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DEVELOPMENT STRATEGY OF EARTHWORMS NANOPARTICLE PRODUCTS USING BALL MILL METHODS IN INDONESIA

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Abstract

In facing 4.0 industrial revolution, creation and optimization of different products are considered as a way for improving sales. Here, this study aimed to produce a new type of product based on earthworms. Specifically, this study evaluated the production of earthworm nanoparticles, including the strategies for providing business feasibility and improving nanoparticle products in Indonesia. This study used the ball-milling method and the internal external analysis matrix. The study found that in producing nanoparticle using ball mill tools, the capacity and quality of products depend on the size and volume of the nanoparticle production tool. In addition to the dimension of the tool, the physicochemical properties of raw materials must be considered. The present strategy is prospective for being applied in developing nanoparticle products in developing countries such as Indonesia.

Keywords: Ball mill, Earthworms, Nanomaterials, Nanoparticles, Strategy.

1. Introduction

Nanotechnology is expected to serve more effective and efficient technology for human life. Nanotechnology has a major impact in coping with the 4.0 industrial revolution, whereby the focus is directed toward the development of energy, health, and medical systems [1]. Nanoparticles can be defined as dispersions of particles or solid particles ranging from 10 to 100 nm in size [2]. Nanoparticles are considered as the advanced materials that can perform excellently in terms of the electrical, chemical characteristics, and so on compared to the traditional ones. Hence, they benefit in increasing the value of the product as well as the economic value. Accordingly, nanoparticles have been widely used in various industries such as in the cosmetics, health, medicine, electronics, food, and so on. The application of the use of nanoparticles can be seen in Table 1.

Table 1. Applications of nanoparticles in various fields [3].

No	Field	Application
1	Textile	Antinode material, wound cover material, electrical conductive material, natural/synthetic polymer fibers
2	Health and Biomedicine	Cancer therapy, biomarkers, drug delivery, imaging (MRI, IR), antibacterial, controlled drug release, UV protection
3	Industry	Catalyst chemicals, nano pigments, nano ink, technical refraction index
4	Food and Agriculture	Nutrasetikal, fungicide, food processing catalyst, food safety analyst sensor, food packaging
5	Electronic	Sensors with high sensitivity, computer quantum, chemical sensors, gas sensors, high-quality magnets, quantum lasers
6	Environment	Pollution observation sensor, environmental catalyst, pollutant catcher, handling waste water
7	Energy	Fuel cell catalyst, hydrogen production photocatalyst, fuel catalyst

Researches relating to nanoparticles have also been carried out in various ways: (i) Modification of microcapsules with gold nanoparticles, especially polyelectrolyte microcapsules that have attracted great interests in drug delivery applications [4], (ii) The strong optical absorption and scattering of precious metal nanoparticles as an effect of parameters called localized surface plasmon resonance. This allows the development of new biomedical applications. This application also shows that precious metal nanoparticles are a class of nanomaterials that are very promising for new biomedical applications [5], (iii) In the field of food and beverages, the use of nanoparticles with a layer of zinc oxide can protect the compounds of conjugated linoleic acid (CLA) and gamma linoleic acid (GLA). Thus, nanoencapsulation increases the time and temperature stability of CLA and GLA [6], (iv) In the other study, fruits that can also act as a good source for synthesizing silver nanoparticles [7], (v) Starch nanoparticles that are capable of functioning hosts of bioactive components because their very small size will expand the active surface so that the ability to bind the active ingredients is also greater. Suwarda and Maarif [3] explained the small size of the nanoparticles also causes the main components inside them to pass through the blood vessel membrane and deliver the drug to the target cell.

Abdassah [8] reported that nanoparticles are possibly made in several processing ways covering both top-down and bottom-up processing categories. And, high-energy ball-milling process is one of the most efficient and simple top-down processing methods for reducing the material size to micro, submicron, and further nanometer range. It takes a simple process, which balls are loaded into a rotated milling vial [9]. The ball-mill process has been conventionally known and used in the industry. In fact, several patents were issued, such as Patent Number: 5,383,615 [10], 5,205,499 [11], 4,125,057 [12], 5,287,714 [13], 6,126,097 [14], 6,334,583 B1 [15], 5,967,432 [16], 6,010,085 [17], 5,702,060 [18], 4,789,278 [19], 5,597,126 [20], 5,967,432 [21], etc.

The nanoparticle production using ball-milling method offers several advantages: (i) low installation costs, (ii) relatively low electrical energy required, (iii) very suitable for continuous production, and (iv) useful for all types of materials and high density [22]. Besides, other advantages include: (i) Drugs that are poorly soluble in both aqueous and organic media can be easily formulated into nanosuspensions, (ii) Ease of scale and batches of batch-to-batch variation, (iii) Narrow size distribution of the final nano-sized product, and (iv) Flexibility in handling the drug quantity, ranging from 1 to 400 mg/mL, enabling formulation of very dilute as well as highly concentrated nanosuspensions [23].

Abundant local natural resources in Indonesia can be an option as the raw materials of nanoparticles including earthworms (*Lumbricus rubellus*). The earthworms are not only functional as the good soil decoder as well as animal and fish feed. Nowadays, they even value more as a cure for various diseases and have an influence as antipyretic, antispasmodic, antidiuretic, antiasmatic, antihypertensive, hypo-allergenic, and anti-inflammatory. Based on studies by Sasmito [24], earthworms contain a fairly high protein (between 58 and 71% of dry weight), complete amino acid, fats, carbohydrates, calcium, phosphorus, sulfur, succinic acid, and hyaluronic acid.

Nonetheless, such opportunity is rarely seen, regardless of any resources that we can easily get. The raw materials are processed conventionally that have low economic value. Indonesia is by far depending on the supply of nanoparticles from abroad, while they are expensive. Such concerns left the gap to complete and trigger us for an opportunity in developing nanoparticle products. Thus, this study aims to produce worm nanoparticle products, determine its business feasibility and the strategies for developing nanoparticle products in Indonesia using ball-milling method as a new opportunity and challenge to face the industrial revolution 4.0.

2. Methods

The raw material for nanoparticles production used in this study is earthworms that have been dried. Detailed information for the earthworms used are in the following:

Phylum: Annelida
- Class: Oligocheta
  - Order: Ophistopora
    - Family: Lumbricidae
      - Genus: Lumbricus
        - Species: Lumbricus Rubellus

The present study used the ball-milling method in the process of making earthworm nanoparticle products. This method is effective for producing material from large sizes to micrometer sizes and even submicrometers and nanometers. Nandiyanto et al. [9] proposed that in principle, the ball mill is a process of destruction of material size that uses collision energy between crush balls and reactor walls that are rotated and moved in a certain way. The ball-milling process is shown in Fig. 1.

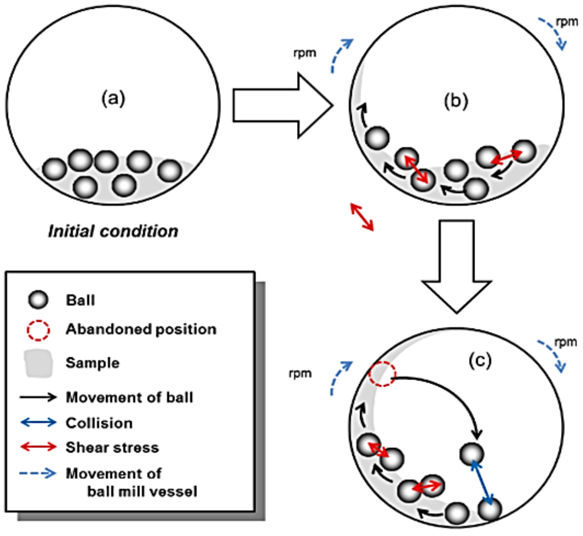

Fig. 1. Illustration of ball-milling process for making particles. Images are adopted from [9].

The results of the ball-milling process were then purified using filtering or gravity shakers. The products were then stored in a container. After obtaining product powder, powder weight calculation and particle size analysis were carried out using a microscope or particle sizer. Detailed information for the ball-milling process is explained in literature [9, 25].

Meanwhile, the strategy for developing earthworm nanoparticles products is by analyzing (1) the input stage, which includes analysis of internal and external factors, (2) the matching stage, by connecting internal and external factors into the Internal External (IE) Matrix, and (3) the decision stage, a stage that objectively shows, which strategy is chosen.

3. Results and Discussion

This ball-milling process was effective for destructing the material size. However, in general, this process is only able to do one variation in one process of shuffling. Although there was a strategy to make one process capable of producing several variations, it is necessary to have additional processes, such as additional vibration systems, right-left shuffling, planetary motion, additional milling / stirring in the reactor, and so on [9, 25]. As a result, when other factors are added, the design system is not that simple anymore. Accordingly, this will relate to several weaknesses, such as production and design costs, material types, energy used, maintenance costs, and so on. Due to the aforementioned weaknesses, most industries eventually use simple or conventional ball mills. Other than that, this type of ball mill is effective and at the same time easy to maintain.

This research is a preliminary study and the apparatus is still for laboratory experimentation. The ball-milling method in this study was initiated from the development of a mechanical process using a conventional ball-milling process [9, 25]. However, with the new ball mill tool system proposed, it is able to do multiple variations (2, 3, 4, 5, and so on) in one process. The variations in the conditions that can be adjusted include the rotation ratio (rpm), the ratio of the material being destructed and the crushing ball, the amount of material to be destructed, the type of material and the ball that is used, and the working volume of the ball mill.

Being able to regulate multi variations will be affecting the destruction process of the materials in the laboratory scale, in which, the processes tend to find the optimum process only. Therefore, the tool will improve work and time effectiveness as it enables to multivariate on one trial. In addition, this tool can also be used in the industrial scale. Selecting these types of material and dimensions for the design of this tool can be economically valuable and suitable for students training at the school to describe the mechanical process of ball mill in industry.

In producing nanoparticles using a ball-milling method, the design and effective capacity depends on the size and volume of the tool while for production time depends on the type of material that will be converted into nanoparticles. The trial of making earthworm nanoparticle products was carried out in production capacity with a 400-mL reactor volume of electricity requirements as can be seen in Table 2. The results showed that using a ball-mill (400 mL in volume) and a working volume of 30%, the tool could produce 15 grams of nanoparticles. However, when calculating maximum capacity (design) using a 100% of working volume, it will produce a capacity of 52 grams of nanoparticles.

Table 2. Comparison of production capacity and electricity requirements with 400 mL reactors. Data was adopted from reference [25].

Work volume (%)	Elec tricity (Watt)	Ball mass per reactor (g)	Total spherical mass (g)	Production capacity (mass of reactant) (g)	Electricity/ mass of material (W/g)	Electric Power/ material (Wh/g)
0	21	0	0	0	0	0
10	21	130	520	5.2	4.038462	2.019231
20	21	260	1040	10.4	2.019231	19615
25	21	325	1300	13	1.615385	0.807692
30	22	390	1560	15.6	1.410256	0.705128
40	22	520	2080	20.8	1.057692	0.528846
50	23	650	2600	26	0.884615	0.442308
60	23	780	3120	31.2	0.737179	0.36859
70	23	910	3640	36.4	0.631868	0.315934
75	24	975	3900	39	0.615385	0.307692
80	24	1040	4160	41.6	0.576923	0.288462
100	25	1300	5200	52	0.480769	0.240385

Meanwhile, in analysing the business feasibility of earthworm nanoparticle products, we can employ commonly used parameters such as Benefit Cost Ratio

(BCR), Internal Rate Return (IRR), Payback Period (PB), Net Present Value (NPV) and/or Cumulative Net Present Value (CNPV) [26]. Net present value (NPV) is the present discounted value of the current cost and discount value of income. If the net present value of a project is greater than zero, then the project is said to be even or "feasible" in the current discount value requirement. Whereas Cumulative Net Present Value (CNPV) is the net present value of a project in several years or in year X. In this study, the assumptions used include:

- The raw material is earthworms
- 5-year engine durability was used
- Price of wet earthworms is IDR 50,000/Kg
- Price of dry earthworms is IDR 500,000/kg
- Nano earthworms' selling price on the market in the form of capsules is IDR 8,333,333/kg
- Unprocessed selling price of nano earthworms is 50% of selling price of nano capsule
- Employee wages is IDR 3,100,000/person/month
- The price of electricity is IDR 1500/kwh [26].

The results of the CNPV (Cumulative Net Present Value) calculation and the time during total production is shown in Fig. 2 with several assumptions used: (1) Working capital is considered non-existent, (2) Income tax is 10%, (3) Interest rates used as much as 10%, indicating that the earthworm nanoparticle production business is feasible to do with an estimated return on capital in the fifth year.

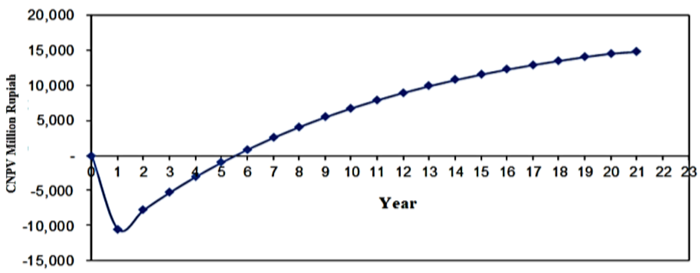

Fig. 2. The results of the CNPV calculation of time.

In meeting the needs and requirements of stakeholders in the creation and delivery of values, the products and services must be managed strategically based on the goals or mission of the institution [27]. According to Weelen et al. [28], the holistic approach utilizes various tools and concepts into the overall framework where the linkages can be understood when responding to internal and external challenges. In strategic management, a series of managerial decisions and actions determine the long-term performance of a company [29, 30]. This includes environmental scanning (external and internal), strategy formulation (strategic or long-term planning), strategy implementation, and evaluation and control. The study of strategic management emphasizes monitoring and evaluating external opportunities and threats based on the strengths and weaknesses of the company. Initially called as a business policy, strategic management combines topics such as strategic planning, environmental scanning, and industrial analysis.

The analysis of internal and external factors of earthworm nanoparticle products in Indonesia was done to determine the position of earthworm nanoparticle products in Indonesia, competitors, and internal conditions. Internal factor evaluation of earthworm nanoparticle products in Indonesia is shown in Table 3. Based on the IFE matrix, the total score is 3.10, which shows that nanoparticles in Indonesia are good for anticipating existing internal threats.

Table 3. IFE (Internal Factor Evaluation) matrix.

	Strength	Weight	Rating	Score
1.	**The raw material for worm nanoparticle products is available in Indonesia**	0.1	3	0.3
2.	**Alternative raw materials (other than worms) are available in Indonesia**	0.1	3	0.3
3.	**Nanoparticles are very feasible to produce**	0.15	4	0.6
4.	**Increase the use value and economic value of product**	0.15	4	0.6
5.	**Nanoparticles with ball mill production equipment are cheaper than imported products**	0.1	4	0.4
6.	**The quality of the nanoparticle products produced by ball mill is very good not inferior to imported products**	0.15	4	0.6
	Weakness	**Weight**	**Rating**	**Score**
1.	**Human resources have not been trained in producing nanoparticles**	0.1	1	0.1
2.	**The amount of worm raw material available is not stable because it is widely used conventionally**	0.05	2	0.1
3.	**Facilities and infrastructure for nanoparticle production are still minimal**	0.1	1	0.1
	TOTAL	**1**		**3.1**

The external factor evaluation is shown in Table 4. Based on the EFE matrix, the total score is 2.95, which shows that nanoparticles in Indonesia are good for anticipating existing external threats.

Table 4. EFE (External Factor Evaluation) matrix.

	Opportunities	Weight	Rating	Score
1.	**Indonesian economic growth**	0.15	4	0.6
2.	**Indonesian population**	0.1	3	0.3
3.	**Technological development**	0.1	3	0.3
4.	**Number of industries in Indonesia**	0.15	4	0.6
5.	**Only a few companies are able to produce and/or provide nanoparticle products**	0.15	4	0.6
6.	**Government regulations (Law no. 4 of 2009, require domestic processing)**	0.1	3	0.3
	Threat	**Weight**	**Rating**	**Score**
1.	**Overseas company producing nanoparticle products**	0.15	1	0.15
2.	**Technological development**	0.1	1	0.1
	TOTAL	**1**		**2.95**

The next step is to connect or match IFE and EFE into IE Matrix, in which, the results are shown in Fig. 3.

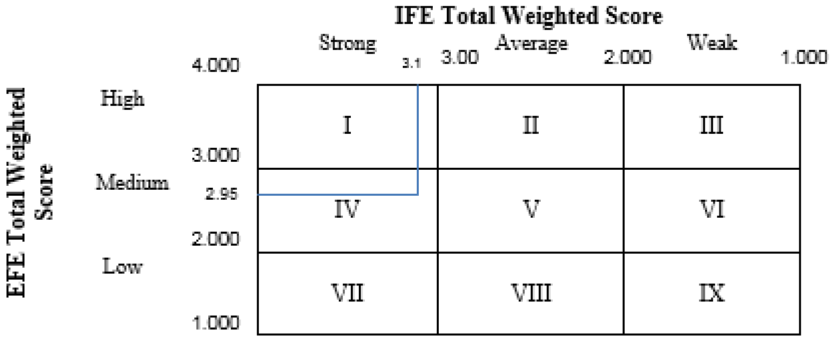

Fig. 3. IE (Internal-External) matrix.

The IE matrix shows that nanoparticles in Indonesia are in quadrant IV so that it is best developed with growth and build strategies. The strategies that can be applied are intensive strategies and integration strategies.

The intensive strategy can be done using (i) looking for a larger market share for Indonesian nanoparticle products in the market that already exists today through various marketing efforts such as promotions, competitive prices, quality products, and places or locations that are easily accessible both online and offline (market penetration), (ii) introducing Indonesian nanoparticle products in new geographical areas so that they are not only nationally well-known but also regionally and internationally reputable (market development), and (iii) always making improvements and development of Indonesian nanoparticle products with quality products and services better and offer new nanoparticle products that are not yet on the market (product development).

The integration strategy is by (i) striving for greater ownership or control of raw material suppliers using local native Indonesian raw materials (backward integration), (ii) controlling over the distributor or retailer of Indonesian nanoparticle products (not only relying on distributors already exists but also using other distribution channels such as direct sales, online sales, and so on (forward integration)), and (iii) controlling over competitors by cooperating with similar companies both at home and abroad (horizontal integration).

4. Conclusions

This study shows the technical perspective for earthworm nanoparticle production through the ball-milling method and its business feasibility. Technical analysis in this study is still on a laboratory scale and it is possible to be carried out on an industrial scale. Meanwhile, the results of business feasibility show that earthworm nanoparticle production is feasible and/or developed by applying intensive and integration strategies.

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