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Techno-Economic Analysis of Healthy Herbal Ice Cream Product

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Abstract. *Gynura procumbens* (longevity spinach) is typically used in Asian folk medicine to treat inflammation and rheumatism. Studies show that *Gynura procumbens* has many applications, especially as a therapeutic medicine for antimicrobial, anti-inflammatory, antioxidant, organ protective, antihyperglycemic, antihypertensive, cardioprotective, anti-cancer, and fertility enhancement. The consumption of ice cream in Indonesia is increasing each year. Most consumers perceive ice cream as a sweet treat, with indulgence the most important trend in the market. Adding herbal ingredients to ice cream can address several consumer problems, such as high sugar intake, and provide the health benefits of herbals with ease of consumption. This study examines the techno-economic analysis of a healthy herbal ice cream product that can not only provide herbals in a trendy mode of consumption but can also address the problems that occur from consuming ice cream. The formulation of the supplement consists of longevity spinach 5%, skim milk 69.75%, extract flavor 0.6%, sugar 3.25%, salt 1%, lecithin 20%, and food coloring 0.4%. The manufacturing process consists of a typical ice cream production line with *Gynura procumbens* pretreatment at the start. The plant designed will produce 57,734 jars per day with a price of Rp 5,066 for each jar. The capital investment of our plant is Rp 10,305,160,564. We gain Rp 77,216,401,229 per year, with IRR as high as 46%. Our NPV is Rp 21,819,500,900 with a payback period of 2.24 years. Our product is relatively sensitive to the selling price and the price of the raw materials.

Keywords: Flavonoid; *Gynura procumbens*; Herbal; Ice cream; Polyphenols

1. Introduction

Ice cream is a mixture of mainly dairy ingredients and ingredients for sweetening and flavoring, such as fruits, nuts, and chocolate chips. American-style ice creams are churned quickly to whip in plenty of air. The air portion of the product is called overrun, held by the high proportion of cream in the base. Most luxury ice creams have an overrun of around 25%, which means they have increased the mix in volume by 25%. Cheaper commercial versions can run from 50% to over 90%, which gives them a light, thin, fast-melting texture with fewer flavors (Morelli's Gelato, 2017). The ice cream market in Indonesia forecasted growth at a compound annual growth rate (CAGR) of 7.8% during 2014–2019 (Canadean, 2015). The volume consumption of ice cream products has reached 158 million kg in 2018 and forecasted to grow by 16% per year until 2020 with the market value reached Rp19.8 trillion (Ciptadana Sekuritas Asia, 2018).

However, ice cream can harm health for several reasons. First, it has a high sugar content, and up to 12 to 16% of its compositions are sweeteners such as sucrose and corn

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syrup. Second, it also has a high fat content: in some cases, ice cream contains 16% fat. Third, the lack of fiber in ice cream can lead to constipation and weight gain. Finally, the usage of additives such as preservatives, artificial flavoring, and artificial coloring can lead to an allergic reaction of the consumer, and the chemical compounds can accumulate inside the body (Marshall et al., 2012).

Longevity spinach (Gynura procumbens) is an evergreen shrub found abundantly in tropical Asia, especially Indonesia, Thailand, and Malaysia, which is of considerable medicinal and culinary value but is still mostly unknown outside those regions (Mou and Dash, 2016). Longevity spinach's beneficial properties have been attributed to bioactive compounds such as flavonoids, unsaturated sterols, triterpenoid, polyphenols, glycosides, and the many essential oils in this plant (Sudarto and Pramono, 1985). Longevity spinach extract has resulted in a significant decrease in heart rate which help reduce the effect of hypertension. It shown a strong negative chronotropic effect in rats' right atria and adverse ionotropic effects in rats' left atria (Hoe et al., 2011; Kaur et al., 2012; Abrika et al., 2013). The antioxidant activity of Longevity spinach extracts was evaluated by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay to measure its free radical scavenging. In a comparative study, longevity spinach extract exhibited the highest percentage of DPPH inhibition (52.81%) compared to various other plant extracts (Maw et al., 2011). Longevity spinach is commonly used to treat inflammation. It has been proven to prevent the increase in ear thickness in mice caused by croton oil-induced inflammation (Iskander et al., 2002).

This study aims to design a plant to produce healthy herbal ice cream as a highly nutritious product and healthier snacking alternative, to improve public health. The study was carried out by formulating the product using information obtained from a customer survey and from the international food regulations of the U.S. Food and Drug Administration. The complete composition of the healthy herbal ice cream product can be seen in Table 1. The nutritional value of the final product can be seen in Table 2.

Table 1 Composition of healthy herbal ice cream

Ingredient(s)	Amount(g)	Composition (% total amount)
Longevity spinach	10	5
Skim milk	139.5	69.75
Lemon or vanilla extract	1.2	0.6
Glucose	6.5	3.25
Salt	2	1
Lecithin (eggs)	40	20
Food coloring	0.8	0,4
Total	200	100

Table 2 Nutritional value of healthy herbal ice cream

Specification	Value	Reference
Fat	5.6	Guinard et al., 1996
Carbohydrate	10.8	Chou and Tobias, 1960
Dietary fiber	5	Soukoulis et al., 2009
Sugar	4.6	Guinard et al., 1996
Protein	12.8	Patel et al., 2006
Vitamin A	0.00064	
Calcium	0.00098	
Vitamin D	0.00016	USDA, 2019
Vitamin B-12	0.00062	
Vitamin C	0.0002	

2. Methods

The research is done by designing a product, synthesizing and simulating the process needed in order to define process parameters and economic parameters for the techno-economic analysis (Rosyidi et al., 2016; Kusrini and Kartohardjono, 2019). The process synthesized in this study has gone through a selection process where various extraction methods and ice-cream-making methods were scored. After the selection, the chosen methods were integrated into the main block flow diagram (Figure 1) and Process flow diagram (Figure 2). There are six main processes in the production of healthy herbal ice cream: grinding, leaching of *Gynura procumbens* as the primary source nutrient, blending of the herbal extract with ice cream premix, homogenizing of the mixture, cooling of the mixture to below room temperature, and finally packaging of the final product, which consists of jar filling and packaging to boxes. The final product will be stored in freezer storage to freeze the ice cream.

The *Gynura procumbens* is washed to guarantee hygiene. This process operates at ambient temperature. Water and ash are the residues of the washing process. The wastewater is then separated from the raw material. There are two output streams from this process: wastewater and cleaned *Gynura procumbens*. The clean *Gynura procumbens* is then transferred into the grinding process. The raw material is ground into smaller pieces. The most crucial goal of the process is to reduce the size of the material from discrete to bulk flow, to ease the extraction of the active herbal compound. The ground *Gynura procumbens* is then extracted using solid–liquid extraction by leaching in a mixer–settler extractor. Water is the primary solvent of this process to ensure the halal aspect of the product. The extract is then blended with other materials, such as milk, flavoring, emulsifier, and air, and mixed into an almost homogenous mixture. Milk cannot be blended homogeneously because the forming milk clots out of the fat content. Therefore, we used high-pressure homogenization to homogenize the milk in the mixed compound. To produce cooled ice cream and maintain the product's air content, we use a freeze–thaw module to decrease the temperature in our product. The cooled mixture is then filled into a plastic jar using a filling machine, and it is packed per unit in cardboard. The mass and energy balance are calculated using SuperPro Designer v9.0.

This healthy herbal ice cream plant will be built in a large-scale factory located in Jl. Raya Parung, Bogor District, West Java, Indonesia, occupying approximately 5,100 m^2.

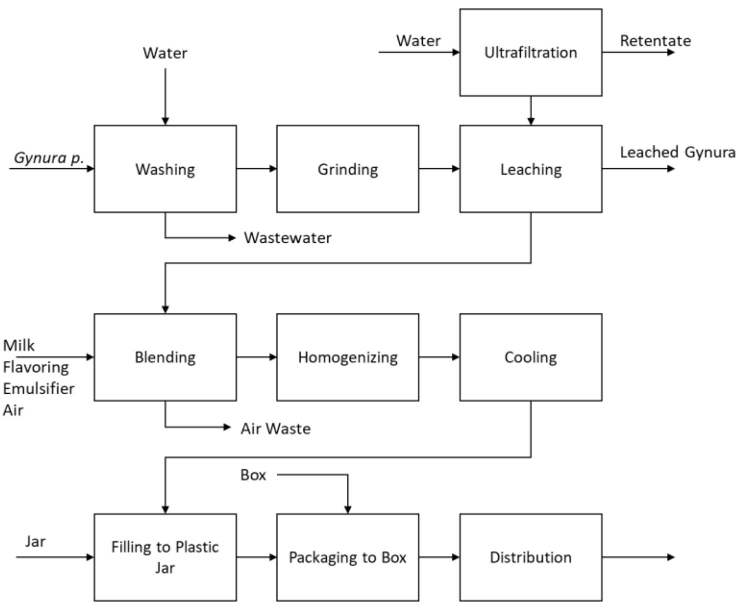

Figure 1 Block flow diagram of healthy herbal ice cream production

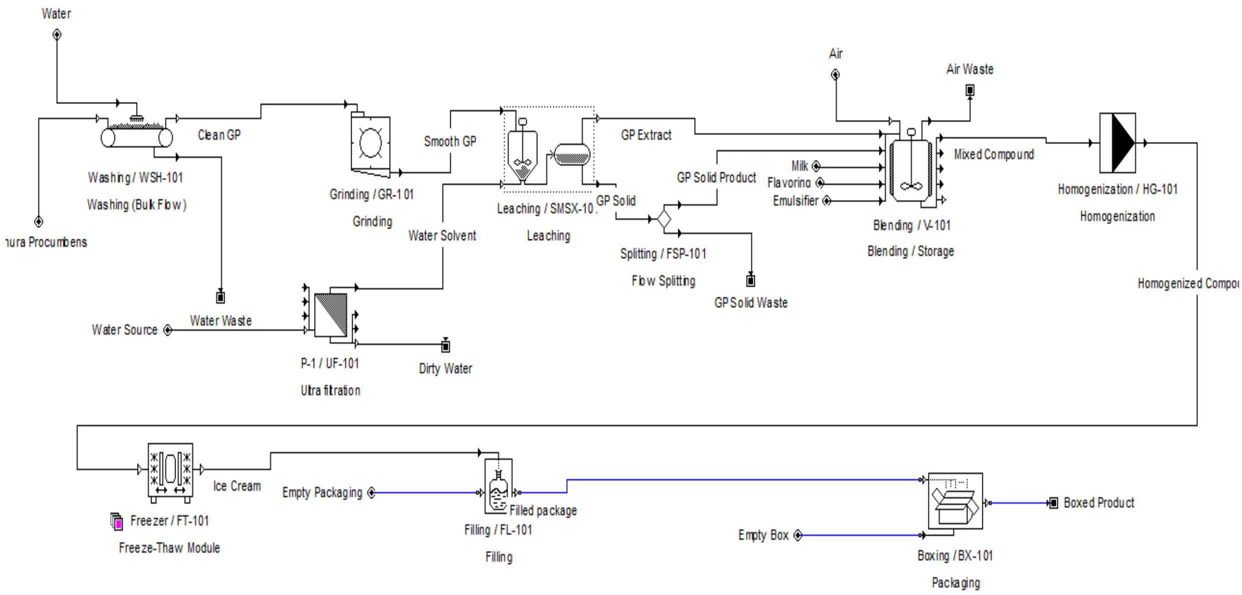

Figure 2 Process flow diagram of healthy herbal ice cream production

3. Results and Discussion

3.1. System Performance Benchmark

Based on a selection process carried out previously, we carried out the technical design of the equipment we used. In this research, we choose to design nine key pieces of equipment for the whole process: washer, grinder, ultrafiltration unit, solids mixer–settler extractor, blending tank, high-pressure homogenizer, freeze-thaw module, jar filler, and box packer. We calculate the specification using SuperPro Designer v9.0, as used in several preliminary designs of plant research (Surya et al., 2018; Harahap et al., 2019; Hidayat et al., 2019). The results are presented in Table 3.

Table 3 Technical specification of main production equipment

Equipment	Flow Rate (kg/batch)	Temperature (°C)	Power Consumption (kW/batch)	Length (mm)	Width (mm)	Height (mm)
Washer	100	28	0.633	4,034	1,689	1,718
Grinder	100	28	3.546	1,030	900	1,100
Ultrafiltration unit	810	28	8.625	1,050	800	1,320
Solids mixer-settler extractor	750	70	2.179	2,000	2,000	2,500
Blender	1,146	28	27.408	840	840	1,000
High-pressure homogenizer	1,146	28	16.316	1,000	750	1,100
Freezer	1,046	-4	75.9	500	750	600
Filler	1,197	-4	2.875	1,200	1,200	1,850
Packer	1,197	-4	1.38	1,550	750	1,050

The total factory area planned for this plant is approximately 5,100 m^2. The factory layout and its area distribution can be seen in Figures 3.

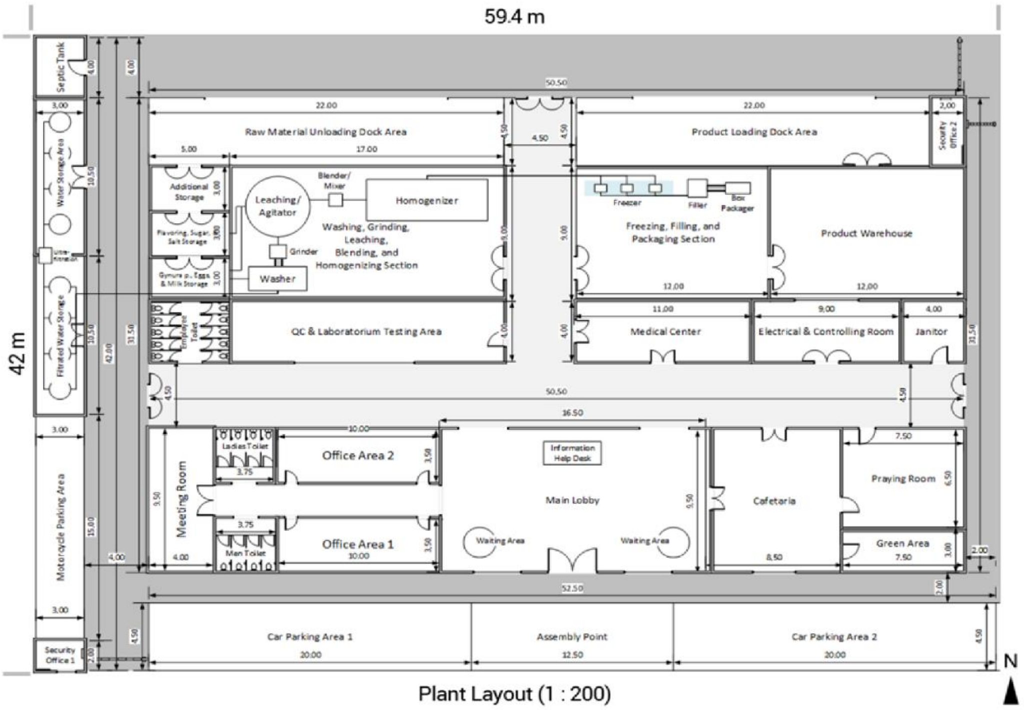

Figure 3 2D plant layout

For the utilities of the plant, we calculate electricity and water requirements. To calculate the electricity requirement of the plant, we sum up the electricity needs in each piece of equipment based on the simulation done in SuperPro and multiply it by 1.25 to allow for line losses and contingencies. The electric power required for this plant is 138.86 kW/batch for direct power and 54.2 kW/day for office and supporting facility electricity. With 11 batches per day, the total consumption cost per day in Rupiah is Rp 2,320,770.

The utilization of water in the plant is generally categorized into process water and domestic water. The process water usage is calculated from the amount of water needed in each process. The amount of water required for the process (including in steam form) is 13,323 kg/day. Meanwhile, the domestic usage of water is calculated from the usage of water for drinking water, toilets, laboratory, mosque, canteen, and gardening. We use USGS's data as the base of this calculation (USGS, 2016). As a result, we obtain a total usage of domestic water of 4000 kg/day.

The economic analysis of this plant is done by calculating capital expenditure (CAPEX) and operational expenditure (OPEX), which are evaluated using profitability analysis. CAPEX consists of total equipment cost, site development cost, building cost, offsite facilities cost, contingency cost, contractor fees, working capital, supporting facilities, bulk material cost, and additional cost. Total equipment cost was calculated using SuperPro Designer v9.0 with adjustment. The calculation of total CAPEX is shown in Table 4.

The OPEX consists of equity, raw material cost, utility cost, labor cost, maintenance cost, insurance cost, distribution cost, marketing cost, and depreciation. The calculation of OPEX can be seen in Tables 5 to 8. The calculation of income and cash flow is crucial for profitability analysis. Income is determined by the money obtained by selling the product with the deduction of tax and expenses. We predict sales of the product using an integrated supply chain model (Aritonang et al., 2020). Cash flow can be calculated by subtracting outgoings from the income. The cumulative cash flow can be seen in Figure 4.

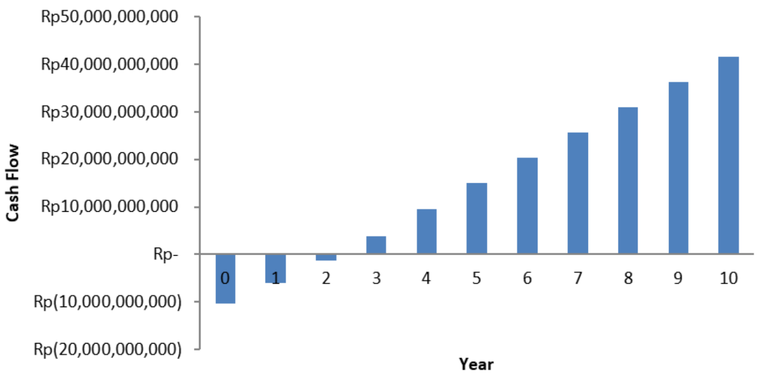

Figure 4 Cumulative cash flow calculation

Table 4 Total capital expenditure calculation

Component	Cost (Rp)
Equipment	1,546,087,035
Site Development	1,995,840,000
Building	4,830,750,000
Offsite Facilities	186,593,000
Working Capital	1,344,151,378
Contingency	401,739,151
Total Capital	10,305,160,564

Table 5 Total equity cost to bank (in *Rupiah*)

Year	Investment	Interest	Investment Payment	Payment	Annual Payment
0	7,213,612,394	0	0	0	0
1	7,213,612,395	721,361,239	721,361,239	1,442,722,479	1,118,109,921
2	6,492,251,155	649,225,116	721,361,239	1,370,586,355	1,118,109,921
3	5,770,889,916	577,088,992	721,361,239	1,298,450,231	1,118,109,921
4	5,049,528,676	504,952,868	721,361,239	1,226,314,107	1,118,109,921
5	4,328,167,437	432,816,744	721,361,239	1,154,177,983	1,118,109,921
6	3,606,806,197	360,680,620	721,361,239	1,082,041,859	1,118,109,921
7	2,885,444,958	288,544,496	721,361,239	1,009,905,735	1,118,109,921
8	2,164,083,718	216,408,372	721,361,239	937,769,611	1,118,109,921
9	1,442,722,479	144,272,248	721,361,239	865,633,487	1,118,109,921
10	721,361,239	72,136,124	721,361,239	793,497,363	1,118,109,921
	Total	3,967,486,817	7,213,612,395	11,181,099,212	11,181,099,212

Table 6 Total equity cost to investor (in *Rupiah*)

Year	Investment	Interest	Investment Payment	Payment	Annual Payment
0	3,091,548,169	0	0	0	0
1	3,091,548,169	340,070,299	309,154,817	649,225,116	496,193,481
2	2,782,393,352	306,063,269	309,154,817	615,218,086	496,193,481
3	2,473,238,535	272,056,239	309,154,817	581,211,056	496,193,481
4	2,164,083,718	238,049,209	309,154,817	547,204,026	496,193,481
5	1,854,928,902	204,042,179	309,154,817	513,196,996	496,193,481
6	1,545,774,085	170,035,149	309,154,817	479,189,966	496,193,481
7	1,236,619,268	136,028,119	309,154,817	445,182,936	496,193,481
8	927,464,451	102,021,090	309,154,817	411,175,907	496,193,481
9	618,309,634	68,014,060	309,154,817	377,168,877	496,193,481
10	309,154,817	34,007,030	309,154,817	343,161,847	496,193,481
	Total	1,870,386,642	3,091,548,169	4,961,934,812	4,961,934,812

Table 7 Total operational cost calculation without equity and depreciation

Component	Cost/Year (Rp)
Raw Material	55,752,213,000
Packaging	5,815,804,500
Electricity	937,904,503
Water	61,877,118
Direct Labor	1,294,920,000
Indirect Labor	2,671,148,000
Worker Insurance	49,660,680
Building and Plant Insurance	60,869,568
Distribution Cost	1,892,238,171
Marketing	256,016,000
Operating Supplies	90,644,400
Communication	163,200,000
Maintenance Cost	149,178,804
Total	69,195,674,744

Table 8 Total depreciation cost calculation

Year	Total Depreciation (in *Rupiah*)
1	318,951,022
2	288,857,504
3	262,923,034
4	241,530,853
5	221,156,570
6	204,354,320
7	189,744,980
8	177,006,174
9	165,863,723
10	156,084,468

Based on the calculated cash flow, we can analyze the plant's profitability by calculating minimum acceptable rate of return (MARR), internal rate of return (IRR), net present value (NPV), Payback Period, and rate of return (ROR). The results of the profitability analysis are shown in Table 12. The MARR shows the minimum value of ROR that is acceptable for starting a project, given its risk and opportunity cost (Park, 2007). Therefore, the IRR needs to surpass the MARR for the project to be categorized as a profitable project. Based on the calculation, the ROR and IRR obtained are 44.98% and 46%, respectively, much higher than the MARR, which has a value of 8.19%. The obtained payback period shows the number of years needed to return all the funds expended or to reach the break-even point (Farris et al., 2010). The obtained payback period of this plant is 2.24 years, which is considered average for an ice cream factory (Gunawan et al., 2020). The NPV determines the value of an investment over a period (Lin and Nagalingam, 2000). The NPV obtained is more than 21.8 billion rupiahs, which is more than twice the initial capital investment.

Compared to other studies, the results show that this plant is profitable and, in turn, can revitalize the local economy in the area where the plant is built. Gunawan et al. (2020) found that an ice cream factory built in East Java and using local ingredients resulted in only 17.28% ROR and had a more extended payback period of 4.65 years. On the other hand, a study by Almena et al. (2020) found that a distributed manufacturing ice cream factory can produce a $298.1k net profit per year. Meanwhile, our factory can produce a Rp 5,148,481,511.59, or about $349.7k, net profit per year. Therefore, we can conclude that this factory is feasible to build.

Table 9 Profitability analysis

Component	Value
MARR	8.19%
IRR	46%
NPV (in *Rupiah*)	21,819,500,900
Payback Period	2.24 years
ROR	44.98%

4. Conclusions

Healthy herbal ice cream made out of *Gynura procumbens* can be a solution to improve public health, provide a healthier snacking alternative, and improve the national economy. The profitability analysis shows that the plant has a relatively short payback period, favorable break-even point, and feasible other costs. The payback period of the plant is 2.24 years. ROR and IRR obtained from this plant are 44.98 and 46%, respectively. The NPV of this plant is Rp21,819,500,900.

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