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# Redesign of Green Coffee Processing Machine using Value Engineering with Ergonomic approach

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**Abstract**

Green Coffee (Coffea Canephore Var. Robusta) is coffee made from unroasted coffee beans (Coffea spa). Green coffee extract contains higher levels of antioxidants compared to roasted coffee. The current issue is the variability in the quality of green coffee produced, mainly due to manual processing methods. To enhance the economic value of coffee, its quality must be maintained, especially during the production process. Based on this issue, this research is conducted to design a coffee processing machine to improve the quality of the produced coffee. Although coffee machines already exist, their design process often overlooks user comfort. Hence, this research employs anthropometric approaches to produce ergonomic product designs. Additionally, utility engineering is utilized to identify costs. This research results in innovative product designs of green coffee processing machine wich considering ergonomic aspects and value engineering approach.

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## A. Introduction

Green coffee is a variant of coffee that has not undergone the roasting process, resulting in higher chlorogenic acid content compared to black coffee or roasted coffee [1][2]. This research aims to test the antihyperglycemic activity of ethanol extract of Arabica green coffee (Coffea arabica L.) on alloxan-induced diabetic mice (Mus musculus), assuming that green coffee can lower blood glucose levels [3][4]. Additionally, the use of green coffee extract containing chlorogenic acid can help in weight reduction for obese patients [5]. Chlorogenic acid in green coffee works to reduce weight by influencing adiponectin and leptin regulation, thereby decreasing glucose absoIDRtion and acting as an antioxidant [6][7].

Based on observations, although green coffee machine products have been developed previously, they have not adequately considered the safety and comfort of the users. These machines have the potential to cause spinal injuries because operators often have to squat while operating them. To address this issue in this research, a redesign of the green coffee processing machine is conducted using ergonomic approaches, along with value engineering analysis.

The ergonomic approach in design has indeed been proven to reduce or minimize the risk of injuries during the operation process of a machine [8][9]. This approach has been widely implemented before, including research conducted by [10], [11], and [12], which consider ergonomic factors in workplace or workstation design. In addition to workplace design, the ergonomic approach can also be applied to product design, as demonstrated in research conducted by [13] and [14].

## B. Research Method

The Ergonomic approach aims to ensure that tasks and job designs align with workers' abilities and capacities, with the goal of achieving efficiency and well-being at work [15][16]. Ergonomics is crucial in every field of work, where ergonomic principles are tailored to the work environment to enhance work efficiency and make workers feel comfortable [17]. Factors of particular concern in ergonomics in the workplace include how people work, body posture and movements, equipment used, and their impact on workers' health and comfort [18][19]. Workplace accidents often occur in industries due to employees' lack of attention to work rules and management's insufficient focus on safety and ergonomics [20].

In the Ergonomic approach, anthropometric data and percentile values are used in the design process [21]. Anthropometry is a collection of quantitative data related to physical characteristics, measurements, and human body strength used to solve product design problems and work system interactions that require human-computer interaction [22][23].

In this study, a value engineering analysis is also conducted on the designed product. The Value Engineering process consists of 5 stages [24]: (1) Information Stage: The initial stage involves formulating problems and identifying the highest costs that require value engineering. (2) Speculation Stage: New ideas and alternatives are considered at this stage to fulfill the same function while reducing costs. Alternatives may include component reduction, simplification, or modification. (3) Analysis Stage: The generated ideas are analyzed and criticized, considering the interests of production processes, marketing, and product functions [25]. At this stage, ideas are refined and broken down into concrete solutions. (4)

Development Stage: Selected alternatives from the analysis stage are further developed through a comprehensive development program. If necessary, specialist experts may be involved for more detailed and specific assessments. (5) Presentation and Follow-Up Stage: This stage involves presenting the conclusions of the value engineering study to stakeholders. The report is presented clearly, covering facts, comparative information between technical aspects and initial design costs, and arguments supporting the value engineering study findings.

## C. Result and Discussion

### *1. Machine Redesign using Ergonomic Approach*

Based on anthropometric data, 30 respondents were selected as samples. The body dimensions measured in this table are: elbow height (EH), Hand Reach (HR), palm width (PW), and grip diameter (GD):

**Table 1.** Results of Body Dimension Measurements

| Respondents | Body dimension(cm) | | | |
|---|---|---|---|---|
| | EH | HR | PW | GD |
| 1 | 886 | 610 | 82 | 43 |
| 2 | 887 | 607 | 84 | 46 |
| 3 | 894 | 606 | 80 | 36 |
| 4 | 893 | 613 | 81 | 47 |
| 5 | 893 | 612 | 81 | 44 |
| 6 | 889 | 614 | 82 | 49 |
| 7 | 893 | 616 | 85 | 48 |
| 8 | 891 | 610 | 78 | 41 |
| 9 | 891 | 613 | 81 | 42 |
| 10 | 891 | 608 | 78 | 36 |
| 11 | 889 | 605 | 78 | 38 |
| 12 | 893 | 603 | 80 | 36 |
| 13 | 889 | 603 | 78 | 36 |
| 14 | 886 | 604 | 80 | 40 |
| 15 | 893 | 615 | 81 | 40 |
| 16 | 889 | 607 | 85 | 49 |
| 17 | 891 | 615 | 86 | 48 |
| 18 | 887 | 612 | 84 | 44 |
| 19 | 887 | 607 | 79 | 41 |
| 20 | 889 | 609 | 81 | 43 |
| 21 | 892 | 612 | 84 | 46 |
| 22 | 891 | 611 | 83 | 45 |
| 23 | 892 | 612 | 84 | 46 |
| 24 | 889 | 609 | 81 | 43 |
| 25 | 887 | 607 | 79 | 41 |
| 26 | 895 | 615 | 85 | 49 |
| 27 | 891 | 611 | 83 | 45 |
| 28 | 888 | 608 | 80 | 42 |

| Respondents | Body dimension(cm) | | | |
|---|---|---|---|---|
| | EH | HR | PW | GD |
| 29 | 894 | 614 | 86 | 48 |
| 30 | 892 | 612 | 84 | 46 |
| ∑X | 26708.36 | 18300 | 2453 | 1298 |

Here are the control chart results for each body dimension variable (As shown in Figures 1-5).

A. Control chart for elbow height dimension (EH)

The Figure 1 below shows that the measurements of elbow height dimension (EH) are within control limits, and no additional sampling is required.

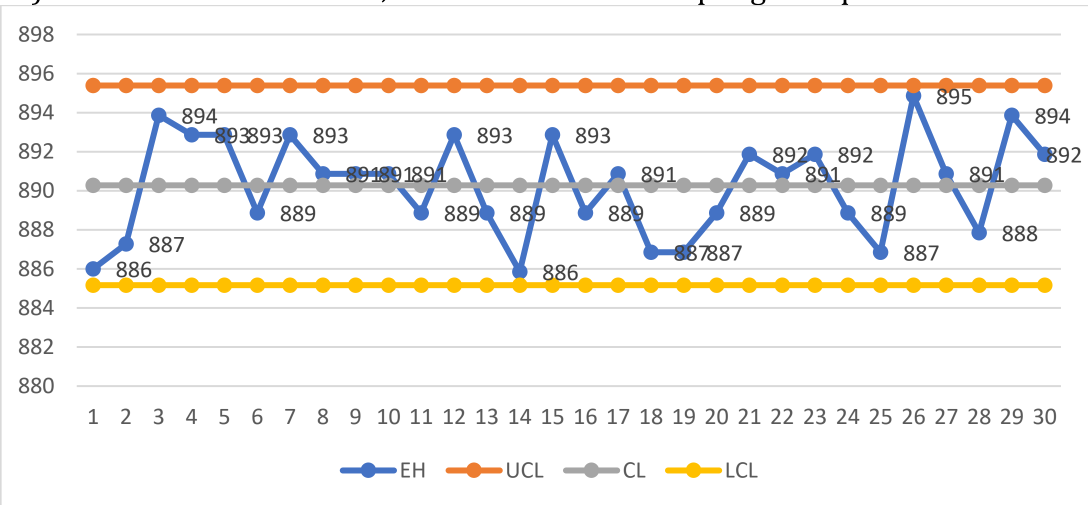


**Figure 1.** Control chart for elbow height dimension

B. Control chart for Forward Reach Hand Dimension (HR)

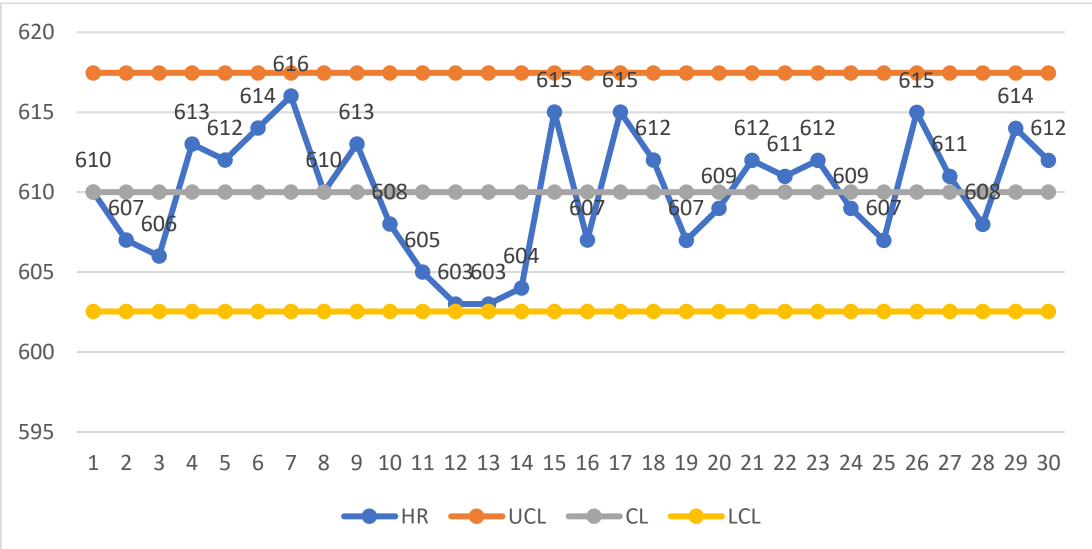


**Figure 2.** Control chart for Forward Reach Hand Dimension

As seen from Figure 2, the measurements of Forward Reach Hand Dimension (HR) are consistent, and no additional sampling is required.

C. Control chart for Thumb Palm Width Dimension (PW)

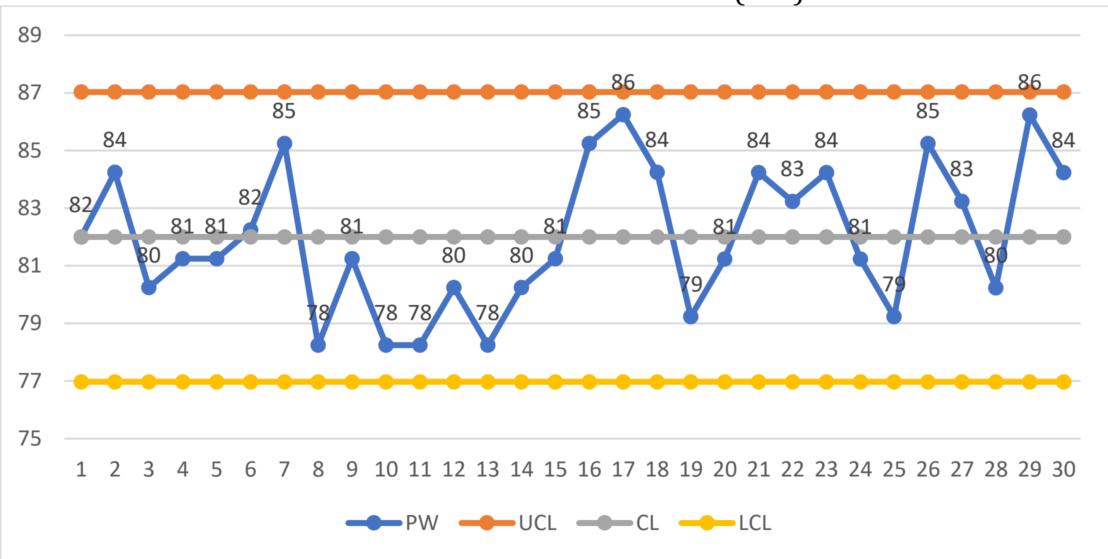


**Figure 3.** Control chart for Thumb Palm Width Dimension

From Figure 3 above, it is evident that the complete data for the width of the palm from the thumb (PW) dimension is consistent, and no additional sampling is required.

*D.* Control chart for Grip Diameter (GD)

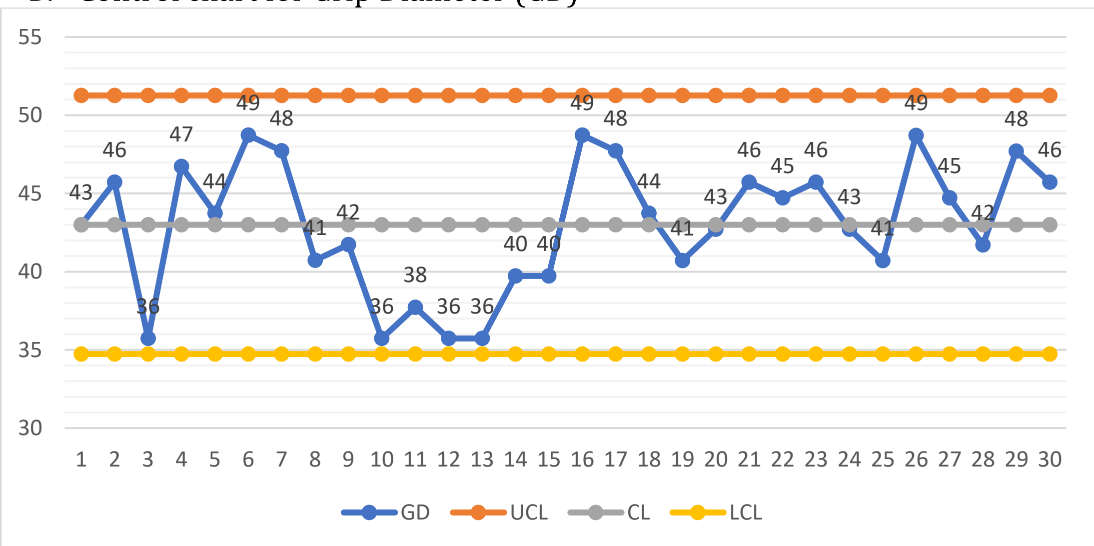


**Figure 4.** Control chart for Grip Dimension

As seen from Figure 4 above, the Grip Diameter (GD) data is consistent, and no additional sampling is required. Based on the control charts, the results of the data uniformity test for all body dimension measurements of the respondents can be seen in the following Table 2:

**Table 2.** Data Uniformity Result

| Body Dimension | BKA (cm) | BKB (cm) | ∑X (cm) | X̄ (cm) | Min (cm) | Max (cm) | Exp. |
|---|---|---|---|---|---|---|---|
| EH | 895.389 | 885.168 | 26708.356 | 890.279 | 886 | 895 | Uniform |
| HR | 617.463 | 602.537 | 18300.000 | 610.000 | 603 | 616 | Uniform |
| PW | 87.027 | 76.973 | 2460.000 | 82.000 | 78 | 86 | Uniform |
| GD | 51.266 | 34.734 | 1290.000 | 43.000 | 36 | 49 | Uniform |

After all the obtained data has been uniform, the next step is to perform a data adequacy test. The data adequacy test is useful to demonstrate that the collected sample data represents the general population. In the calculation, equation 1 can be used. With a 95% confidence level, the data adequacy test is conducted as follows:

$$N' = [\frac{\frac{K}{S}\sqrt{N(\sum x_i^2)-(\sum x_i)^2}}{\sum X}]^2 \quad (1)$$

*A.* Adequacy test for elbow height dimension (EH)

Based on the measurement data in Table 1, the calculation for the required sample size with 95% confidence level and 5% of precision level (s) for the elbow height dimension (EH) is as follows:

∑x = 26708
$\sum x^2$ = 23778065
N = 30
K = for 95% concidence interval, the value of K is 2
S = 5%

$$N' = \left[\frac{2/0{,}0\,5\sqrt{30\ (23778065)-(26708)^2}}{26708}\right]^2 = 0.233 \approx 1$$

Because N' ≤ N wich is 30, therefore, it can be concluded that the sample size taken is sufficient to represent the population.

B. Adequacy test for Forward Reach Hand Dimension (HR)

Based on the measurement data in Table 1, the calculation for the required sample size with 95% convidence level and 5% of precision level (s) for the Reach Hand Dimension (HR) is as follows:

∑x = 18300
$\sum x^2$ = 11163404
N = 30
K = for 95% concidence interval, the value of K is 2
S = 5%

$$N' = \left[\frac{2/0{,}0\,5\sqrt{30\ (11163404)-(18300)^2}}{18300}\right]^2 = 0.338 \approx 1$$

Because N' ≤ N wich is 30, therefore, it can be concluded that the sample size taken is sufficient to represent the population.

C. Adequacy test for Thumb Palm Width Dimension (PW)

Based on the measurement data in Table 1, the calculation for the required sample size with 95% convidence level and 5% of precision level (s) for the Thumb Palm Width Dimension (PW) is as follows:

∑x = 2453
∑x² = 200757
N = 30
K = for 95% concidence interval, the value of K is 2
S = 5%

$N' = \left[\frac{2/0,0\,5\sqrt{30\,(200757)-(2460)^2}}{2460}\right]^2 = 0.758 \approx 1$

Because N' ≤ N wich is 30, therefore, it can be concluded that the sample size taken is sufficient to represent the population.

D. Adequacy test for Grip Diameter (GD)

Based on the measurement data in Table 1, the calculation for the required sample size with 95% convidence level and 5% of precision level (s) for the Grip Diameter (GD) is as follows:

∑x = 1298
∑x² = 56656
N = 30
K = for 95% concidence interval, the value of K is 2
S = 5%

$$N' = \left[\frac{\frac{2}{0,0}5\sqrt{30\,(56656)-(1298)^2}}{1298}\right]^2 = 3,18 \approx 3$$

Because N' ≤ N wich is 30, therefore, it can be concluded that the sample size taken is sufficient to represent the population. Since the data adequacy test results indicate that the data collected is sufficient, the calculation of the machine dimensions is then conducted. In the calculation of machine dimension, equation 2 can be used. The calculation of each machine dimension can be seen as follows:

$$Machine\ Dimension\ P5\% = \overline{x} - 1{,}645\sigma_x \quad (2)$$

A. Machine height

To determine the machine height data, elbow height data (EH) is needed as follow:

$TSB\ P5\% = \overline{x} - 1{,}645\sigma_x = 886.075\ mm$

So, the height of the Coffee Machine is 886.075 mm.

*B.* The Forward Reach Hand Dimension (HR)

To determine the width and length of the reach to the Coffee Machine, Forward Reach Hand Dimension (HR) data is needed as follow:

TLB P5 % == $\overline{x} - 1{,}645\sigma_x$ = 603.861 mm

So, the width and length of the reach to the Coffee Machine is 603,861 mm.

C. The Thumb Palm Width Dimension (PW)

To determine the size of the coffee machine handle, Thumb palm width dimension data is needed as follow:

$$TLB\ P5\% = \overline{X} - 1{,}645\ \sigma x = 77.866\ mm$$

So, the size of the coffee machine handle is 77,866 mm.

D. The Hand Grip Dimension (GD)

To determine the length of the coffee machine, Hand grip dimension data is needed as follow:

$$PRT\ P5\% = \overline{X} - 1{,}645\ \sigma\, x = 36.201\ mm$$

So, the size of the length of the coffee machine is 36,201 mm.

***2. Development of Coffee Machine with Value Engineering Approach***

A. Initial Condition

This stage describes the current situation and the conditions that have led to the emergence of problems. It also includes the initial design of this product.

**Figure 5.** Current condition

As seen in Figure 5, the current condition of the machine does not yet consider ergonomic aspects in its design.

B. Functional Analysis

Functional analysis is conducted as a functional approach to the current condition of the machine before redesign. Besides being non-ergonomic, the machine only functions to process raw coffee. The aim of this research is to create a machine design that supports coffee making and feels more comfortable for its users, enabling respondents to use the tool effectively and enhance respondents' enthusiasm and productivity.

C. Creative Stage

In this stage, alternative improvements will be provided as steps towards the development of a raw coffee processing machine with the proposed design. Then, an analysis of its strengths, weaknesses, and feasibility will be conducted.

**Figure 6.** The Proposed Product

In this phase, product development is carried out by adding the latest innovations to the developed product using a Value Engineering approach. The innovation added to the green coffee machine product depth is the inclusion of a thermometer to control the temperature of the coffee being processed to achieve optimal coffee results with the best quality. Additionally, a timer is added to the new coffee bean processing machine to prevent overcooking. A blower is also added to the new machine to expedite the cooling process of matured coffee beans as seen in Figure 6.

D. Analysis stages

In this stage, the emerging alternatives are evaluated based on the criteria established in the product feasibility analysis. Analysis is conducted for the users of this machine by the value engineering team through post-development product studies.

E. Benefit and Loss Analysis

The benefit and loss analysis is the final stage of this value design. In this stage, researchers conduct a price-based analysis with machines that have a similar concept to the developed machine. This approach involves comparing the prices of similar machines available in the market with the developed machine. This stage is crucial to ensure that the benefits and price of the machine remain competitive in the market. Table 3 below are machines with similar specifications available in the market.

**Table 3.** Specifications of the new product

| Product | : Coffee Processing Machine |
|---|---|
| Price | : IDR. 3.500.000 |
| Main constituent material | : Iron frame and iron plate |
| Frame material | : Iron |
| Container bin material | : Wood |
| Features | : Timer, Blower, Container bin, thermometer |

Meanwhile, the price of similar products in the market is still in the range of 6.6 million, which is almost twice the price of the proposed product.

F. Feedback on innovative product

Feedback is necessary to determine whether the designed product is safe and comfortable (ergonomic) by distributing questionnaires to 30 respondents in the Surabaya area and its surroundings, as summarized in Table 4 below.

**Table 4.** Feedback on innovative product

| No | Questions | Strongly Disagree | Disagree | Neutral | Agree | Strongly agree | Total |
|---|---|---|---|---|---|---|---|
| 1 | The design of the innovative product development meets the needs of users. | 0 | 0 | 0 | 3 | 27 | 30 |
| 2 | The use of the innovative product is effective, comfortable, safe, healthy, and efficient. | 0 | 0 | 0 | 0 | 30 | 30 |
| 3 | The height dimension of the machine is ergonomic. | 0 | 0 | 0 | 0 | 30 | 30 |

| No | Questions | Strongly Disagree | Disagree | Neutral | Agree | Strongly agree | Total |
|---|---|---|---|---|---|---|---|
| 4 | The width dimension of the machine is ergonomic. | 0 | 0 | 0 | 0 | 30 | 30 |
| 5 | The length dimension of the machine is ergonomic. | 0 | 0 | 0 | 0 | 30 | 30 |
| 6 | The price of the machine is economical compared to machines available in the market. | 0 | 0 | 0 | 0 | 30 | 30 |

Based on Table 4 above, 27 people agree with statement 1 and 30 people strongly agree with statement 2, indicating that the Design for Innovation product development is in line with user needs and the use of innovative products is effective, comfortable, safe, and healthy. Additionally, 30 people also agree with statement 3, indicating that the size of the machine is ergonomic. Statement 5 is also deemed appropriate, according to the source, as 30 people agree with it. Statement 6 is also strongly supported, with 30 people strongly agreeing. In conclusion, this product design is deemed suitable and ergonomic in design, function, and size based on the questionnaire results distributed.

## D. Conclusion

From the research results, it can be concluded that the design of innovative product development has met user needs. Additionally, the machine has met ergonomic standards for height and length dimensions. In terms of price, this innovative machine is also more economical with production cost was only IDR. 3,500,000.

These research results have produced an ergonomic and effective design and innovation product. The questionnaires conducted indicate that the use of this innovative product has provided the comfort, safety, health, efficiency, and ergonomics desired by users. This is based on the ergonomic approach applied with specific specifications: Elbow Height Data (EHD) to determine the height of the Coffee Machine is 886.075 mm (using 5th Percentile), Forward Reach Hand Distance (FRHD) to determine the width and length reach of the Coffee Machine is 603.861 mm (using 5th Percentile), Thumb Palm Width (TPW) to determine the handle size of the Coffee Machine is 77.866 mm (using 5th Percentile), and Grip Diameter (GD) Data to determine the handle size of the Coffee Machine is 36.201 mm (using 5th Percentile).

The development of the coffee machine with a value engineering approach begins with the information stage, which includes initial concepts and searching for information related to the state of the machine before development. Then, functional analysis is carried out by adding innovations such as a thermometer, timer, blower, and coffee output location to improve the quality and efficiency of coffee processing. The creative stage is conducted with an organized and innovative value engineering approach. In the analysis stage, evaluations are made of the emerging alternatives based on established criteria through feasibility assessments and evaluations. The analysis of benefits and drawbacks is conducted to ensure that the alternatives created by the researchers are truly beneficial and that the price of the machine produced is more economical than those available in the market.

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