

## Article

# Feasibility Assessment of an Encapsulated Longevity Spinach (*Gynura procumbens* L.) Extract Plant in Indonesia

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**Abstract:** The rise of globalization in recent years has favored the adoption of unhealthy lifestyles for many people, increasing their likelihood of diseases with silent symptoms. Longevity spinach (*Gynura procumbens* L.) is a medicinal plant that has strong phenolic compounds which could act as natural antioxidants to reduce the chance of contracting severe silent diseases. This study was focused on the feasibility of an affordable herbal supplement manufacturing plant using longevity spinach with a water solvent. Production simulation was carried out using SuperPro Designer v.9.0, and an estimated annual production of 26,082 bottles was analyzed based on several economic parameters. The production process for herbal supplements from longevity spinach extract consisted of leaf-washing, drying, and grinding, as well as active compound extraction from leaves with water, filtration, evaporation, freeze-drying, and encapsulation. For 30 encapsulated herbal supplements, prices started from USD 22.8/bottle, and the designed production plant was economically feasible (PBP = ±17 months, IRR = 91.65%, and NPV = USD 3,972,653.13). It can be concluded that encapsulated longevity spinach water extract could become an affordable herbal supplement, with feasible manufacturing for further investment activity.

**Keywords:** silent diseases; longevity spinach; herbal supplement; plant design; viability



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## 1. Introduction

Due to globalization, many people live unhealthy lifestyles and have high-stress jobs [1]. In this regard, more than 60% of the global population has a high possibility of suffering from silent diseases, ranging from minor illnesses such as the flu or cough to major complications such as diabetes mellitus or organ degeneration [2]. In the context of the pandemic, coronavirus disease 19 (COVID-19) is a further complication for the immune system, which may already be exhausted due to previous diseases [3,4]. To reduce the risk of silent disease, there is a trend among people to consume expensive functional and organic foods which are believed to provide greater nutrition [5]. However, most modern citizens maintain their health with chemical-based supplements because of the preference for products with a longer shelf life and fast effectiveness [6]. Therefore, there is an opportunity to capture this market through a stable organic-based supplement to promote health.

Longevity spinach (*Gynura procumbens* L.) is a medicinal plant, with strong phenolic compounds (such as p-hydroxycinnamic acid) that act as natural antioxidants [7]. Longevity spinach has been used from ancient times in Southeast Asia in fresh appetizers and for medicinal purposes [7,8]. The plantation of longevity spinach is also relatively simple because of the characteristics of spinach plants as vegetable plants. Although it has many functions, fresh longevity spinach still rare in the modern market because of the need for low-temperature storage conditions to prolong freshness and optimal efficacy [9]. Thus, longevity spinach must be mass-produced in a more stable form in order to penetrate any type of market. Several scientific approaches have been used to this end, including an

antioxidant activity test, an immunomodulator test with anti-inflammatory characteristics, lymphocyte cell activation, a T-cell regulator, and an antihyperglycemic activity test. All of these methods showed positive results in pre-clinical tests [10–13].

Indonesia, as one of the most biodiverse countries in the world, has versatile land with a tropical climate and fertile soil. Those conditions mean that Indonesia has high longevity spinach availability [14]. Indonesia also has the third-largest population in the world, with significant market value. With the addition of Indonesia's strategic location, a manufacturing plant study could show great feasibility and potential [15].

This study is focused on the feasibility of an affordable herbal supplement manufacturing plant using longevity spinach with a water solvent to provide a product with anti-hyperglycemic, antioxidant, and immunomodulatory properties in its phenolic compounds. This research focuses on process simulation to prevent unsuccessful supplement manufacturing, and produces credible chemical data and process conditions, as direct production trials would consume a good deal of resources [16]. In response to the production feasibility of longevity spinach leaf extract supplement, it is hoped that the pharmaceutical industries will be encouraged to develop longevity spinach extract products.

## 2. Materials and Methods

### 2.1. Feedstocks

Longevity spinach requires the same treatment as common spinach, for example, low intensity of sunlight and moderate temperature [17]. Tropical countries usually have a climatic advantage, as there are no summer and winter seasons. With the addition of fertile soils, longevity spinach can be easily cultivated. Longevity spinach cultivation is not centralized, but some private companies in West Java have built several farm fields for this plant and have stated in private interviews that those fields produce almost 1000 kg of longevity spinach per day. In this research, 48 kg of longevity spinach were used for batch simulation.

Longevity spinach consists mainly of lignocellulose and water, with other components such as cellulose, hemicellulose, and several phytochemicals which can be seen in Table 1 [18,19]. The chemical compound details used in production simulation can be found in the SuperPro Designer v.9.0 databank and/or several chemistry websites ([chemeo.com](http://chemeo.com); [chemspider.net](http://chemspider.net); [pubchem.ncbi.nlm.nih.gov](http://pubchem.ncbi.nlm.nih.gov), accessed on 14 April 2021). The extraction solvent was 60 L of drinking water, as it complied with the results of the longevity spinach extraction test in various solvents [20]. Water extraction provided greater yields because of the lower volatility of water compared to other solvents, and the extract quality was greater than that of organic solvent because of the high solubility of components in water [20].

**Table 1.** The biomass composition of longevity spinach leaf.

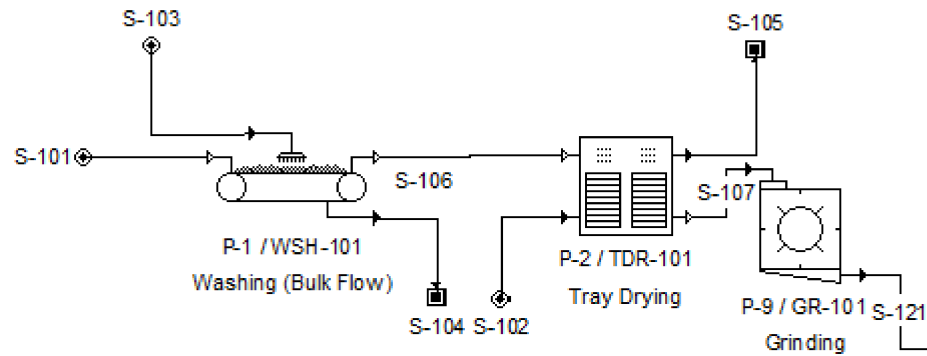
Component Name	Mass Composition (%)
Cellulose	9.490
Hemi-cellulose	8.450
Lignocellulose	39.810
p-Hydroxybenzoic acid	0.003
p-Hydroxycinnamic acid	0.027
Quercetin	0.002
Water	36.628

### 2.2. Process Design

#### 2.2.1. Pre-Treatment Process

The process started with the washing of fresh leaves in the washing machine. The leaf-washing process lasted for 40 min. The water consumption was calculated against the mass of leaves to be washed, with an amount of 1 L of water for every 1 kg of fresh leaves. After the washing process, the wet leaves were drained and dried using an open dryer for 60 min at 60 °C. The open dryer used in the drying process of longevity leaves pumped

hot air streams and removed the evaporated air molecules. The temperature that was used in this process was based on previous research which reported that process at 60 °C did not damage the chemical composition of the leaves [21]. The dried leaves (with 7% water content) were ground using a milling machine for 20 min. Using dry milling it could be assumed that the mass loss was not significant [22]. The pre-treatment process simulation diagram can be seen in Figure 1.

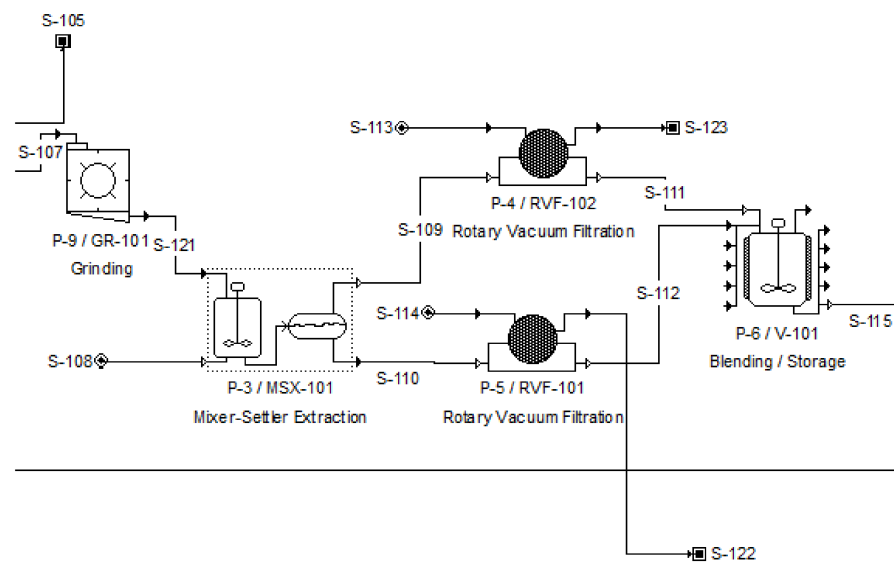


**Figure 1.** Pre-treatment processes for fresh longevity spinach.

### 2.2.2. Main Process

The extraction process was carried out using drinking water as the solvent, and this process was performed for 60 min with agitation under 50 °C. This temperature was used based on research that examined extraction in longevity leaves [23]. It was reported that extraction temperatures above 50 °C reduced the total yield of the phenolic components of the leaf extract. The mechanical stirring during the extraction process increases the mass transfer process of phytochemicals to the solvent and helps the diffusion of water into the cell walls of the leaf [24]. The fraction in the light phase or the total extraction yield was set to 0.845 based on the same extraction yield with water [20]. The extract components were assumed to be ash, p-hydroxybenzoic acid, p-hydroxycinnamic acid, and quercetin, for which all partition coefficients were based on their respective chemical properties.

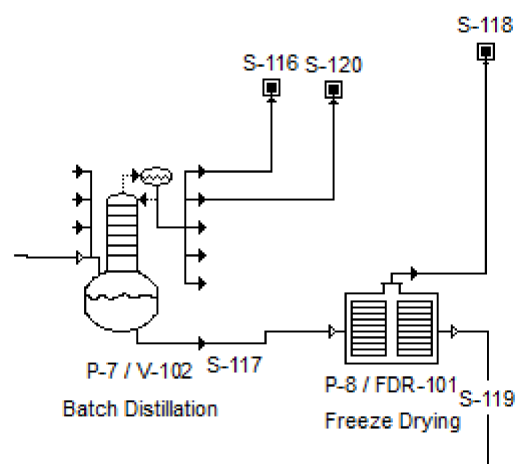
After extraction, filtration was performed with a rotary vacuum filtration process for 70 min. In the rotary vacuum filtration, a low-pressure column was used to pull the suspension and provide a relatively constant cake thickness. By applying the crossflow filtration system, the shear stress was less than that of dead-end flow filtration methods such as plate and frame filtration [25]. In this process, the cake was formed and maintained with a moisture content between 30% and 35%, with the simulation value set at 34% [26]. For the rejection coefficient of the filtration process, it was assumed that the rotary vacuum filtration worked with an efficiency of 90–95%, with simulation values set at 92.5% for ash content, 7.5% for dissolved phytochemicals, and 100% for cellulose, hemicellulose, and lignocellulose. The process lasted for 70 min, with preparation 1 h beforehand to reach low-pressure conditions. The water consumption for cake washing used a ratio of 0.3–0.33 kg of water to 1 kg of cake [27]. The main process simulation diagram can be seen in Figure 2.



**Figure 2.** The main process of longevity spinach extract production.

### 2.2.3. Final Drying Process

The filtrate was evaporated using a vacuum batch distillation which could evaporate water solvent from the leaf extract. Since the operation condition was of low pressure, the evaporation process was faster. The operating condition was obtained from interpolating data from the experimental results of water evaporation using an oven at 1.013 bars and the rotary vacuum evaporator at low pressure. The experiment data can be seen in Appendix A. Based on the calculation, evaporation occurred at 0.05 bars, with the temperature at 50 °C for 60 min. From this experiment, evaporation was able to reduce total volume up to 60% with regard to the initial volume. The concentrate was transferred for the freeze-drying process, where sublimation time was calculated using a simulation based on modeling data from a study on ice [28]. Based on the simulation, the processing leaf extract became solid extract after 390 min. Water content set at 1% was the maximum level allowed in the solid extract powder [29]. The final drying process simulation diagram can be seen in Figure 3.



**Figure 3.** The evaporation and freeze-drying process of longevity spinach extract.

### 2.2.4. Packaging Process

Before the packaging process, the solid extract was mixed with a preservative and drug filler in the capsulation machine. The materials used for this herb supplement were longevity leaves, Avicel ph-2, sodium benzoate, and hydroxy-methyl-propyl cellulose (HMPC) capsules. Avicel was used as the filler material in the longevity herb supplement.

The filler material in a pharmaceutical product has the function of equalizing the weight of each dose, and it has to be inert and nontoxic [30]. Furthermore, sodium benzoate has a function as a preservative to maintain quality and the ability of bio-actives to work in the body. Preservatives must not be toxic and have a maximum level determined by health institutions, in this case, the Indonesian Food and Drug Agency [31,32]. HMPC was used because it is produced from cellulose, which provides the best-quality preservation [33]. The capsule was packaged in a bottle containing 30 capsules for 1 month of consumption. For each 100 mL capsule bottle, a semi-permeable silica gel package was provided to maintain the water content in the bottle. The longevity spinach extract capsule components can be seen in Table 2.

**Table 2.** Longevity spinach extract capsule components.

Component Name	Mass Composition (mg)	Mass Percentage (%)
Avicel ph-101	194	32.61
Ash content	279.96	47.05
Hypromellose	100	16.8
p-Hydroxybenzoic acid	1.59	0.27
p-Hydroxycinnamic acid	14.34	2.41
Sodium benzoic acid	1	0.17
Quercetin	1.06	0.18
Water content	3.05	0.51
TOTAL	595	100

### 2.3. Economic Assessment

The payback period (PBP), internal rate of return (IRR), and net profit value (NPV) were used as economic parameters. Using cumulative cash flow calculations, economic parameters could be learnt and analyzed [34].

## 3. Results

### 3.1. Process Summary Result

The simulation process using SuperPro Designer v.9.0 was carried out successfully, and plant scheduling was also successfully arranged, with the plant operated 24 h for 330 days per year. Fifteen batches were produced per production day, where each batch produced 835 capsules in 780 min or 13 h in total. The process conditions and efficiencies can be seen in Table 3.

**Table 3.** Overall process condition summary.

Process Conditions	Washing	Drying	Grinding	Extraction	Filtration	Evaporation	Freeze-Drying
Equipment (units)	1 unit	2 units	2 units	2 units	2 units	2 units	5 units
Temperature (°C)	25	60	25	50	25	50	12
Pressure (atm)	1	1	1	1	1	0.05	0.05
Time (min)	20	30	10	60	60	60	390
Efficiency	-	86.4	-	88.97	49.99	61.15	99.3
Process Details	Using tap water	Only removes water content	Provides uniformity of size	Using drinking water and agitation	Using rotary vacuum filtration	Only removes water content	Only removes water content

Although some efficiencies were set, the simulation showed some marginal differences with respect to the empirical results. The extraction efficiency was calculated from p-

hydroxycinnamic acid content that had been extracted. The washing efficiency could not be calculated because the spinach was assumed to be clean, which resulted in a steady-state water mass flow. The grinding efficiency also was considered negligible because the empirical result from dry milling only lost 1%, so the dried leaf's mass flow was in a steady state [22].

### 3.2. Economic Summary Result

After the process simulation had been performed, the economic analysis was focused on determining the product price as the first step. The price was determined by trial-and-error to find the minimum price for selling. The minimum selling price was calculated when net present value (NPV) equaled 0. This calculation resulted in USD 0.38 as the minimum selling price. The expected profit margin was 100% and the final product cost with an adjustment was USD 0.76 per capsule. Hence, a bottle with 30 capsules would have a price of USD 22.8.

The production capacity was targeted at citizens of Jakarta in Indonesia. From the statistical data, more than 70% of the total population of 10.56 million citizens of Jakarta is of productive age [35]. However, only 250,000 individuals in this population were considered, resulting in 2,053,125 longevity spinach extract capsules to supply potential needs [36]. In this simulation, the product sold rate was set at 60%, with an overall production capacity of 10 years in the economic simulation. The economic analysis summary can be seen in Table 4. The capital expenditure consisted of direct and indirect fixed capital and working capital for the first 3 months of operational expenditure. The operating costs consisted of direct production costs, tax and insurance, health, safety, environment (HSE) costs, general affairs, and maintenance costs. The economic analysis also included depreciation costs to obtain gross income before tax. The depreciation was calculated with the single declining method and coefficient from the US Bureau of Economic Analysis [37].

**Table 4.** Economic summary of longevity spinach extract production.

Plant Summary	Value
Total capital expenditure (USD)	598,127.77
Operational cost (USD/year)	819,735.03
Revenues (USD/year)	1,928,217.68
Batch size (kg)	0.251
Batch quantities/day	15
Feedstock (kg/day)	720
Conversion (%)	0.52
Production rate (bottles/year)	26,082
Payback period (months)	17
IRR (after taxes) (%)	91.65
NPV (at 9.95% interest) (USD)	3,972,653.13

## 4. Discussion

Empirically, Indonesians use longevity spinach in their meals with quantities ranging from 5 to 8 leaves or a mass equivalent 10–16 g once per day. Considering the acceptable daily intake for longevity spinach extract and its water content, 300 mg of longevity spinach extract powder is equivalent to 16 g of fresh longevity spinach [38,39]. Therefore, the product was planned to be eaten once a day by individuals in Jakarta and its satellite cities.

Indonesia's capital city area was chosen because of its upper-middle class population, which is the biggest in Indonesia. Middle-to-upper socioeconomic groups were chosen because this group was considered to have a greater awareness of the importance of maintaining health to stay productive without any significant complications, especially during the pandemic [40]. In Jakarta, 250,000 citizens suffer from diabetic disease, of which only a quarter use herbal supplements in addition to conventional medicines [36,41].

Considering the growth of the herbal industry of 9% per year, the market share was fixed to 5625 diabetic citizens who would use the supplement [42].

Indonesia, as a tropical and biodiverse country, serves as a region of maximum potential in this feasibility study. With the advantage of being a maritime country, Indonesia has a strategic location for developing industry because products can be shipped in two opposite directions at the same time [43]. The Indonesian government has executed an integrated port network plan for international purposes, which has opened a bigger market [15]. Thus, Jakarta not only serves as the highest-value market but also is a major supply chain point for the global market.

The longevity spinach manufacturing plant would also need sustainable feedstock. The longevity spinach can be cultivated optimally in low terrain at a maximum of 1250 m above the sea surface. The cultivation process also requires moderate water intake, at about 1500 to 3000 mm rainfall intensity per year [44]. Most areas in Southeast Asia concur with those requirement conditions, while other sub-tropical areas such as South China and Eastern Australia must build closed farms with a constant water supply in their low terrains [13,45,46]. It is important to meet these requirements so the longevity spinach can achieve the greatest phytochemical composition [14]. It is calculated that 1000 m<sup>2</sup> of farm area will produce 450 kg of longevity spinach per year, so the extraction plant would need around 500 hectares of land for cultivation purposes [44].

Longevity spinach extract has high anti-hyperglycemic activity, with more than 40% effectiveness [38]. The previous research also used dried leaves as the feedstock and drinking water as the solvent. However, from research on the isolated compounds no more than 30% effectiveness was found for each phytochemical compound [47–49]. Thus, the higher effectiveness in longevity spinach extract as compared to the isolated compounds can be considered as due to the synergetic activity between those compounds. Moreover, the main phytochemical compound of the longevity leaf extract is p-hydroxycinnamic acid, which has immunomodulatory potential. Based on a study by Kilani-Jaziri et.al, p-hydroxycinnamic acid can induce splenocyte proliferation at 80%, with decreasing values at increasing concentrations [50].

As shown by the economic assessment, the operational expenditure was greater than the capital expenditure. This result was caused by the abundant amount of longevity spinach leaves required for production. However, in this simulation the longevity spinach was assumed to be bought from a third party such as an Indonesian national cultivation company. Hence, self-cultivation is recommended, with some part of the supply conditioned from a third party with a regulated schedule. The IRR value was also very high, but it still could be considered to be normal as most fast-moving consumer goods need a quick payback period to compensate for their short shelf life [51].

## 5. Conclusions

To build the extraction plant, an area of approximately 600 hectares consisting of cultivation and manufacturing areas is required. Although longevity spinach is an easily cultivated plant, the recommendation is to build extraction plants in tropical countries with low terrain in order to produce high-quality phytochemicals. The content of p-hydroxycinnamic acid in the product is very important to monitor because it represents the overall quality of encapsulated extract. Analyzing all results, it can be concluded that encapsulated longevity spinach water extract could become an affordable herbal supplement, and its manufacturing is feasible for further investment activity.

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## Appendix A

**Table A1.** Water evaporation trial in 1 h with a rotary vacuum evaporator.

Initial Volume (mL)	Final Volume (mL)	Evaporated Volume (mL)	Pressure (mbar)	Evaporation Efficiency (%)
200	182	18	1013	9
	140	60	110	30
	82	118	80	59
	80	120	60	60
	78	122	40	61

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