Design of Production Line of 2000 Tons of Fermented Milk Beverage with Annual Output of Whole Bean

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Abstract：The whole soybean fermented milk beverage designed by this production line is a beverage made of soybean as raw material and fermented under the fermentation action of compound probiotics. The design optimizes the production line of whole soybean fermented milk beverage with an annual output of 2000t and strictly refers to the relevant national regulations to determine the process design, material balance, equipment selection, water and electricity estimation, and workshop design of the whole soybean fermented milk beverage production line. Finally, the technical and economic analysis of the scheme shows that the fixed investment of the project is 7.95 million yuan, the annual production cost is 15193.72 million yuan, the total profit after tax reached 16.80628 million yuan, the construction period is 1 year, and the payback period is expected to be about 2 years.

keywords: Whole Bean； fermented milk beverage； production line design

1. Introduction

Grains should be nourished, and lost beans are bad. Soybean contains 35%~40% protei n, contains a complete range of amino acids, and its essential amino acid composition ratio is closest to the proportion required by the human body, and is rich in soybean isoflavone s and saponins with anti-cancer, antioxidant, and immunity-improving functions [1-3]. A larg e number of okara by-products are produced during the processing of traditional soybean pr oducts, and beany odor is produced due to the enzymatic reaction of lipoxidase and the oxi dation of unsaturated fatty acids [4]. Okara is highly nutritious, but it is often used as feed or fertilizer, reducing its value. It is urgent to develop a production model of clean soybea n products without beany odor.

Lactic acid bacteria are a class of probiotics that have nutritional, antibacterial, and int estinal rectification, anti-cancer and anti-cancer and scavenging free radicals produced in the body, and have the effect of delaying cell aging and prolonging life [5]. The yellow syrup produced in the processing of traditional soybean products is used as a natural nutrient to provide energy and nutrients for the growth and reproduction of lactic acid bacteria, and th e production of nutritional and health care soybean products that not only regulate the bala nce of human intestinal microecology but also facilitate clean production can promote the s ound and rapid development of the bean industry, which has good application value and pr actical significance.

Fermented soy dairy products are favored in Japan, Europe, and the Americas as a nat ural food [6-7]. At present, the degree of industrialization of whole soybean product product ion is low, which greatly hinders the development of the soybean products industry [8] to r ealize the industrialization of whole soybean fermented milk beverages, the whole soybean f ermented milk beverages designed by this production line start from the processing technolo gy, and use oxygen insulation, wall breaking, tropical treatment, and other methods to impr ove the product quality. (1) Heat treatment, homogenization, and wall-breaking treatment are carried out in the processing process to soften the hard fibers, reduce the particle density, increase the stability of the product, and optimize the taste of the product. (2) The direct st erilization machine is used on the production line for sterilization treatment, which reduces the heat load, reducproduct, and strengthens the fluidity. (3) To prevent the polyunsaturated

fatty acids in the whole soybean beverage from being oxidized in large quantities and pro ducing bad odors, and prolonging the shelf life, the production line will minimize the mixin g of oxygen, and will also choose a packaging type with low oxygen permeability and hig h permeability when packaging, to prolong the shelf life and ensure product quality. The in dustrial production of whole soybean fermented soybean milk contains huge development po tential and broad market prospects.

2. Production process design

2.1 Product solutions

Construction of an annual output of 2000 tons of finished products of whole soybean f ermented milk beverage factory 1, the design plans to arrange the number of production da ys is not less than 280 days, 1 shift per day, the design of the class output: 2000t/year÷28 0d/year÷1/day = 7.14 t/shift.

Soak soybean raw materials with 0.2% sodium bicarbonate, refine according to the rati o of 1:8 to water, add 8% white sugar, 0.12% stabilizer pectin, and sodium carboxymethyl cellulose CMC 0.4%, the inoculation amount is 0.1%, and the formula ratio is calculated ac cording to 1000kg of water, and the ingredient list is as follows:

Table 1. Formula of soya fermented milk beverage

Ingredients	Content (kg/t).
Soybeans (after soaking)	125
Water	1000
Sugar	80
Pectin	1.2
CMC	4
Strain	1
Sodium bicarbonate	2

2.2 Quality Standards

The quality standards for whole soybean fermented milk beverages refer to GB/T 3088 5-2014 vegetable protein beverages, soybean milk, and soybean milk beverages [9] and GB 7101-2022 national food safety standard beverages [10]. Among them, the sensory requireme nts, physical and chemical indexes, and microbial limit indicators for whole soybean fermen ted milk beverages are as follows:

Table 2. Quality standard index of soya fermented milk beverage

Inde	Project	Requirements/Indicators	Method
Sen sory requ irem ents	Color	It has the color that whole	Take about 50ml of the evenly mixed sample in a colorless and transparent container, observe the color and luster under natural light, identify the smell, gargle with warm
	Taste, smell	It has the taste and smell of a	
	State	It has the state that a whole soybean fermented milk drink should have, and there is no foreign body visible with normal vision	
Phy sical and che	Total	≥2.0	GB/T 30885-2014 6.2
	Protein/(g/100g).	≥1.0	GB5009.5
	Fat/(g/100g)	≥0.4	GB5413.3
	Urease activity	Feminine	GB/T 5009.183
Mic robi al	Yeast/（CFU/g or	≤20	GB4789.15
	Coliform/（CFU/g or	≤10	GB4789.3
	Mould/（CFU/g or	≤20	GB4789.15

	Lactic acid bacteria/	≥106	GB4789.35

2.3 Production process

The main production processes are soybean washing→ soaking→ refining→ boiling→ b lending→ homogenization→ sterilization→ fermentation→ filling→ labeling→ refrigeration → finished products.

2.4 Key points of production process operation

(1) Preliminary preparation of raw materials: carefully select soybeans with plump and saturated particles, no mildew and deterioration, and no insect mouth, soak them in an aque ous solution of NaHCO3 with a mass fraction of 0.2% at room temperature for 1h, and the n refine them with room temperature water at 25 °C according to the ratio of 1:8 to obtai n soybean milk stock solution for later use. (2) Boiling of slurry: keep it for 15 minutes af ter boiling, and keep the temperature at 100 °C during the whole cooking process in the sa ndwich pot. (3) Blending: Add white sugar and stabilizer to the blending tank. (4) Homoge nization: High pressure homogenization at 20Mpa [12]. (5) Sterilization: 121 °C, 20min ster ilization. (6) Inoculation and fermentation: After cooling to room temperature, add compoun d probiotics (Lactobacillus paracasei and Lactobacillus plantarum) at a ratio of 0.1% and a ratio of 1:1 [13-14], and ferment at a constant temperature of 37 °C for 6 hours. (7) Canni ng and cooking: canning after fermentation is completed, and then placed in the refrigerator at 4 °C for 12h to make the product clear and improve the flavor.

3. Material balance

Through the calculation of materials, the consumption quota of raw materials, the outpu t of products and other by-products, and the amount of waste generated can be calculated, and the economy of the entire production process can be measured, to study and formulate improvement measures to improve production efficiency and reduce by-products and waste emissions according to the existing problems and nodes, which has important guiding signifi cance for guiding the technical improvement and design optimization of the whole process[1 5].

Table 3..Basic data

Project	Name	Percentage %
Quota indicators	Raw material utilization	99
	Soybean water content	11
Raw material ratio	Soybean	12.5
Loss rate	Refining loss	1
	Cooling loss	2
	Fermentation losses	1.6
	Canning losses	0.8
	Other process losses	0.1
Total loss ratio	Total losses	5.5

The ratio of soybean to water in this production process is 1:8, and the water absorpti on ratio of dry soybean is 1:2. The refining temperature is 25 °C, the boiling temperature i s 100 °C, and the fermentation temperature is 37 °C. In this calculation process, the densit y of beverages is calculated based on the density of water. The PET bottle specification is 250g/bottle, the loss rate is 0.1%, and the outer material specification is 12 bottles/box. Be cause the total loss of refining, cooling, fermentation, canning, and other processes in the p roduction process is 5.5%, the final product fermented milk beverage is 7661.10× (1-5.5%)= 7239.74L when it is cooled to 4 °C after fermentation. The consumption of the rest of th e excipients is not large and has little impact on the overall total volume. According to the

data in Table 1 and Table 3, the annual consumption of each material can be obtained by synthesizing the above data.

Table 4. Material balance of soya fermented milk beverage

The name of the item	Unit	Class consumption	Annual consumption
Soybean	kg	317.08	8.878×104
Sugar	kg	608.8	1.705×105
Pectin	kg	9.13	2556.4
CMC	kg	30.44	8523.2
Strain	kg	380.5	1.065×105
Sodium bicarbonate	kg	15.22	4261.6
PET bottles	Bottle	30471	8.532×106
Outsourcing materials	Piece	2540	7.112×105
Ground soy milk	L	8587.79	2.405×105
Boil the soybean milk	L	8961.11	2.509×106
Fermentation stock	L	7661.10	2.145×106
Product: Fermented milk beverage	L	7239.74	2.027×106

4. Equipment selection

4.1 Selection and calculation of main equipment (calculated by shift output)

According to the requirements of the process, equipment production capacity required by the project is calculated, and then the number of equipment units is specified according to the requirements of the production cycle.

(1) Pulp boiling equipment: the amount of soybean milk when boiling pulp is 8961.11 L, the capacity of the tilting sandwich pot has a variety of specifications from 50 to 1000 L, and the design selects 1000L tilting sandwich pot for boiling pulp, each pot is 814.65L, and 11 sandwich pots are needed.

(2) Blending tank: the remaining auxiliary materials of the processed soybean milk are proportionally blended, the amount of each shift is 7661.10L, and the capacity of the mixing tank is 100 to 10000L a variety of different specifications, the design selects 5000L tank for deployment, 3830.55L per tank.

(3) Fermenterto save costs and better control product quality, the fermentation selection adopts batch fermentation technology to realize the one-time addition of strains and fermentation stock solution during the fermentation process, and the one-time harvest of products. The fermentation raw material for the design and production of whole bean fermented beverages is 7661.10L. The capacity of the fermentation tank has a variety of specifications from 300 to 15000L, to shorten the fermentation time while ensuring complete fermentation, the design uses a 3000L tank body to ferment the raw materials and selects 3 fermentation tanks, each tank is 2553.70L.

(4) canning equipment: the design and production of the final product of the whole bean fermented milk beverage is 7239.74L, and the filling specification is 250mL/bottle, a total of 30471 bottles, to achieve automation, and high precision, to ensure accurate and consistent filling, fast filling speed and reduce loss, the design selects 2 sets of automatic washing, filling and sealing machine, and the production efficiency is 2000 bottles/h for filling.

3.2 Equipment selection and main equipment description

(1) Tubular UHT instantaneous sterilizer: Tubular UHT instantaneous sterilizer can be widely used for instantaneous UHT sterilization of liquid food materials (such as dairy products, beverages, fruit juices, low-viscosity fruit pulp, etc.). After UHT heat treatment, the product will no longer contain microorganisms that can grow and multiply under indoor temperature storage standards, and will be able to meet commercial sterilization requirements. Due to the short UHT processing time, the product preserves the original color, flavor, and nutritional content of the food very well. The automatic control system uses a programmable logic controller and touch screen, equipped with advanced operating software and a good HMI system to monitor the entire processing process, which can complete the automatic operation process from mechanical equipment sterilization, and production to cleaning-in-place. The whole system has the characteristics of simple operation, low cost, and good sterilization effect.

(2) Fermenter: Fermentation tank is widely used in dairy products, beverages, the biochemical industry, and other fields.InsulationIt can be heated, cooled, and kept warm. To ensure that the production process meets the production quality management practices, the tank body is made of SUS304 or 316L imported stainless steel, and the tank is equipped with a fully automatic spray cleaning head. The tank body and the upper and lower filling heads are processed by spinning R angle, and the inner wall is warpedpolished treatment, no hygienic dead ends, and the fully enclosed design also ensures that the materials can be mixed from beginning to end in a zero-pollution environment. ferment equipment is also equipped with breathing valves, on-site cleaning nozzles, access ports, and other devices.

(3) Washing, filling, and sealing machine: The washing, filling, and sealing machine integrates washing, filling, and sealing, and the whole working process is automated by PLC, which is convenient to operate and has a high degree of automation.

(4) Continuous spray cooler: The continuous spray cooler adopts four stages of circulating warm water preheating, circulating hot water sterilization, circulating warm water pre-cooling, and cooling water spray cooling, which can effectively save water consumption, save heat energy, intelligently control the degree of cold and heat during sterilization, and customize the smooth adjustment of sterilization time, which can be applied to the sterilization and cooling of PET polyester bottle packaging.

(5) CIP cleaning equipment: A CIP cleaning system, commonly known as an in-situ cleaning system, can add a washing liquid with a higher temperature and more solute content to the equipment and equipment that needs to be cleaned without decomposing the device, to enhance the effectiveness of the cleaning degree of the equipment.

Table 5. Equipment selection

Equipment	Model	Production	Power/	Dimensions/mm	Quant
Clean the	PT2000	2000L	-	1300×1420	1
Refiner	DM-LZ400	500kg/h	11	700×1380	1
Tiltable	JCG-1	1000L	30	2000×2000×1700	11
Dispensing	-	5000L	11	2100×4250	2
High-pressure	GJJ-Q-4500-P25	9000L	37	1350×1100×1360	1
Tubular UHT instantaneous	HE-UHT-SN-8	8000L/h	3.7	4500×1800×2000	1
Seed pots	-	500L	1.1	600×1650	2
Fermenters	-	3000L	5.5	1200×2600	3
Washing, filling	YT4T-4G1000	2000	1.25	4000×1000×1750	2
Continuous	PLS-2000	1800	10.6	17880×2250×1735	2
Fully automatic	T962	6000	0.98	3000×1450×1600	1
Fully automatic	AC-12	120 box/h	5.65	2000×1500×1800	1

CIP cleaning machine	YZ-CIP-02	1t	4.5	550×750×650	1

5. Water, electricity, and gas estimation

5.1 Water Estimation

The production water is mainly used for soybean washing, soaking, and refining. Let's say 2kg of water is needed to wash 1kg of soybeans. The equipment cleaning water is used for pretreatment equipment, blending tank, homogenization, sterilization equipment, strain culture equipment, fermentation tank, washing, filling, and sealing machines. According to the calculation of daily water consumption $\frac{mpCp(t_{serum1}-t_{serum2})}{Cw(t_2-t_1)\eta}$ S, the cooling efficiency η= 85%. (1) Cooling water before fermentation: use 2 °C cooling water to cool the fermentation raw materials, and the outlet temperature of the cooling pipe at the end of cooling is about 60 °C. After blending, homogenizing, and sterilizing, the temperature of the fermentation stock solution is reduced from 121 °C to 37 °C before fermentation. The specific heat of soybean milk is Cp=4.0156kJ/kg°C, the specific heat of water is Cw=4.182 kJ/kg°C, and the daily consumption of fermentation stock is mp=7610kg; S=7610×4.0156×（121－37）/4.182×（60－2）×0.85＝8995.42kg＝8.995t. (2) Spray cooler water: The temperature of the finished product obtained after fermentation is 37 °C, and the cooling water is used to spray the glass bottle to cool down. The daily beverage consumption is about 7.6 tons, and the spray water consumption is 15 tons. Therefore, the daily cooling water consumption: is 8.995+15=23.995t, and the annual water consumption: is 23.995×280=6718.6t.

Table 6. Water consumption

Classification	Project	Class water	Annual water consumption/t
Process water	Wash soybeans	0.634	177.5.
	Soak soybeans	0.634	177.5
	Ground soy	7.61	2130.8
Water for equipment cleaning	Pre-treatment	10	2800
	Dispensing	16	4480
	Homogenization	15	4200
	Strain culture	12	144
	Fermenters	18	5040
	Washing, filling	6	1680
	Cooling	23.995	6718.6
Other water use	Floor cleaning	25	7000
	Domestic water	10	2800
Total			33797.2

5.2 Electricity estimation

The electricity used for production is the rated power multiplied by the working time. If the electric lighting is used at night or when the light is insufficient, if it is calculated according to 18w/m2, the daily electricity consumption is: 18×10-3×1000=18 kWh, and the annual electricity consumption is: 18×280=5040 kWh.

Table 7. Electricity consumption

Project	Daily electricity consumption/kWh	Annual electricity consumption/kWh
Electricity used in production	1467.36	410860.8
Electricity for lighting	18	5040

Total	1485.36	415900.8

5.3 Steam estimation

The steam consumption of the sandwich pot is 0.2t/h, and the cooking time is 35min. The steam consumption of the sterilizer is 0.3t/h soybean milk. The steam consumption of the washing, filling, and sealing machine is 25kg per 1000 bottles. The steam consumption of the CIP cleaning machine, labeling, packing, intermediate pipeline, etc. is calculated as 0.4t/h products, and the daily and annual steam consumption are shown in Table 8.

Table 8. Gas consumption

Project	Daily steam consumption/t	Annual steam consumption/t
Sandwich pots	1.28	358.4
Sterilizer	2.688	752.64
Washing, filling, and sealing	0.762	213.36
CIP cleaning machine	3.04	851.2
Other equipment	3.04	851.2
Total	10.81	3026.8

6. Workshop design

6.1 Design Requirements

The production capacity of this whole soybean fermented milk beverage production line is 7.6 tons. Depending on the equipment chosen, the workshop is designed with a length of 40m, a width of 25 m, and a total area of 1000 m2. The workshop consists of setting up cold storage with an area of 40 m2, which is 8 m long and 5 m wide. Excellent production workshop graphic design, equipment placement should be staggered, should maximize the use of space, make it beautiful, convenient and smooth production, easy to maintain. Accordi the requirements of GMP for the construction of food factories, the equipment placement of the workshop should be arranwith the following standards [17]: ensure the sequence and continuity of the process, minimize the number of material lifting, Conveying distance, there should be a certain safety distance between the placement of machinery and equipment, and there should be room for the workshop according to the production requirements; heavy objects and equipment with large vibration should be placed under the floor as much as possible, and equipment with low containers should be placed on the upper floor as much as possible, and if necessary, it should be raised and placed on the bottom floor.

6.2 Design area and description

(1) Warehouse: store the raw and auxiliary materials of various whole soybean fermented milk beverages. (2) Pretreatment room: washing, soaking, refining, boiling, and other treatments for soybeans. (3) Ingredient room: mix the raw materials according to the formula ratio. (4) Sterilization room: homogenize and sterilize the blending solution. (5) Fermentation room: inoculation and fermentation of the feed liquid. (6) Filling room: filling the finished product. (7) Packing room: packing the finished products. (8) Packaging material warehouse: used to place packaging materials such as glass bottles and cartons. (9) Cold storage: the fermented whole soybean fermented milk beverage is post-matured. (10) CIP cleaning room: responsible for cleaning the production line. (11) Biochemical laboratory: inspect the hygiene of strains and finished products. (12) Control room: control the production line. (13) Locker room: an area where employees change their work clothes and shoes, place items, and disinfect them. (14) Air shower room: blow away the dust attached to the employees and items in and out of the workshop, and prevent unpurified air from entering the workshop

area. (15) Toilet: should be set up outside the production workshop, the door can not direct ly face the production workshop, and for the non-manual water flushing, the interior needs to be equipped with hand-washing facilities and odor removal devices, but also set up anti-mosquito, anti-fly facilities.

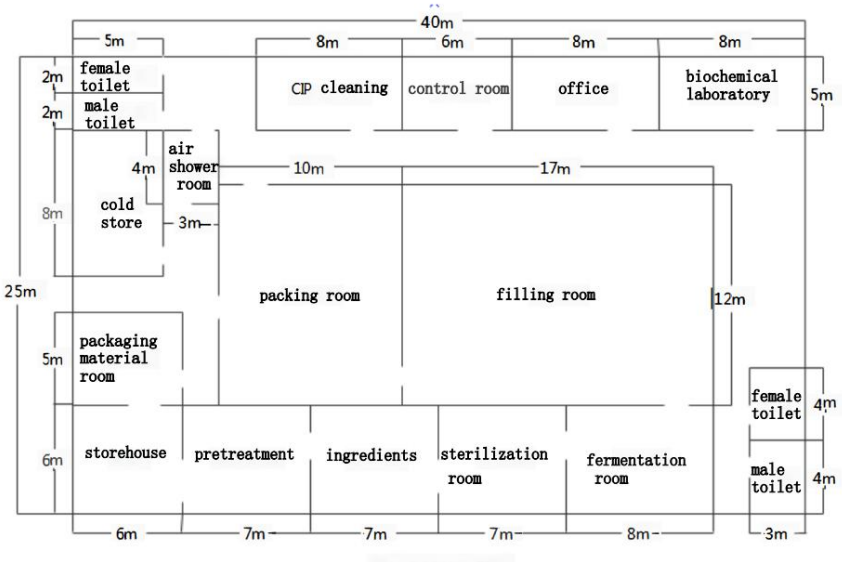

Fig.1 General plan of the workshop

7. Economic analysis

7.1 Investment in factory construction

The production line is expected to have a construction period of one year, and half a year of trial production. After strict approval procedures, the selected area needs to meet th e following conditions:

(1) The terrain is flat, which meets the land leveling requirements of engineering const ruction. (2) Keep away from sensitive areas such as residential areas, reservoirs, and scenic spots to avoid affecting the surrounding environment. (3) The transportation is convenient, which is conducive to the transportation of raw materials and products.

Table 9. Investment in plant construction

Use	Fee (10,000 yuan)
Land costs	100
Factory construction	220
Purchase equipment	250
Install the device	25
Liquidity	200
Total	795

7.2 Annual cost estimates (see Table 10)

Table 10. Annual cost estimation

Use	Fee (10,000 yuan)
Utilities	138.08
The cost of the material	206.44
Employee salaries	264
Equipment maintenance	50
Other Fees	65.85

Total annual cost	724.37

7.3 Calculation of annual output value:

The ex-factory price of whole soybean fermented milk beverage is 5 yuan/bottle, with an annual output of 2,000 tons, and a bottle of 250g/bottle, then 8×106 bottles are produced, and the annual output value is: 5×8×106=40 million yuan.

6.4 Calculation of corporate profits and payback period

Annual gross profit = annual output value - annual cost, that is, 4000-1519.372 = 24.80628 million yuan. Corporate income tax is levied at a rate of 20%, net profit = gross profit - income tax, that is, 2480.628 - (4000×20%) = 16.80628 million yuan. Assuming that the annual net cash flow is equal, the estimated construction period of the production line is 1 year, and the static payback period formula method is calculated: 1519.372÷1680.628+1≈2 years.

8. Conclusion

This paper is the design of the whole soybean fermented milk beverage production line with an annual output of 2000 tons, designed according to the production standard of fermented milk beverage, selected the appropriate process for production, analyzed the process flow, product scheme, equipment selection, etc., explained the design of the whole soybean fermented milk beverage production line, and completed the material balance, the estimation of water, electricity and steam, and the selection and calculation of equipment. Estimated the total investment, profit and payback period of the project, after the design project is put into operation, the annual output value is 40 million yuan, and the production cost is 15193.72 million yuan, and the after-tax profit can reach 16.80628 million yuan. If it is successfully put into production as planned, the production funds can be recovered within 2 years after it is put into operation. The later income is considerable, and it has a certain investment value.

Funds

Provincial Department of Education Characteristic Innovation Project-DNA Fingerprint Identification of Multi-strain Active Probiotics and Key Technology Research of Special Diet Whole Soybean Products (2019GKTSCX054); Key Project-Preparation and Application of Sweet Potato Resistant Starch under the Background of Rural Revitalization Strategy (XJZD202001); Provincial Department of education innovation and entrepreneurship training project-multi-strain active lactic acid bacteria whole soybean products wall breaking technology research ; 2020 Guangdong Provincial College Key Areas Special (Rural Revitalization) (2020ZDZX1094) ; guangdong Provincial Department of Education Guangdong Provincial College Key Areas of Special (Biomedicine and Health) (2023ZDZX2081);Teaching and Research Project of Wuhan Technology And Business University (2022Y09)

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