

# Design and Research of Multi-functional Plate Recycling Machine Based on Artificial Intelligence

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**Abstract:** For the problems of low efficiency and low use rate of intelligent technology in the high-traffic restaurants' plate recovery process, this study proposes the implementation of fully automated mechanization using gravity sensing technology on the plate of the flipping & tipping, and the multi-functional intelligent plate recycling machine using oil-water separation technology for slop and oil separation as the core function. Throughout the cleaning process, the device avoids direct contact with the residue, ensuring the cleanliness of the device. In addition, the residue is deposited in the storage barrel without causing secondary pollution, making it recyclable for secondary use. The device offers clean, fast, convenient and safe functions, which greatly improves the hygienic standard of cafeteria dining, playing an important role in the classification and recycling of after-meal trays and the recycling of food waste.

**Keywords:** artificial intelligence; multi-functional plate recycling machine; oil-water separation; gravity sensing

## 1. Introduction

In the first half of 2023, as the economy and society fully resumed normalized operation, the national economy steadily rebounded while the revenue of China's catering industry in the first half of the year reached RMB 2,432.9 billion, at an increase of 21.4% (source of data: National Bureau of Statistics). While the revenue of the catering industry keeps growing, the amount of tableware used and the amount of catering waste generated are increasing day by day. China's catering industry is a huge market, the current number of people dining in schools, enterprises, factories, restaurants and other public eating places where have set up a special plate recycling office, leaving a large number of tableware waiting for sorting and recycling after meals, need to be equipped with a large number of manpower to collect after meals with food residues on the plates, to be collected and then unified for cleaning<sup>[1]</sup>.

Due to the large flow of people in the cafeteria, concentrated mealtime, backward device and other reasons, this paper presents a multi-functional plate recycling machine for the existence of artificial treatment of low efficiency, high labor costs, cleanup & cleaning labor intensity, unsatisfactory plate cleaning effect, and that the residue recycling is not hygienic & centralized with other issues. The function of plate recycling conveyor technology, cleaning device and oil-water separators existed in the market currently is single, with narrow scope of application scenarios, which cannot realize automation. The device designed in this paper has the functions of plate recycling, cleaning & residue treatment, which can solve the shortcomings of the existing device.

The cleaning technology of foreign automatic tableware recycling is more advanced with a higher level of automation, and its automated assembly line machinery and device can realize tableware slugging, sorting, disinfection and packaging. Some of the functions and technologies of foreign device are worthy of reference, but the workload of this processing method is large, and the cost of the machine is very high. At the same time, due to the differences between the food service market and the diet of Chinese and foreign diners, foreign device cannot be fully adapted to the Chinese market<sup>[2]</sup>. Bosch<sup>[3]</sup> tableware cleaning patents use ultrasonic high-frequency compression of the liquid medium vibration, so that it dramatically produces tiny cavitation bubbles, and instantly closed, resulting in a strong small scale explosion and shockwave to make the surface of the cleaned object dirt to be destroyed, off from the cleaning surface. Fan Weiwei et al<sup>[4]</sup> proposed that foreign large-scale food machinery cleaning and disinfection in microwave sterilization is often used, short heating time, rapid heating speed, sterilization uniformity, no chemical residues, and safety has been improved.

Some domestic scholars have designed tableware cleaning and recycling machine. Wang Liu Yi et al<sup>[5]</sup> designed a cafeteria self-service tableware recycling and cleaning system, using a combination of conveyor belt conveying and high-temperature water washing, which can complete the process of two times of spraying, washing, high-temperature hot air drying, and disinfection of the dinner plate. However, the low degree automation of the system cannot achieve the functions of slagging, stacking and counting of plates. Xiao Bing et al<sup>[6]</sup> designed the cafeteria tableware recycling machine, using mechanical arm design, to realize tableware transportation, slagging, and classification. However, the cost of a single mechanical arm design is high and inefficient and the machine lacks functions such as stacking and counting. Shi Lijin et al<sup>[7]</sup> designed the bowl and plate separation device of automatic tableware recycling machine, which utilizes the principle of height difference to realize the accurate classification of bowls and plates. But the device is not perfect with a low automation degree. Cao Jianmeng et al<sup>[8]</sup> designed the automatic tableware sorting and recycling machine. It integrated the control to the automatic tableware sorting and recycling machine through the control system to realize the automation of a series of machine functions. However, it has poor functions and the overcurrent and overvoltage protection of the module power supply is decentralized, which will reduce the impact capacity of the system.

## 2. Design Instructions

### (1) Overall structure and working principle of the machine

The overall structure and working principle of the machine as shown in Figure 1.

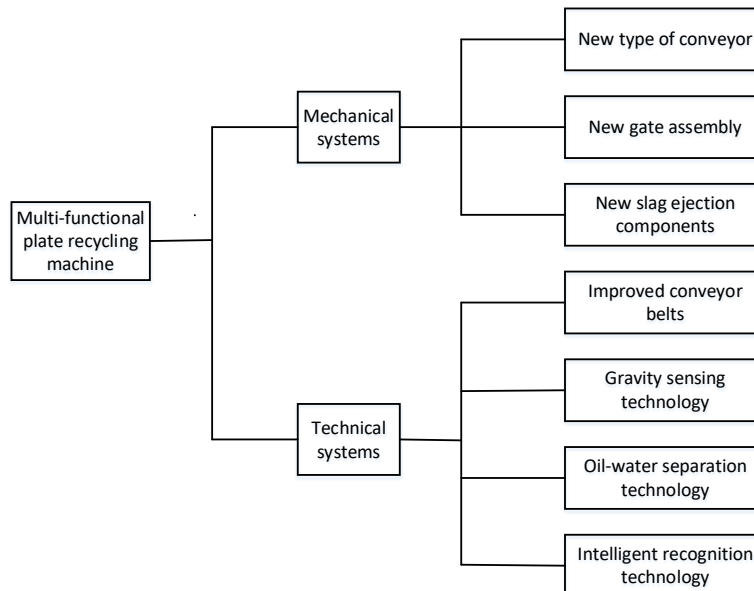


Figure 1. Plate Recycling Machine Design

Multi-functional plate recycling machine is mainly composed of three parts: plate recycling, food residue filtration and oil-water separation.

The plate recycling consists of a plate inlet, a conveyor belt and a plate outlet. The inlet and outlet of the trays adopt sloped plane design, and the tray conveyor belt inside the machine is equipped with a catch post, so that the trays can be placed in a vertical direction, and the conveyor belt has a shaking function to pour the food into the leakage net more easily.

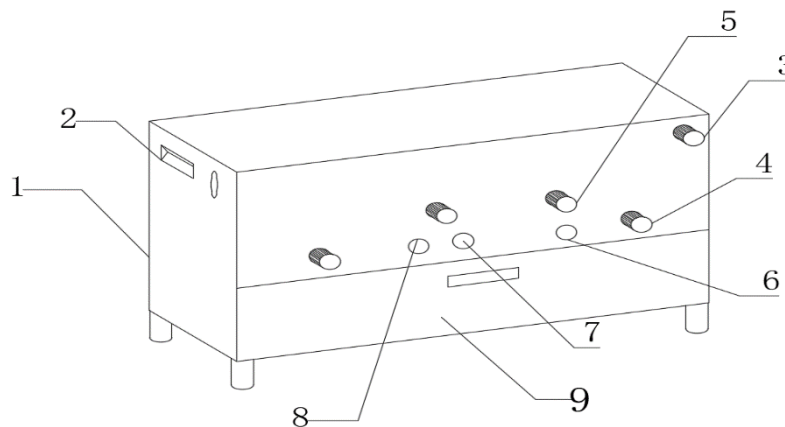
The food residue filtration consists of a leakage net, a gate and a residue tank. The screen adopts double-slope design, with gates on both sides of the slope. When the food residue accumulates to a certain height on the screen, it uses infrared sensors to open the gates, and the food residue will be dumped into the residue tank.

Catering oil-water separator mainly consists of a solid-liquid separation bin, an oil-water separation bin, a sewage lifting bin, pipelines, a control system. The oil-water mixed liquid is decomposed into sewage, water and oil will flow into different containers respectively through the oil-water separator.

The mechanism of multi-functional plate recycling machine: the user puts the plate flat into the

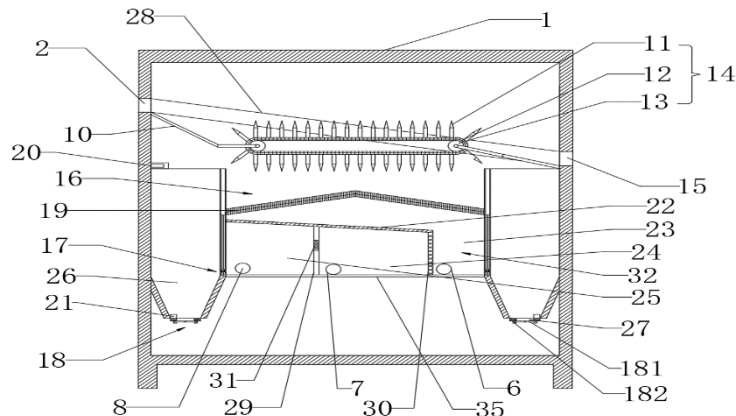
input port, the internal conveyor belt shakes to pour the food residues into the funnel, and the preliminary treatment of the plate is sent to the exit row into the external conveyor belt, and it will be sent to dishwasher in the kitchen; the funnel separates the food residues from the oil and water, and the food residues flow into the residue box while the oil and water flow into the oil and water separator. Finally, the separator breaks down the oil and water into sewage, water and oil which flow into separate containers for storage.

The box is equipped with an infrared sensor, when the food residue accumulates to a certain height on the leakage net, the infrared sensor can detect it. The detection information will be fed back to the second drive motor, and the second drive motor controls the gate assembly to pour the food residue into the residue box. The bottom of the residue box is equipped with a gravity sensor, which can detect when the residue reaches a certain weight. The gravity sensor will feedback the detection information to the third drive motor, controlling the slag discharge component for slag discharge. Specifically, as shown in Figure 2, the machine structure three-dimensional diagram and the sectional view of the machine in Figure 3, the markings and the corresponding names of the parts are shown in the drawings.



1. Box 2. Inlet 3. First drive motor 4. Third drive motor 5. Second drive motor 6. Drainage outlet  
 7. Water outlet 8. Oil outlet 9. Stopper door

Figure 2. Three-dimensional Diagram of Machine Structure



1. Box 2. Inlet 6. Drain port 7. Outlet 8. Oil outlet 10. Sloped plane 11. Card post 12. Drive belt 13. Rotating roller 14. Transmission mechanism 15. Outlet 16. Filtering mechanism 17. Gate assembly 18. Residue discharge assembly 19. Leakage net 20. Infrared sensor 21. Gravity sensor 22. Diversion plate 23. Solid-liquid separation bin 24. Oil-water separation bin 25. Oil storage bin 26. Residue bin 27. Drain port 28. Pipe 29. Partition plate 30. Filter plate 31. Filter port 32. Oil-water separator 35. Support plate 181. Baffle plate 182. Card slot

Figure 3. Machine Sectional View

Diners need to scan the machine's QR code to register and log in to the applet when using the tray recycling machine at the first time. After facial recognition, the diner places the plate flat into the machine's feeding port, and the machine will automatically recognize the remaining amount of food on

the plate. This process mainly consists of three parts: the first part returns points to the user's applet based on the remaining residue, which can be used to exchange points for green products.

The second part is to identify kitchen waste. The funnel separates food into residue and oily water, and the oily water and residue flow out from the upper and lower layers in order through machine operation. The food residue flows into the residue box, and the oily water flows into the oil-water separator. The separator decomposes the oily water into sewage, water, and oil which are stored separately in different containers.

In the third part, after the machine recognizes the plates, the internal conveyor belt shakes and pours the food residue into a funnel. The preliminarily processed plates are sent to the outlet and transferred to the external conveyor belt, which will be sent to the dishwasher in the kitchen for cleaning. During the cleaning process, the wastewater will be reused.

The machine operation flow chart is shown in Figure 4:

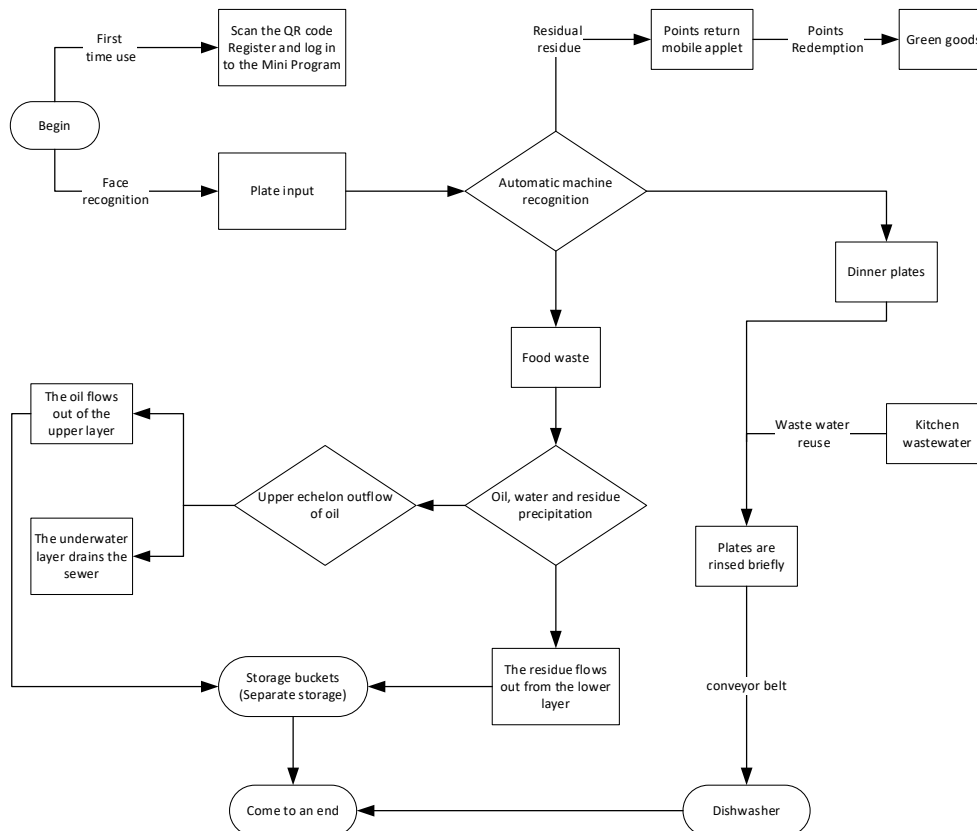
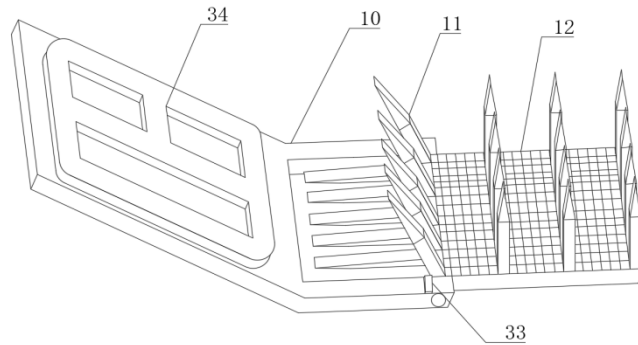


Figure 4 Machine Operation Flow Chart

## (2) Mechanical system design

### ① New transmission machine

Modified conveyor belt means that this machine uses a conveyor that is different from conventional conveyor belts. We plan to install horizontal locking teeth on the conveyor belt to fix the food tray and provide a certain angle for the food residue which can be poured out well. And the conveyor belt is equipped with a mesh screen to make it easier for food residues to fall into the residue filter<sup>[9]</sup>. Specifically, as shown in Figure 5.

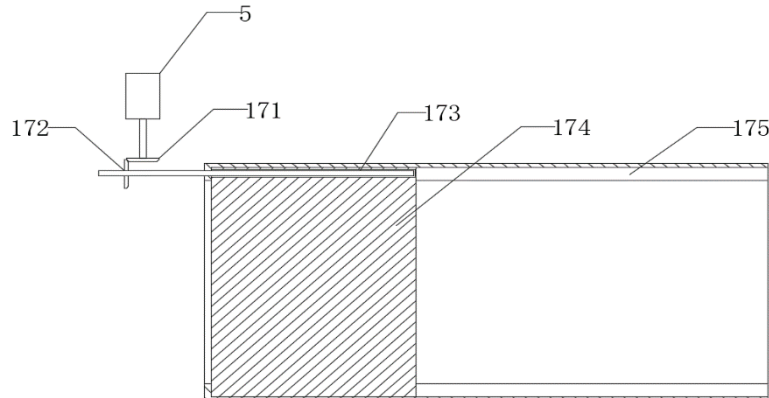


10. Sloped plane 11. Card column 12. Transmission belt 33. Block 34. Dining plate

Figure 5. Schematic Diagram of Transmission Belt Structure

### ② New gate components

Food waste passes through the screen and slop leaks into the oil-water separator below. The solids in the slops settle in a solids separation bin and are eventually discharged into a residue tank. At this time, a new gate component is installed between the solid separation bin and the residue box to facilitate the smooth discharge of solid substances. The gate component includes the second drive motor, and the output end of the second drive motor moves through the residue box. The output end of the second drive motor is connected to a first bevel gear, and the residue box is also provided with a sliding groove. The sliding groove is slidably connected to a gate and the gate is movably connected to a shaft. The end of the shaft is also movably connected to the residue box, and the shaft is fixedly connected to a second bevel gear and matched with the first bevel gear. When the gate slides downwards, the food residue on the leakage net is poured into the residue box through the opening of the gate. The new gate components include gears shafts, gate plates, and sliding grooves. The specific schematic diagram of the gate component structure is shown in Figure 6.

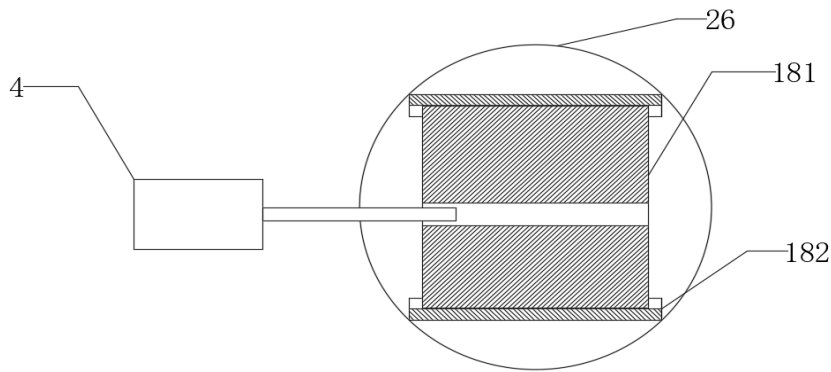


5. Second drive motor 171. First bevel gear 172. Second bevel gear 173. Rotary shaft 174. Gate plate 175. Sliding groove

Figure 6. Schematic Diagram of Gate Component Structure

### ③ New slag discharge components

The filtered food residue is stored in the residue box, and there is a new type of residue removal component at the bottom of the residue box which accompanied by a gravity sensor. When the food residue reaches a certain weight, the residue discharge component starts to operate. The residue discharge component includes a third drive motor, and the output end of the third drive motor is connected to a baffle. The baffle is connected to a card slot which is connected to the residue discharge port. By the cooperative sliding of the baffle and card slot, the food residues in the box are discharged through the discharge port. The slag discharge component includes a driving motor, a baffle, and a card slot. The specific schematic diagram of the slag discharge component structure is shown in Figure 7.



1. Third drive motor 26. Residual box 181. Baffle plate 182. Card slot

Figure 7. Schematic Diagram of Slag Discharge Component Structure

### (3) Technical system design

The tray recycling consists of a tray inlet, a conveyor belt, and a tray outlet. The tray inlet and outlet are both inclined planes. The internal tray conveyor belt of the machine is set with a clamp column which can place the tray vertically. In addition, the conveyor belt is equipped with a shaking function which can pour the food into the mesh easily.

The filtration of food residue consists of a filter, a gate, and a residue box. The leakage net adopts a double slope type with gates on both sides of the slope. The infrared sensor can detect it, and the detection information will be fed back to the second drive motor. The second drive motor controls the gate assembly to dump poor the food residue into the residue box.

Oil-water separation mainly includes catering oil-water separators which are mainly composed of solid-liquid separation tanks, oil-water separation tanks, sewage lifting tanks, pipelines, control systems, etc. The oil-water mixture is decomposed into sewage, water, and oil through an oil-water separator, and flows into different containers respectively.

The device uses improved conveyor belts, the technology of gravity sensing technology and oil-water separation.

#### ① Improved conveyor belt

Modified conveyor belt means that this machine uses a conveyor that is different from conventional conveyor belts. We plan to install horizontal locking teeth on the conveyor belt to fix the food tray and provide a certain angle for the food residue which can be to be poured out well. And the conveyor belt is equipped with a mesh screen to make it easier for food residues to fall into the residue filter. When the food residue accumulates to a certain height on the screen, it uses infrared sensors to open the gates automatically, and the food residue will be dumped into the residue tank. An oil-water separation device is installed under the residue filtering device which applies oil-water separation technology to achieve the philosophy of recycling and green environmental protection.

#### ② Gravity sensing technology

The gravity sensing switch belongs to the new sensor technology which adopts a cantilever-type displacer composed by elastic components, and adopts an energy storage spring composed by elastic insensitive components to drive the electric contact. And it completes the conversion from gravity change to the electric signal. At present, most high-end smartphones and tablet PCs have built-in gravity sensors. For example, the gravity sensor can automatically turn the screen when the phone is horizontal or vertical. This device uses the gravity sensor to control the valve, when the residue reaches a certain weight, the valve automatically opens, so that the residue flows into the slop bucket through the pipe.

#### ③ Oil-water separation technology

The oil-water separation device and oil-water separation system currently have patents. Among of them, the catering oil-water separator is mainly suitable for environments with severe pollution caused by oily wastewater discharge in China. This oil-water separator is an imported "grease trap" and installed at the outlet of the sewer to prevent oil and garbage from being discharged into the sewer. It is

mainly made of fiberglass and stainless steel and so on . Due to its advanced design (the product and its design have been patented both domestically and internationally), over the Oil Resistance Rate is up to 90%. The multi-functional tray recycling machine directly installs an integrated oil-water separator under the residue filtration device of the recycling machine, and the oil-water automatically flows into the oil-water separator, which achieves fully automated oil-water separation.

### **3. Comparison and Innovation of Similar Products**

At present, the tableware recycling devices on the market mainly have conveying and cleaning functions, and the additional tableware classification function is inadequate which cannot effectively classify and collect spoons, chopsticks, bowls, and plates. Also food residues cannot be collected on time. The separation of tableware should complete the separation of spoons, chopsticks, bowls, and plates, and the collection of the separated residue. If these processes are continuously completed by a machine, it can save a lot of labor and greatly improve work efficiency. The following are the innovative points of the intelligent multi-functional tray recycling machine.

#### **(1) Integrated advertising**

The existing plate recycling machine can complete horizontal, inclined, and turning conveying on a conveyor line. The device structure and function of the recycling machine are simple with complex maintenance. Diners need to separate the residue and tableware when placing them into the machine. However, our plate recycling machine only needs to place all the utensils and food residue together. The high level of automation in the operation of the machine makes it more convenient and integrated in comparison.

#### **(2) Residue separation**

The multi-functional tray recycling machine cannot only recycle the plates, but also recycle the food on them. Food scraps, oil and water are filtered and separated, and finally food scraps and slop oil are stored. However, the existing plate recycling machines on the market do not go the next step of separation after initial placement by diners. Relevant personnel will remove these residues and reuse them which forms swill fat to harm human health. The multi-functional food tray recycling machine separates residues inside the machinery and outputs dehydrated and degreased food residues, oil, and water, avoiding the harm of secondary utilization of swill oil to consumers' health.

#### **(3) Transport structure security**

Traditional plate recycling machines only rely on conveyor belts to transport plates. In reality, plates often have a layer of edible oil attached to their surface due to the dumping method which makes them smooth and prone to slipping off the conveyor belt. Finally, resulting in loss of tableware and damage to the dining environment. The multi-functional tray recycling machine has improved the conveyor belt by adding horizontal teeth to fix the tray and provide a certain angle for the tray to pour the food residue. The conveyor belt also uses a mesh to facilitate food residue falling into the residue filtering device.

#### **(4) Intelligent recognition**

The multi-functional tray recycling machine uses facial recognition to give corresponding points based on the amount of food residue contributed by diners. The points can be used to purchase green products on applets. At the same time, the multi-functional tray recycling machine with LED screens can display the amount of food residue and swill oil stored inside the machine, as well as play advertising videos, etc. However, the existing plate recycling machines do not have this function, and don't have functions such as counting of food residues and purchasing.

#### **(5) Save labor**

Due to the high flow and concentrated dining time in large canteens, people send their plates to the plate collection area at the same time, resulting in the crowds and long waiting times during peak dining hours. At the same time, the staff pours the residue from the plates into the recycling bin and then puts the plates into the recycling bin. The staff works for a long time with high work pressure, low work efficiency and high labor intensity, It can also seriously affect the cleaning effect of the meal plate, unclean plates and food residue which is not conducive to further cleaning work. Moreover, during cleaning time, the residue in the meal plate is easily splashed into other places, which is very unhygienic and brings discomfort to users. The multi-functional tray recycling machine can finish it by

itself to save costs.

#### 4. Conclusion

(1) The multi-functional plate recycling machine developed mainly classifies and centralizes the recycling of plates, and filters and recovers citrus oil from food residues. Compared to single device such as food residue conversion machines, residue oil-water separators, and dishwashers that appear on the market, we use integrated connections of main new components such as modular mesh conveyor belts, bottle sterilization machines, top plate chains, PP chains, etc., which is more comprehensive in function and wider in scope of application.

(2) The multi-functional tray recycling machine mainly relies on gravity sensing technology, infrared sensing technology, oil-water separation technology, and improved conveyor belts to achieve its functions. Compared with traditional device, this device is more intelligent and easier to operate. Intelligence primarily reduces the safety hazards brought by mechanical device.

(3) In the recycling process, glycerol and kitchen waste are automatically recycled throughout the entire process. It simplifies the traditional plate recycling procedure, so that slop oil, dry residue and water are separated and stored, which makes it easy to directly interface with formal recycling enterprises. It not only avoids waste, but also eliminates recycling by some unscrupulous traders at source, reduces the generation and secondary use of gutter oil, and maintains people's dietary safety.

(4) This device is suitable for cafeteria operators in the catering industry, such as university canteens and enterprise canteens. Not only to save labour costs, but also to improve the efficiency of plate recycling, the use of plate recycling machines can create a clean and tidy dining environment, giving users a good value experience, so that customers feel more satisfied with the service. For diners, it is more convenient to handle the plates with less waiting time, and achieving a win-win result for both the operators and diners.

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