Analysis on Technical Measures on Energy Saving and Consumption Reducing During Stevia Sugar Production

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Abstract Based on the analysis of actual energy consumptions during stevia sugar production, practical measures were proposed to save energy (gas, water and powder) consumption and reduce cost through waste heat recycle and utilization, process improvement, equipment operation efficiency, application of newly energy-saving equipment, and some project applications were provided as case study for some techniques and methods adopted in the production.

Key words Stevia sugar; Saving energy and reducing consumption; Waste heat recycle; Process improvement

Inulin is a natural, highly sweet, low-calorie sweetener which cannot lead to dental caries, and it is extracted from the leaves and rhizomes of stevia. The annual demand for stevia in the world is nearly 10 000 t. Along with sweetener, the main consumer country, the United States, has approved its use, and its demand increases at a rate of 30% per year. China's annual production is 3 000 t, and the domestic consumption is about 500 t. And more than 80% is exported to Japan, South Korea, the United States and other countries, far from meeting the needs for market development[1].

Status Quo of Stevia Sugar Energy Consumption Index

The preparation process of stevia sugar mainly includes the following steps: liquid phase extraction, flocculation precipitation and impurity removal, resin adsorption, desorption, concentration, refining and spray drying. The intermediate semi-finished products and finished products mainly control total glycoside content, RA content, specific absorbance value, light transmittance and turbidity. Through the analysis of the annual energy consumption data of stevia sugar production in 2015, the consumption values of key energy-consuming equipment in major processes were determined, and the energy-saving and consumption-decreasing points could be determined.

Steam consumption

As shown in Table 1, the steam consumption in the extraction and refining workshops was relatively high, accounting for 86.75% of the total, which was mainly used for solvent heating, solvent recovery and distillation. There was room for reducing the consumed amount of steam.

Water consumption

As shown in Table 2, water could be saved during the extraction, filtration and absorption. The reverse osmosis process was to produce pure water, and if the water consumption of the entire production process was reduced, and the water consumption of the reverse osmosis process was also reduced.

Table 1 Average steam consumption in various processes in 2015

Process	Fresh solution heating	Concentration	Rectification	Spray	Deodorization	Total
Steam consumption per ton of raw material//t	0.45	0.62	2.40	0.29	0.24	4.00
Proportion//%	11.25	15.50	60.00	7.25	6.00	100

Table 2 Average water consumption in each process in 2015

Process	Extraction	Flocculation	Filtration	Adsorption	Desalination and decolorization	Reverse osmosis	Circulating water replenishment	Total
Water consumption per ton of raw material//m^3	5.7	0.8	10.8	5.2	0.6	7.6	1.2	31.9
Proportion//%	17.9	2.5	33.8	16.3	1.9	23.8	3.8	100.0

Electricity consumption

As shown in Table 3, the consumed amount of electricity could be reduced in the processes of spray drying and sewage treatment.

Energy Saving Measures

Waste heat recycle to reduce steam consumption and save steam

The technological process before and after renovation was shown in Fig. 1 and Fig. 2.

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Table 3 Average electricity consumption in various processes in 2015

Process	Feeding	Drying and packing	Extraction	Flocculation	Filtration	Adsorption	Desalination and decolorization	Concentration rectification	Deodorization	Spray drying	Sewage treatment	Total
Installed power//kW	101	219	202	107	243	172	318	242	257	436	398	2 695
Daily power consumption//kWh	972	1 575	1 455	641	877	1 032	1 911	1 451	1 848	5 232	2 418	19 412
Proportion//%	5.0	8.0	7.5	3.3	4.5	5.3	10.0	7.5	9.5	27.0	12.4	100.0

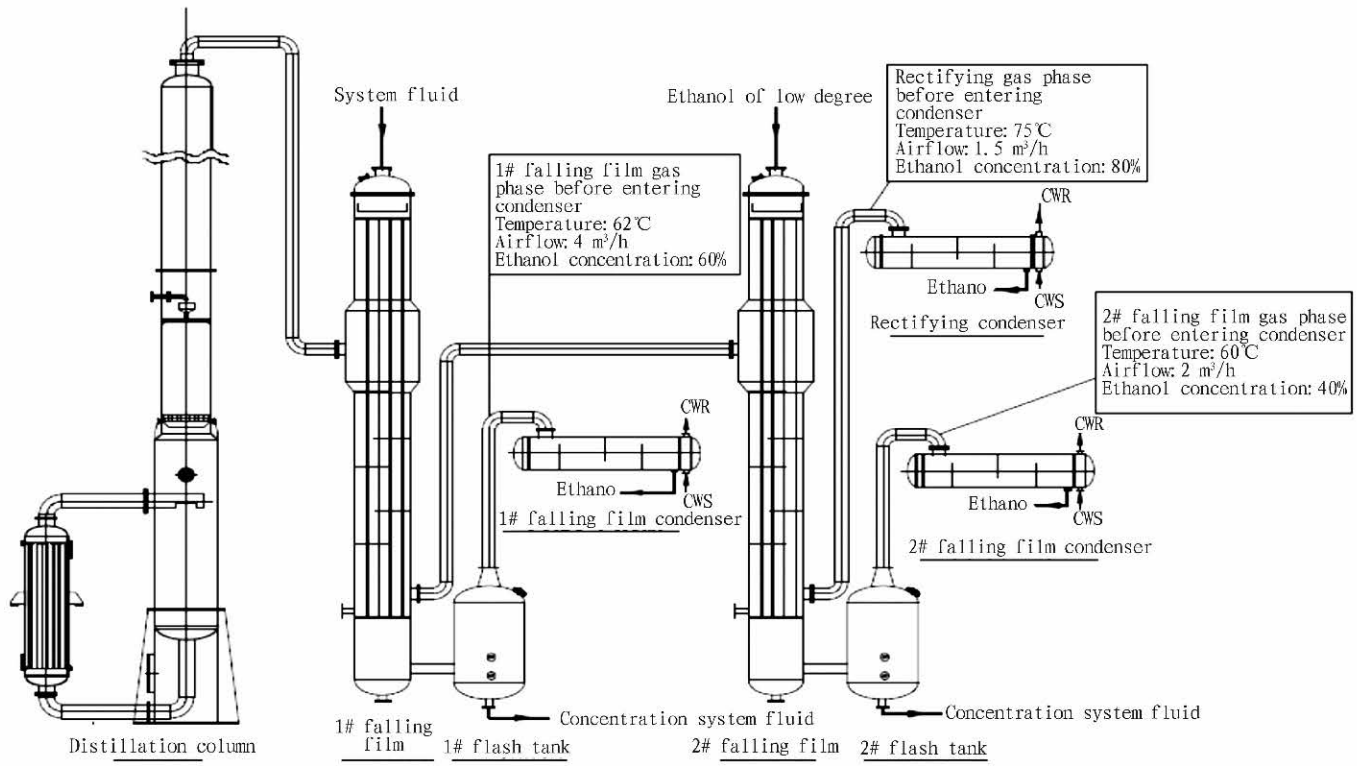

Fig. 1 Flow chart before renovation

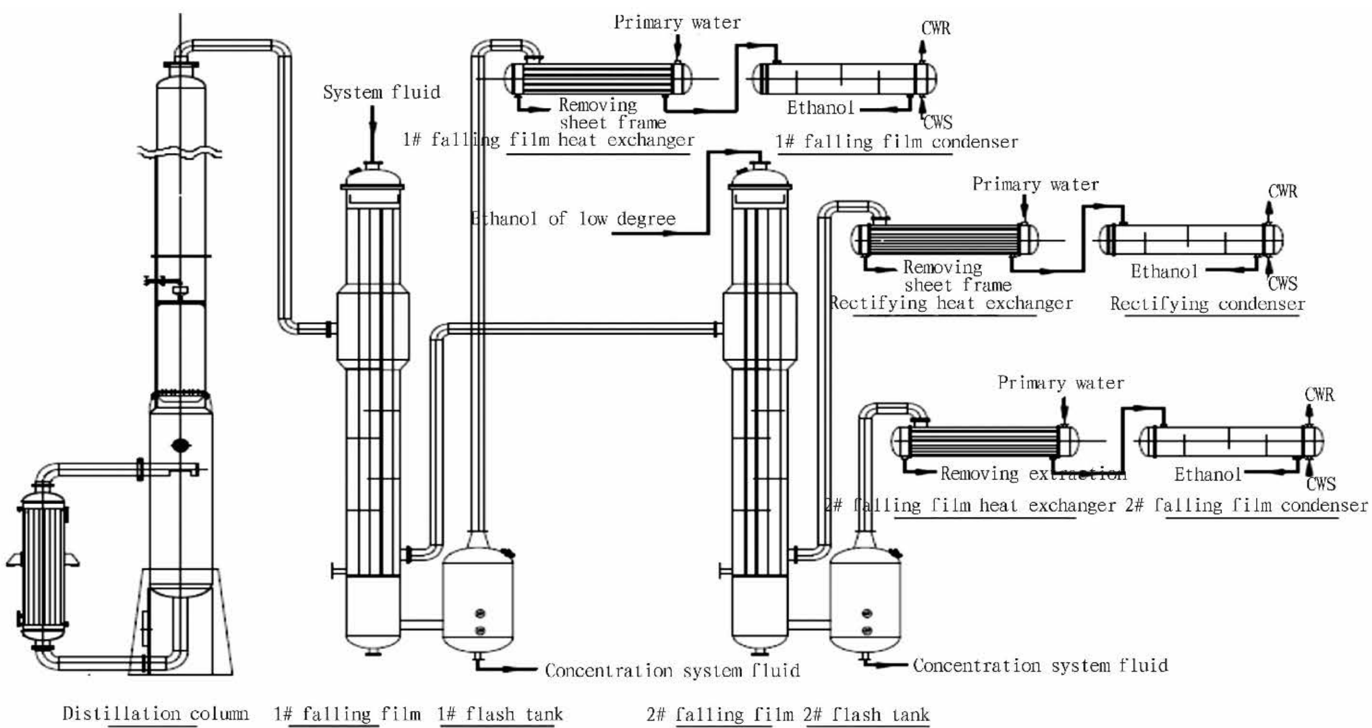

Fig. 2 Flow chart after renovation

Rectifying gas phase and falling film gas phase utilization, and heat exchanging between frame washing water and extraction primary water Process analysis: the gas phase of the rectifying tower was the heat source for the 1# and 2# falling film evaporators. 1# falling film flash tank had the gas phase temperature of 62 ℃, flow rate of 4 m^3/h, solvent concentration of 60%, while 2# flash tank had the gas temperature of 60 ℃, flow rate of 1.5 m^3/h, solvent concentration of 40%. After the 2# falling film, the rectified gas phase had the temperature of 75 ℃, flow rate of 1.5 m^3/h, solvent concentration of 80%. The 3 gas phases directly entered into the condenser to condense and recover the solvent. At the same time, the primary water to wash the broad frame and for extraction should be heated from 20 ℃ to 60 ℃. Before entering the condenser, transferring the heat of the waste heat of rectified gas phase and falling film gas phase with the primary water could not only reduce the steam consumption but also save the circulating water cooling amount.

Energy-saving measures: add 2 heat exchangers, transfer the heat of the gas phase of rectifying tower and falling-film evaporator with the primary water for extraction and washing. At present, the primary water amount for extraction $W_1 = 12$ m^3/h, the primary water amount for washing frame $W_2 = 19$ m^3/h, and the primary water temperature $T_1 = 20$ ℃. After calculation, the water temperature could be raised to 46.8 ℃. Considering only the latent heat of vaporization, the 3 gas phases could release $3.492\ 7 \times 10^6$ kJ of heat, saving steam of 1.6 t/h.

Preheating of tower bottom water and tower inlet of the rectifying tower The bottom water flow of the rectifying tower was 4 m^3/h with the temperature of 98 ℃, and it was directly discharged to the sewage station before renovation. After the renovation, a heat exchanger was added, which made the temperature of the liquid entering the tower at about 30 °C. And then, it was preheated with the bottom water before entering the rectifying tower, which could save 0.5 t/d of steam.

Utilization of waste heat from the outlet of hot blast stove The steam of the exhaust gas from the hot blast stove was 2 m^3/h with the temperature of 105 ℃. After calculation, the heat was equivalent to the heat from 174 kg of standard coal/h, equivalent to 2 321 kg of steam, and it was directly discharged. Before renovation, the waste water was heated to 35 ℃ using steam from the sewage station into anaerobic tank. Considering the dust at the outlet of the hot blast stove, which could lead to the low heat utilization rate, coils were added to the in the adjustment tank of the sewage station, which could heat the waste water to 35 ℃ using the exhaust gas from the hot blast stove. The renovation could save 0.5 t/h of steam.

Improving process to reduce process water consumption

Concentrated reverse osmosis water and board-washing water for extraction It needed 280 m^3 of pure water to rinse the resin column in the finishing workshop, and the reverse osmosis to make pure water could produce 100 m^3 of concentrated water every day, which could be used as the new solvent for the extraction workshop, thereby reducing the amount of primary water. The flocculation process filtered 18 frames per day on average. Each frame cleaning required 30 m^3 of water. The first 7 m^3 of washing water entered the adsorption column after flocculation, a total of 126 m^3, and the other 23 m^3 of cleaning water was injected into the drag chain leacher for recycling. In this way, 414 m^3 of primary water could be reduced every day.

Mixed use of regenerated lye from decolorization resin column Before renovation, each decolorization column was regenerated 9 times, and each time used 5 m^3 of lye, a total of 405 m^3 every day. After renovation, the lye of the first and second regeneration which had high content of impurities was discharged outside, and the other 325 m^3 of regeneration lye was used for regeneration of the adsorption column, which could reduce the amount of consumed lye. After regeneration, the resin column needed to be washed to neutral using water. Before renovation, each resin column needed 30 m^3 of water. After renovation, the water from the second washing of the next column was used to wash the latter column for the first time washing. Each resin column consumed 20 m^3 of water on average for the cleaning. Taking 20 d as a production cycle, 39 adsorption columns were regenerated per cycle. Before leaching, the finishing workshop discharged 2 820 m^3 of waste water for each production cycle, and after the modification, a total of 1 010 m^3 of waste water was discharged, saving 1 810 m^3 of water, an average of 90 m^3 per day.

Some bottom column water produced from adsorption for extraction A new process was used to reuse the bottom water of stevia sugar as a new solvent. Reusing the column water had no effect on the extraction yield of stevia, and the product obtained by using the bottom column water as a new solvent could meet the eligibility criteria. After the column water of low concentration was recycled to the extraction, it had almost no effect on the resin treatment capacity. Taking 6 m^3 of bottom water for the recycling per hour, 2.88×10^4 m^3 of water could be saved every year.

Reducing power consumption through process improvement and operational efficiency testing

Reducing power consumption by modifying the spray drying and heating method Before the renovation, the method of heating the stevia sugar spray drying equipment was steam + electric heating. In order to reduce the costs for spray drying and reduce the power consumption, steam + natural gas was used to for inlet air heating. Before renovation, the cost of steam + electric heating per hour was 263.6 Yuan per hour, and after renovation, the heating cost of steam + natural gas was 169.25 Yuan per hour, a decrease of 35.8%.

Improving equipment operation efficiency through current detection To ensure the operation efficiency of equipment, the energy efficiency of some key energy-consuming equipment was tested on a regular basis from August 2016. The starting current, rated current and operating current of the operation motors were detected in every workshop, and the motors were changed if necessary, so as to avoid the power consumption caused by "big horse pulling a small carriage"[2]. The motor testing and replacement schemes in the stevia sugar workshop are shown in Table 4. After the implementation of the renovation plan, the electricity consumption was reduced by 14.6%.

Table 4 Summary of motor testing and replacement scheme in stevia sugar workshop

Motor name	Power kW	Rated current//A	Running current//A	Starting current//A	Running rated//%	Frequency HZ	Replacement scheme
Crusher	7.5	14.9	9.1	12	61.07		Blocks existing during the feeding process for the large starting load, making it easy to block up, and no replacement
Extraction feed fan	30	59	28.2	70	47.80	25	Two sets with motor power of 30 kW, replaced by a 45 kW blower
Boiler blower	7.5	15	8.9	15	59.33	25	Different fan running frequency, which can be adjusted according to the furnace temperature, and no replacement
Feeding air lock	3	6.1	3.6	6	59.02		Large starting load, and no replacement
Stock bin baiting auger	4	8.1	4.6	8	56.79	4	Uneven material distribution and different loads, and no replacement
Tapping daft fan	18.5	36	31	38	86.11		Old with motor power of 18.5 kW, and replaced with the fan with motor power of 11 kW after recalculation
Blast blower	15	29.4	15.9	30	54.08	42	Diffeerent loading blast capacity during the operation, which can be adjusted according to different process indicators, and no replacement suggested
Pure water main pump	11	21	9.7	21	46.19	29.6	Different water consuming amounts with conversion
T3	11	21	10.2	21	48.57	30.6	Frequency and automatic
Distillate Pump	11	21	11.1	21	52.86	48.6	Adjustment and motor power of 11 kW. It is recommended to replace with the 7.5 kW motor, which can adjust other pumps according to flow and lift

Thoughts and Suggestions

The above-mentioned process renovation has effectively reduced energy consumption, and significant effects have achieved in the recycling use of waste heat, cooling water and primary drainage. The future energy saving and consumption reducing work can start from the following aspects.

First, vigorously promote automation technology and improve operation level: it is hard for manual operation to maintain production in an optimal state. The automatic detection and control devices for process control can make the production maintain at the optimal state by adjusting the production parameters timely according to the changes in raw material properties. The whole-process automation can improve the equipment processing ability, reduce the cost, and also can significantly improve the production index.

Second, adopt the water-saving thinking. It should raise the awareness that "water is a scarce resource" and form a water-controlling model like a pipe-solvent. In the first place, it should reduce the supplement amount of fresh water from the perspective of technology; then it should give consideration to recycling and reusing; finally, consideration should be given to the specific technology for treatment and reuse.

Third, actively adopt advanced production technology to reduce primary energy consumption, increase secondary energy utilization, and maximize energy cascade utilization.

Fourth, vigorously promote the application of new energy-saving equipment: it can take the lead in the use of permanent-magnet variable-frequency air compressors and permanent magnet motors [3].

Fifth, improve the energy consumption structure, and make techno-economic comparative analysis to the available equipment with large energy consumption. Priority should be given to energy saving.

Sixth, avoid disconnected and repeated heating process in the design of the process flow as much as possible. Consideration should be given to the possibility of heat recycling cascade use for the technological process requiring both heating and cooling.

Seventh, do a good job of insulation work, including valves, to ensure that the sum of steam consumed in the workshop and the steam generated in the boiler room can basically be balanced.

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