This technology can convert low-grade biomass into high-quality liquid fuels or high value-added products, and can process a large number of raw materials at a low cost. Therefore, the biomass pyrolysis carbon technology has been applied more and more widely in recent years, and has also received the attention of major enterprises.

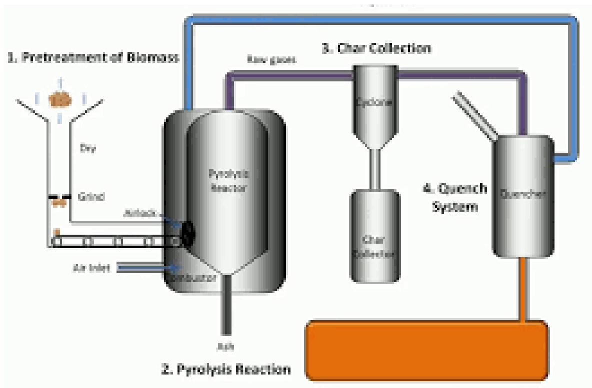

Figure 2: Schematic diagram of processing process of biomass pyrolysis carbon solid

In the biomass pyrolysis solid carbon technology, high energy consumption and harmful gas emission in the activity and carbonization process have always been the shortcomings of this technology, and most of the current activated carbon preparation devices are powered by external energy, and do not make full use of the extra energy[1] generated by themselves, and there is a common problem of high dioxin gas emission.

This project designed an activated carbon preparation device as shown in Fig.3 using traditional Chinese medicine waste residue as raw material, which can make use of the high water content of traditional Chinese medicine waste residue to produce high-quality activated carbon, and at the same time make use of the carbonized gas, which has better energy saving and economic benefits. The whole parameters of the device can be transformed into a device that can prepare traditional Chinese medicine bacterial fertilizer, and the activated carbon can be used as a corrosion inhibitor to improve the curative effect of traditional Chinese medicine. The three-dimensional transmission structure can be used for the transportation of soil, sand and other manufacturing processes. The combination of the designed crank slider and crank rocker can be used for scraping and collecting bulk cement. Based on this device, the nutritional value of traditional Chinese medicine can be fully utilized, and a new idea for the treatment of traditional Chinese medicine waste residue can be provided[2].

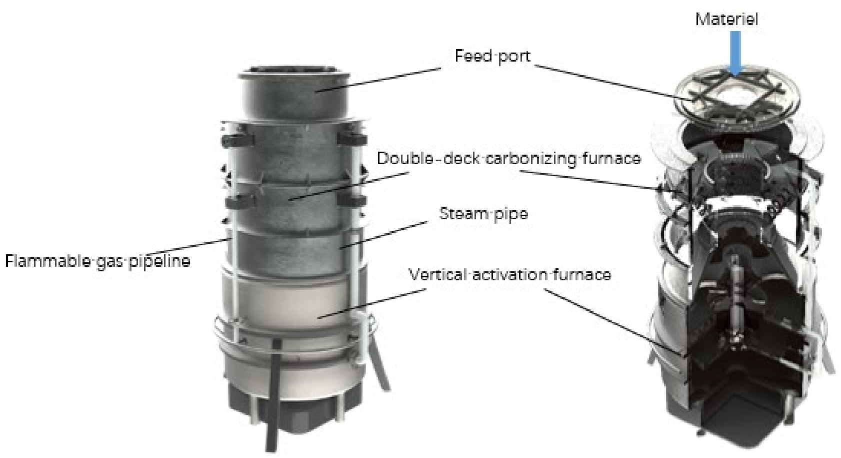

Figure 3: Overall installation diagram

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2. Project Design

2.1. Project Design

2.1.1 Double Layer Carbonizing Furnace Module

2.1.1.1 Dry Area Of Residue

The slag drying area is located in the upper layer of the carbonization furnace and is connected with the slag storage area outside the second layer by a baffle plate. This part is mainly composed of a feed port, a high-temperature steam outlet, a baffle plate, a top of the carbonization area, a heat conductive plate and other devices.

As shown in Fig.2, the operation process of the device is roughly as follows: the Chinese medicine residue containing a small amount of water is poured from the inlet, and after preliminary separation by the conical separation device, it is spread on the top layer of the carbonization area. A thermal conductive sheet is placed under the top layer, and a baffle plate is arranged on both sides to facilitate carbonization. The residue enters the upper part of the carbonization zone for carbonization preheating, and the temperature reaches 160°C. The heat in this part is mainly provided by the combustible gas generated in the activation part[2].

After the delivery of the slag, the inlet is closed, and the residual heat after heating the slag in the carbonization zone acts on the dry zone of the slag through the heat conductive sheet, so that the middle temperature of the lower part of the carbonization zone reaches 120°C required for dehydration operation. Within 2h in the first stage, the pharmaceutical residue in the dry zone is heated to volatilize high-temperature water steam, which passes through the high-temperature water steam outlet above the side and enters the activation furnace through the pipeline.

After the carbonization area is preheated, the baffle at the bottom opens and the residue leaks into the storage area at the bottom.

2.1.1.2 Powder Storage Area

The slag storage area is located outside the second layer of the double-layer carbonization furnace, and the whole is composed of two conical structures. The upper cone and the lower reverse cone are connected through a double-layer fan-shaped orifice plate with a scraper, and the inner wall of the lower reverse cone is composed of four spiral push rods[3].

As shown in Fig.4, the residue falling into the storage area covers the surface of the double-layer fan-shaped orifice plate. When the Chinese medicine residue in the carbonized area is carbonized and cooled, it enters the activation furnace below. At this time, the upper layer of the fan-shaped orifice plate begins to rotate and coincide with the lower orifice plate. The hole where the lower orifice plate is covered is exposed, and the scraper on the surface of the upper plate begins to rotate and push the residue on the fan-shaped orifice plate into the hole.

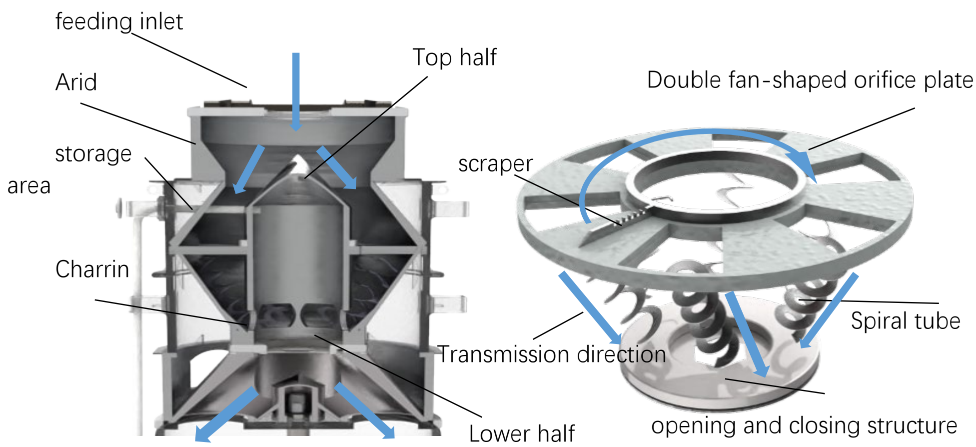

Figure 4: Double-layer carbonizing furnace and residue storage area

The drug residue falls into the spiral push tube through the hole of the lower fan-shaped orifice plate, and the spiral push tube begins to rotate under the drive of the motor, and the drug residue gradually moves downward in the spiral sheet to prevent the slide obstruction of the drug residue due to too small inclination Angle, forming a blockage. The Chinese medicine residue in the spiral tube eventually enters the carbonization zone[4].

2.1.1.3 Carbonization Area

The carbonization area is located in the center of the lower part of the double-layer carbonization furnace, which is mainly composed of the furnace chamber, the flammable gas outlet and the shutter-type opening and closing mechanism.

After the Chinese medicine residue enters the carbonization zone through the spiral tube, the first stage of preheating is started by burning wood in the furnace chamber. When the preheating temperature reaches 160℃, the temperature sensor feeds back to the general control place, and the system controls the temperature at this time for heat preservation. After holding heat for one hour, fuel is added in the furnace chamber, so that the carbonization zone is heated to about 550℃. The wood in the furnace cavity and the Chinese medicine residue in the carbonization zone produce flammable gases such as CO, CH4, etc., which are used for the third stage of warming in the carbonization zone, reaching about 800℃. The furnace temperature is maintained by controlling the escape amount of combustible gas. The excess combustible gas passes through the gas outlet, is piped and treated into the activation furnace for combustion, and realizes the maximum utilization of energy[5].

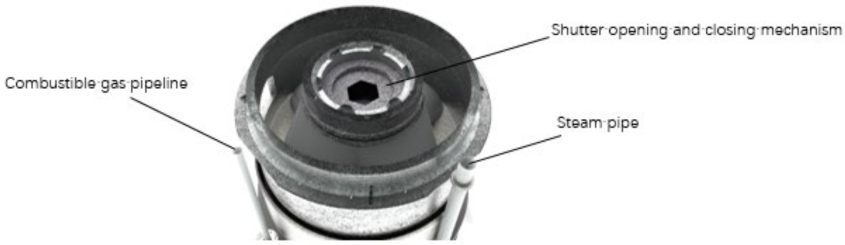

Figure 5: Shutter type opening and closing structure

At the end of the carbonization process, the slag cooled by the furnace enters the activation furnace through the shutter opening and closing mechanism. As shown in Fig.5the shutter-type opening and closing mechanism is composed of a main frame, a turntable and 6 blades, the 6 blades are centrally symmetrical distribution, and the opening and closing diameter ratio is 0.5. When the turntable is driven, the turntable makes the blades shift and rotate through the CAM auxiliary. Under the joint action of the frame CAM and the drive turntable CAM, the 6 blades form an opening and closing action, which effectively saves space and compactly arranges the structure, making the Chinese medicine residue enter the activation furnace[6].

2.1.2 Vertical Activation Furnace Module

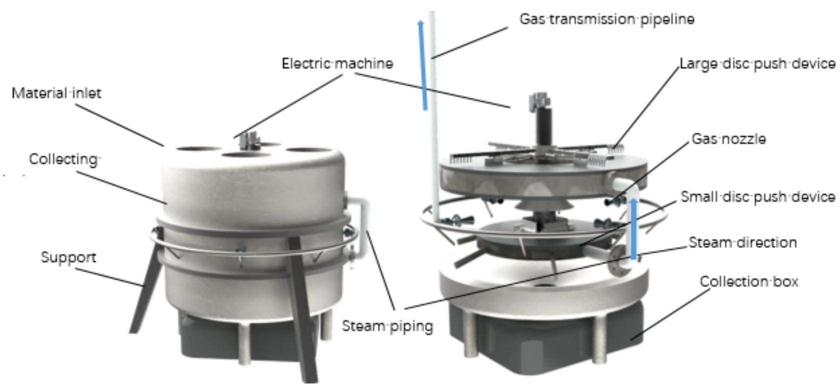

Figure 6: Overall structure of vertical activation furnace

2.1.2.1 Workflow

As shown in Fig.6, the vertical activation furnace is mainly composed of 4 parts, such as feed inlet, slag pushing loose device, heating activation device and collection box, and uses water steam to activate.

The falling drug residue enters the small ring loading table through the arc guide device, and the

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rotary pushing device in the center of the loading table pushes the drug residue to the outside of the small disk, and the rake knife at the side of the drug residue is loosened. The activated residue enters the lower collection box under the action of the push plate.

The annular steam pipe is arranged at the lower part of the small disk, and the steam pipe surface is provided with small holes for water steam ejection. The wall of the pipe is heated by a gas nozzle. Fig.7 is the flow chart of our installation.

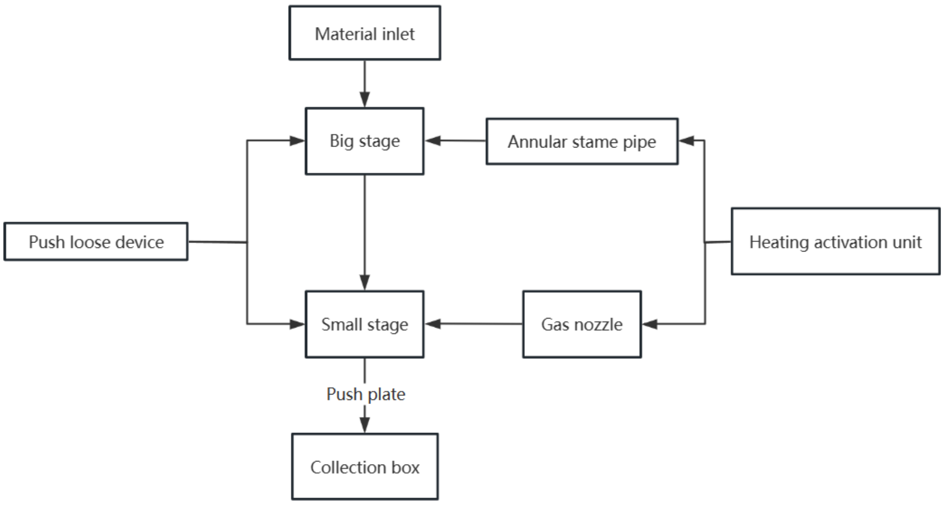

Figure 7: Activation furnace flow chart

2.1.2.2 Drug Residue Pushing And Conveying Device

The slag pushing and conveying device is mainly composed of rotating spindle, rake knife, crank connecting rod, crank rocker, push block and other structures.

The main shaft located in the whole inside of the device rotates under the drive of the motor, the main shaft on the big ring loading table is attached with a big gear, the big gear is engaged with the four pinion gears around it, and drives the rotation, the main shaft located in the center of the pinion is connected with two cranks, which control the rocker and the slider respectively. Through the forward and backward movement of the crank slider, the forward and backward movement of the scraper embedded under the horizontal bar is controlled. By controlling the angular swing of the crank rocker, the back and forth motion of the blade located on the rotating shaft is controlled[7].

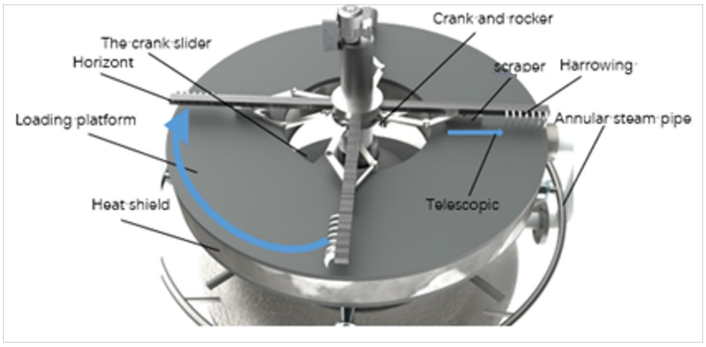

Figure 8: Large disc push device

As shown in Fig.8, when the scraper moves outward along the radial direction, the blade is kept parallel with the radial direction to prevent obstruction caused by the continuous addition of materials; When the scraper moves in the radial direction, the scraper continuously forms a large Angle with the horizontal bar, and the drug residue is scraped into the central ring hole.

Through the push of the crank slider on the small ring loading table, the medicine residue in the center is pushed outward, the whole is rotated through the spindle, and the medicine residue is loosened by the rake knife on one side. We can see it in Fig.9[8].

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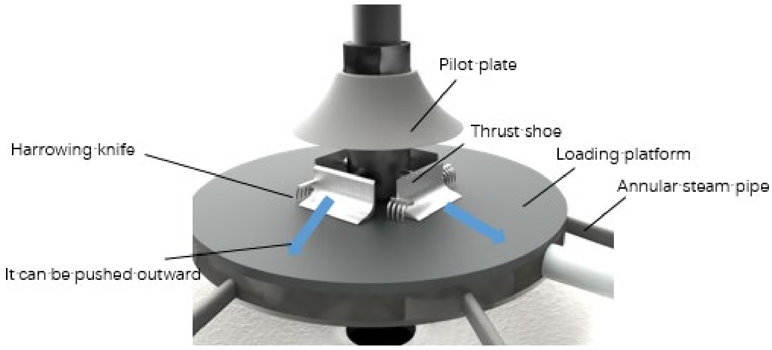

Figure 9: Large disc push Small disc push device

2.1.2.3 Heating Activation Device

The heating activation device is mainly composed of annular steam pipe, insulation layer and gas nozzle.

There is a ring steam pipe under the ring loading table, and the high temperature water steam generated in the dry part and input from the outside is filled in the ring pipe through the entry port, and the ring pipe has a small hole on the surface to facilitate the escape of water steam. The annular tube increases the reaction area of the residue and makes it more reactive [9].

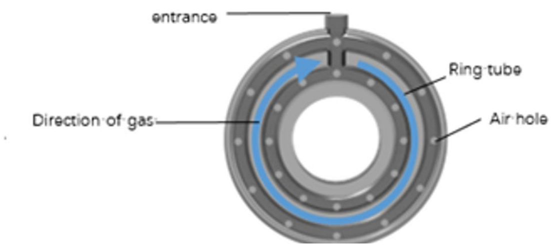

Figure 10: Annular steam pipe

As shown in Fig.11, the combustible gas produced in the carbonization part and the imported combustible gas enter the four gas nozzles through the outer annular gas pipe, and the activation temperature is raised to 800℃ by conveying the combustible gas.

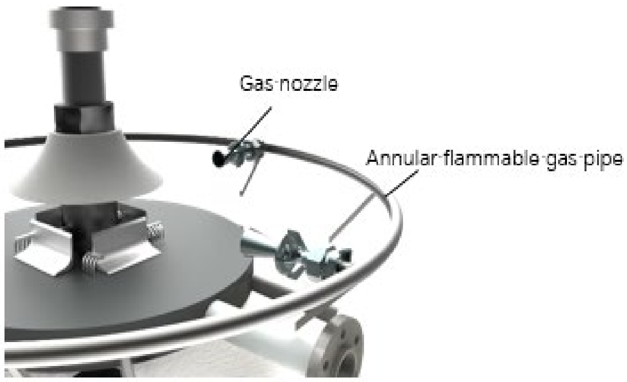

Figure 11: Gas nozzle

2.2. Relevant Principles

2.2.1 Overall Feasibility Analysis Of The Device

2.2.1.1 Structural Analysis

For the unit as a whole, the inner diameter of the carbonization furnace part is 1.5m and the height is 2.5m, and the inner diameter of the activation furnace is 1.5m and the height is 1m. The heating part of the carbonization furnace and activation furnace is made of high aluminum inner fire brick, and the outer layer is made of calcined clay brick, which improves the high temperature resistance of the whole device.

The spiral shaft, shutter type opening and closing structure, the size of the ring turntable are made of refractory 310S stainless steel plate, which has the advantages of high strength, easy to damage, long service life, etc. Its chemical composition is 0Cr25Ni20, which can resist high temperature oxidation, up to 1200℃.

2.2.1.2 Analysis Of Chinese Medicine Residue

The device mainly uses Astragalus and Danshen residue to prepare activated carbon, the water content of the two kinds of residue reaches 70%, and the particle size of the residue is small, including C, H, S, ash and other contents are 40.97%, 4.41%, 0.03%, 5.360%, respectively, so that the residue has high carbon content but low other harmful content, which is suitable for preparing high-quality activated carbon.

2.2.2 Feasibility Analysis Of Preheating Drying Module

The water content of Chinese medicine residue is generally maintained at about 70%, and reaches 55% after mechanical dehydration in the early stage. The process index of carbonizing material required by carbonizing furnace is about 30% water content. The following is the formula for calculating the heat required for drying the standard pharmaceutical residue[10]:

$$Q = m \times k / a \tag{1}$$

In the formula, Q is the calorific value required for drying to 30% water content 1kg pharmaceutical residue, kJ;

Where, m is to reduce the mass of water, kg;

Where, k is the calorific value required for water evaporation per kilogram, kJ/kg;

Where, a is the working efficiency of the drying machine.

According to the data, it can be obtained that the water mass m and k of each kilogram of powder residue reduced from 55% to 30% water content is 0.25kg, and the average drying efficiency a of the dryer is 15%. It can be calculated that Q is 6000kJ energy.

1kg of coal combustion can produce 29300kJ of heat, the following is the calculation formula of air heat transfer and temperature loss:

$$\frac{T}{l} = \frac{k_g(t_P - t_K)}{G \cdot C} f \tag{2}$$

Where, T is the temperature of heat transfer loss of high temperature air, ℃;

Where, l is the length of the furnace cavity tube, m;

Where, k_g is the unit heat transfer coefficient of the furnace chamber, w/m·℃;

Where, t_p is the average temperature of the air in the pipe, ℃;

Where t_k is the ambient temperature, ℃;

Where, G is the flow rate of air in the pipe, kg/s;

Where, C is the specific heat capacity of air in the pipe, J/kg·℃;

Where, f is the friction coefficient.

Where, t_p is 160℃, t_k is 25℃, l is 1m unit length, C is 2.1168J/kg·℃, G is 3kg/s, kg is 6w/m·℃, f is 0.5, T is calculated as 65℃.

The following is the conversion of air temperature and calorific value:

$$Q_1 = 3.14 \times CaT \times r \times r \tag{3}$$

Where, T is the temperature of air change, ℃;

Where, C is the specific heat capacity of air at 160℃, J/kg·℃;

Where, a is the density of air corresponding to the temperature, g/L;

Where, r is the inner diameter of the furnace cavity, m;

In the formula, Q_1 is the corresponding calorific value, J.

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Where T is 65℃, C is 2.1168J/kg·℃, a is 1.293g/L, and r is 1.5m, the value of Q_1 is about 12000kJ. According to the coal combustion efficiency of 0.7, the calorific value generated by 1kg of coal is 20510kJ, and the calorific value is 8510kJ, which is greater than Q6000kJ, after subtracting $Q_1$12000kJ of heat dissipation. Therefore, the device can achieve the effect of drying and removing water[11].

2.2.3 Feasibility Analysis Of Screw Push Device

The spiral push device drives the material forward through rotation, which is suitable for small particles such as sand and soil, and the particle size is less than 1/4 of the spiral pipe. The device has simple structure and wide application range, and its accuracy is affected by spiral speed, material filling speed and other factors.

The device adopts shaft screw conveying, the advantage of the screw conveying is that when the rotational speed is constant, with the increase of the filling rate, the transportation accuracy does not change much; When the filling rate is constant, the accuracy does not change much with the increase of rotational speed. The overall accuracy is higher than that of shaftless spiral transmission. The rotating speed of the device is 75r/min, the horizontal Angle is 15°, the diameter of the feed port is 0.25m wide, and the particle size of the Chinese medicine residue is about 0.55mm-1.87mm, which meets the requirements of screw pushing and has certain feasibility.

2.2.4 Comparative Analysis Of Activation Structure

Table 1: Comparison of activated structures

Activated structure	Advantage	Shortcoming
Rotary activation furnace	Source of motivation	The thickness affects the contact area
Split activation furnace	Steam preheating	Frequent state switching
Vertical tube type activation furnace	Small space, enough heat	Uneven steam distribution

Table.1 show us the Comparison of activated structures.The activation device adopts vertical structure, and the contact area is increased by rake knife and annular steam pipe. The steam pipe has a small opening to ensure uniform steam distribution. At the same time, the connecting rod structure is used to implement material push and realize the simultaneous push and heating, which solves the influence caused by frequent state switching and has certain advantages.

2.2.5 Comparative Analysis of Horizontal Benefits

2.2.5.1 Comparison of Activated Carbon Preparation Technology

Table 2: Horizontal comparison of activated carbon preparation technology

Way	Process efficiency	Shortcoming
Gasifier heating	1.5t/h	The waste residue of traditional Chinese medicine has high water content and high energy consumption due to dehydration
Industrial ethanol preparation	15.1%	The low utilization rate of chemical raw materials has caused pollution
Microbial medium raw material	30g/L	Low throughput
Preparation of activated carbon and other adsorbent	40%	Water content is large, need to be dehydrated pretreatment

Through the horizontal comparison of the preparation process, we obtained Table 2.For the preparation of activated carbon from wood, the device makes full use of the flue gas and water vapor generated in the carbonization process by taking advantage of the high moisture content in the waste residue of Chinese medicine, reducing the consumption of coal and reducing the emission of SO_2.

For carbon activated carbon, it consumes 3.2-4.5kg of raw coal for every 1kg of production, and emits 2.0-5.0kg of dust, 1.0-5.0kg of smoke, and 4.0-35kg of SO_2 gas. The production of 1kg activated carbon requires 3.8kg of traditional Chinese medicine waste residue, and its ash content is small, which can reduce the emission of related pollutants.

2.2.5.2 Comparison Of resource Utilization of Chinese Medicine Residue

Traditional Chinese medicine waste residue has been used in gasifier heating, paper making, industrial ethanol preparation, microbial culture medium and other fields. Due to the immaturity of relevant technology and low economic benefit, only 3% of traditional Chinese medicine waste residue was treated.

2.2.6 Calculation Of Yield And Benefit

The device uses traditional Chinese medicine waste residue as raw material to prepare activated carbon. Through full energy utilization of flue gas and water vapor generated in the preparation process, the device realizes waste utilization of traditional Chinese medicine waste residue while reducing energy consumption, and has better emission reduction benefits. The following is the formula for calculating the volume of activated residue:

$$V = 3.14 \times [(D - D_0)^2 + (d - d_0)^2] \cdot h \tag{4}$$

Where, V represents the volume of material in the activation chamber, and its unit is m^3;

Where, D, d represents the size of the activated disk diameter, m;

Where, D_0 represents the diameter of the central blanking port, m;

Where, d_0 represents the diameter of the drive shaft, m;

Where, h represents activation layer thickness, m.

D is 1.5m, D_0 is 0.43m, d is 1.2m, d_0 is 0.15m, h is 0.05m, the total volume of activator on the activation furnace disk is 0.3992m^3, which is equivalent to activated carbon about 139.72kg. The activation of the device is expected to be 6h, a total of 535kg of Chinese medicine waste residue raw materials are invested, and the yield of the device can be calculated to be 26.18%.

2.2.7 Calculation Of Emission Reduction Benefits

The hypothetical scenario is that Chinese herbal residue is used to prepare 1kg activated carbon, and about 3.8kg of Chinese traditional medicine waste residue raw material can be treated by this device. Since 90% of Chinese traditional medicine waste residue will be stacked and other treatment, a large amount of dioxin gas will be produced. Dioxin emission is calculated as follows:

$$\mathrm{d}[D]/\mathrm{d}t = 5.0 \times 10^4\, exp(-12150/T[P])ng/(m^3 \cdot s) \tag{5}$$

Where, d[D]/dt represents the generation rate of dioxins, ng/(m^3·s);

Where, T[P] indicates the temperature of chlorophenols during incineration, ° C.

The dioxin content of traditional Chinese medicine waste residue was 5~50 NgTeQ /kg. In the process of carbonization, although the important waste residue after drying is treated at 500℃, it will not cause additional dioxin formation. The plant reduces dioxin emissions by at least 19ngTEQ/kg compared to bulk treatment.

2.2.8 Economic Benefit Analysis

2.2.8.1 Energy Supply Simulation Analysis

Table 3: Modules and uses used in simulation

Module	Module name	Functions and applicable objects
RYIELD	Yield reactor	To determine the yield, it is necessary to know the yield distribution of the reaction and calculate the stoichiometric number to achieve chemical semi-equilibrium and phase equilibrium.
RGIBBS	Gibbs reactor	Chemical equilibrium and phase equilibrium are achieved by minimization of Gibbs free energy.
SEP	Component separator	The import logistics is divided into multiple groups according to the specified components and the export logistics is multi-strand logistics.
FLASH2	Two outlet flash evaporator	With strict vapor-liquid balance or vapor-liquid-liquid balance, the incoming material is divided into two export flows.

In this part, Aspen Plus software was used to establish the process of pyrolysis of traditional Chinese medicine waste residue to produce activated carbon. Before simulation, elements and characteristics of traditional Chinese medicine waste residue were input, and then five parts including pretreatment, activation, carbonization, separation and cooling were passed. The specific workflow was shown in Figure 10. The parameters of the simulation process are listed in Table 3[12]. Before simulation, the following hypothetical simulation ideal conditions need to be carried out in advance:

(1) All chemical reactions are steady-state reactions, and the reaction environment and reaction conditions change during the reaction process;

(2) After the activation process, the O, N, S and H elements exist in the form of gas, while the C element is not completely transformed, and the ash in the raw material does not participate in the reaction;

(3) The quality difference of traditional Chinese medicine waste residue is small and there is no temperature gradient.

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In Aspen Plus software, the molar mass of substances that cannot be determined, such as Chinese medicine residue and biomass, is set to 1, and the following formula can be obtained:

$$CMR(wet) \rightarrow \phi H_2 0 \tag{6}$$

After the activation unit, carbonization unit, separation unit and cooling unit are adjusted according to the known parameters in turn, the simulation results at 550°C are compared with those of Guo Feiqiang at the same temperature. The results are shown in Table 4, with an error of less than 10% and a high reliability.

Table 4: Comparison between simulation results and experimental results

Item	Simulated value	Experimental value	Relative error
Biochar	33.67	30.62	9.96%
Gas	45.56	43.67	4.32%
Tar oil	22.33	23.70	5.7%

Table 4 shows the comparison between simulation results and experimental results. The material balance and energy balance results of the whole process can be obtained by simulating the pyrolysis of Chinese medicinal residue, which can provide data basis for the technical and economic evaluation and thermoeconomic analysis. When the treatment capacity of the slag is 10t per hour and the pyrolysis temperature is 550°C, the material balance and energy balance results of the system are shown in Table 5 and Table 6.

Table 5: Material balance table of pyrolysis system

Cell	Matter	Input (kg/h)	Output (kg/h)
Drying unit	Nitrogen	10000	—
	Wet Chinese medicine waste residue	5000	—
	Flammable exhaust gas	—	5278
	Dried Chinese medicine residue	—	9722
Activation unit	Dried Chinese medicine residue	9722	—
	Coke	—	2865
	Volatile matter	—	6857
Carbonizing unit	Volatile matter	6857	—
	Air	20800	—
	Exhaust gas	—	27567
Separation unit	Air	15800	15800
Cooling unit	Water	2495	2495
Gross amount	—	38295	—
	—	—	38295

Table 6: Energy consumption table of pyrolysis system

cell	Energy-consuming equipment	Electrical energy (MJ/h)	Thermal energy (MJ/h)
Drying unit	dryer	—	+2746
Activation unit	Two-layer activation furnace	—	+23010
Carbonizing unit	Vertical charring furnace	—	-59322
Separation unit	Air compressor	1494	—
Cooling unit	pump	0.77	—

The heat released by the heating unit of the system is greater than the sum of the heat required by the drying unit and the pyrolysis unit, which indicates that no additional fuel is needed as a heat source in the process of producing biochar by pyrolysis of Chinese medicinal residue. It can be seen from Table 6 that the power consumption equipment in the system includes air compressor and pump, among which the power consumption of the air compressor is the largest 1494MJ/h, while the power consumption of the pump is the smallest.

2.2.8.2 Analysis of economic Benefits of Pyrolysis

Here, the operating parameters will be used when the pyrolysis temperature is 550°C, when the biochar production is 2865kg/h, and the total biochar production in 20 years is 452,500 tons.

Table 7: APEA module mapping objects

Unit name	Mapping object
Activation unit	Activating furnace
Carbonizing unit	Box type process furnace
Heat exchange unit	Frame type heat exchanger
Separation unit	Bag type dust collector

In this study, the raw material is the residue left after the finished product of the Chinese patent medicine manufacturer, so the purchase cost of raw material is 0. At this time, the transportation cost of the traditional Chinese medicine waste from the pharmaceutical factory to the factory is the cost of raw materials. In order to improve the overall economic benefits of the system and reduce this part of the transportation cost, the location of the pyrolysis plant should be located in a relatively distributed zone of the pharmaceutical plant. Here, the average transportation distance is assumed to be 20km, and the price is selected at 40 yuan /t. The APEA software can map the unit model in the above part to the actual equipment model, estimate the equipment size by entering the given material balance data, and then calculate the cost.

Table 8: Estimates equipment costs based on the APEA module

Device name	Equipment purchase cost (ten thousand yuan)	Installation cost (ten thousand yuan)
Activating furnace	611	938
Box type process furnace	242	364
Frame type heat exchanger	5.43	34.25
Bag type dust collector	28.56	48.67

Table 7 and Table 8 are the APEA module mapping objects and estimated equipment costs based on the APEA module, respectively[15] .It is assumed that according to the simulation calculation, the total capital investment of the project to prepare activated carbon is 986.8419 million yuan[14]. The cost of each ton of activated carbon is 2864.35 yuan, and according to the simulation results, the top three are reagent cost, electricity cost and depreciation cost. When the price of activated carbon is set at 3,300 yuan/ton, the NPV is 22.35 million yuan, the IRR is 11%, and the investment payback period t=7.61 years, indicating that the project has a high earning capacity and economic benefits[13].

3. Conclusions

We designed a double-layer carbonization furnace and a vertical activation furnace to realize the drying of pharmaceutical residue through the combination of drying zone and carbonization zone. On the one hand, it saves space, on the other hand, it reduces the energy loss in the process of activation and carbonization, and plays a role in saving activation energy consumption and reducing the emission of harmful gases such as dioxin.

The crank slider and crank rocker are designed in the vertical activation furnace to realize the transportation of drug residue, which can effectively push the material forward, loose the raw material and increase the reaction rate.

The reaction rate can be accelerated by increasing the contact area between the rake and the annular steam pipe. At the same time, the connecting rod structure is applied to the material pushing to realize the simultaneous pushing and heating, which solves the influence of frequent state switching and has certain advantages. Increase the heating area and improve efficiency.

The diffusion heat of preheating in carbonization furnace was used to dry the Chinese medicine residue. At the same time, the water vapor and the resulting flammable gas are used in the activation. That is, energy is saved by complementing the remaining energy of activation and carbonization.

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