DESIGN OF MATERIAL HANDLING EQUIPMENT IN ROLLING TO ENZYMATIC OXIDATION PROCESS USING RATIONAL PRODUCT DESIGN METHOD AT PT PERKEBUNAN NUSANTARA VIII RANCABALI

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Abstract

PT Perkebunan Nusantara VIII Rancabali is one of the orthodox black tea processing company in Indonesia which produce twelve kinds of black tea to be sold domestically and exported to several countries. The quality of tea produced by this company will certainly affect the price of tea to be sold. In the orthodox black tea processing, enzymatic oxidation process is a process that most determines the quality of the tea leaves that will be generated later, so it takes a strict monitoring of the technical provisions of the process. In this process found irregularities implementation of the technical provisions of enzymatic oxidation process on rolling and enzymatic oxidation room which caused by the specification of material handling equipment.

By using rational product design process is expected to improve existing material handling system be continue and in accordance with the technical provisions of the process, so as to improve the quality of tea leaves to be produced.

Formulation of recommendations compiled based on data processing, data analysis, and discussion with the company that aims to enhance the enzymatic oxidation process. The recommendation given is the specification design of industrial truck especially four-wheel hand truck which is customized with the provisions of the enzymatic oxidation process.

Keywords: Four-wheel hand truck, material handling equipment, Nigel Cross, orthodox black tea, rational product design method.

1. Introduction

Tea is one of Indonesia's export commodities are quite important as a foreign exchange earner of country after oil and gas. Indonesian tea quality is steadily declining, the decline in the quality of reciprocally also resulted in a decrease in selling prices. Out of the seven types of export products of tea in Figure 1, there are two types of tea most of the volume of exports is Other Black Tea (Fermented) Dust whose volume in 2009 reached 66.075 tons, or approximately 68.68% of the total volume of exports of tea and then Other Black Tea (Fermented) Leaf with an export volume of 13,677 tons or about 14:22% [1].

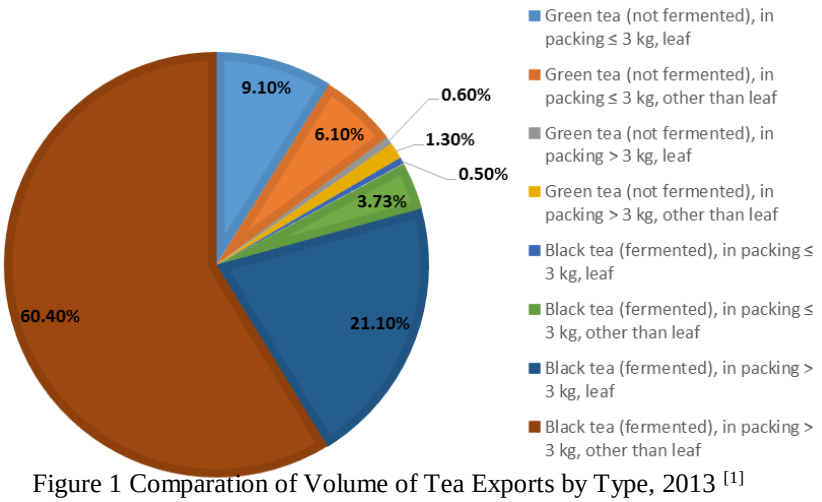

Figure 1 Comparation of Volume of Tea Exports by Type, 2013 [1]

PT Perkebunan Nusantara VIII Rancabali is one of the orthodox black tea processing company in Indonesia which is largely the result exported to Indonesia. In the orthodox black tea processing, enzymatic oxidation process is the most important process of all other processes because this process occurs between an enzyme reactions with air to form the characteristic black tea is the taste, color and dense black appearance [2]. To improve the quality of tea leaves to be produced, the oxidation process must be conducted in accordance with the technical provisions that have been determined. Based on Table 1, it can be seen that the oxidation process of tea leaves excessive from the time the process is supposed to be.

Table 1 Enzymatic oxidation processing time

No	Processing Time	No	Processing Time	No	Processing Time
1	124.13	11	125.30	21	126.05
2	126.17	12	126.28	22	125.70
3	125.57	13	125.67	23	124.55
4	126.00	14	124.83	24	124.72
5	126.23	15	124.03	25	125.52
6	126.07	16	124.75	26	124.22
7	125.28	17	125.90	27	124.65
8	126.17	18	125.95	28	124.55
9	126.12	19	125.75	29	125.93
10	124.93	20	125.95	30	125.60

Besides excessive oxidation process time, there are some deviations from the technical provisions which occurs in the rolling and enzymatic oxidation room, as described below

1. In a time of movement, there were 7 trays where at one time there are only five trays produced by the sieve machine. By doing so will cause the powder is transported in existing material handling equipment is not uniform and will cause over or under fermenting in enzymatic oxidation process.
2. The height of tea leaves pile on the tray excess of 10 cm (±12 cm) because of the absence of the re-measurement or height indicator powder to make tea leaves pile height is appropriate.
3. Tray which is used has a height of 4 cm, while the optimal pile height in the oxidation process that is 10 cm, so it causes the tea leaves pile on unequal and will lead the process of enzymatic oxidation is not evenly distributed throughout the powdered tea.

To overcome these problems, it needs a continue material handling system and support technical provisions. This study focused on designing material handling equipment in the rolling process to enzymatic oxidation to improve the working conditions of the technical provisions of enzymatic oxidation process. Expected with the improvement of material handling equipment is able to improve and maintain consistency in the quality of tea produced and increase the selling price of tea for export.

2. Rational Product Design

The conceptual model is concept study guides for researchers in formulating and solving the problem making proposals or solutions to issues discussed. In Figure 2 shows the method of describing the concept of research to be conducted. This research perform designing of material handling equipment that helps the process of handling the material (tea leaves) from the rolling to enzymatic oxidation process. This research requires a design of the material handling equipment by observing the need variables to succeed the result of design. The needed variables identified and collected by direct observation and interviews to determine the new attributes that will be input in the design process. Input is needed in the process of designing of this research are the environmental condition / the existing layout, enzymatic oxidation process time, and the production capacity per batch. The input is then used as the needs to support the design process of material handling equipment. The input is processed and adapted to the design objectives and the constraints to produce the supporting material handling equipment specifications. Specifications are then used to design 3D Modelling of material handling equipment concept that has been chosen.

3. Collecting and Data Processing

3.1 Data Collecting

In this study, data collection using primary data and secondary data. Primary data were obtained by direct observation in the rolling, enzymatic oxidation room, and drying, such as the type of material handling equipment is used, the dimensions of the tray and the trolley, the layout of the rolling and the oxidation room. While the secondary data used to support the analysis in this study was obtained from the documents of the company. These

data include the Standard Operating Procedures, the production capacity/batch and the tea leaves processing time oxidation.

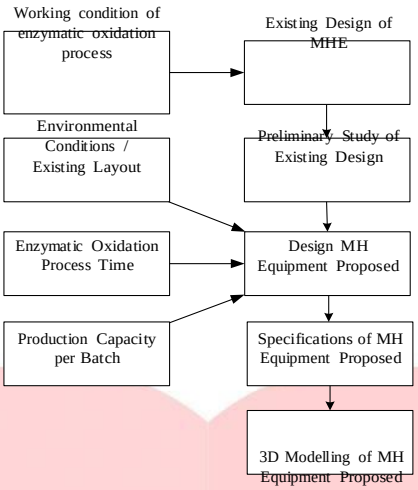

Figure 2 Conceptual Model

3.2 Data Processing

3.2.1 Clarifying Objectives

Classification of the objectives is the initial stage is done by setting a goal of designing. At this stage, the method used is the Objectives Tree method to help identify the and sub- objectives of the design as well as the relationship between the two. The list of objectives is obtained from observations researcher, questions submitted to the client and technical provisions oxidation process that has been validated to the client (customer) [3].

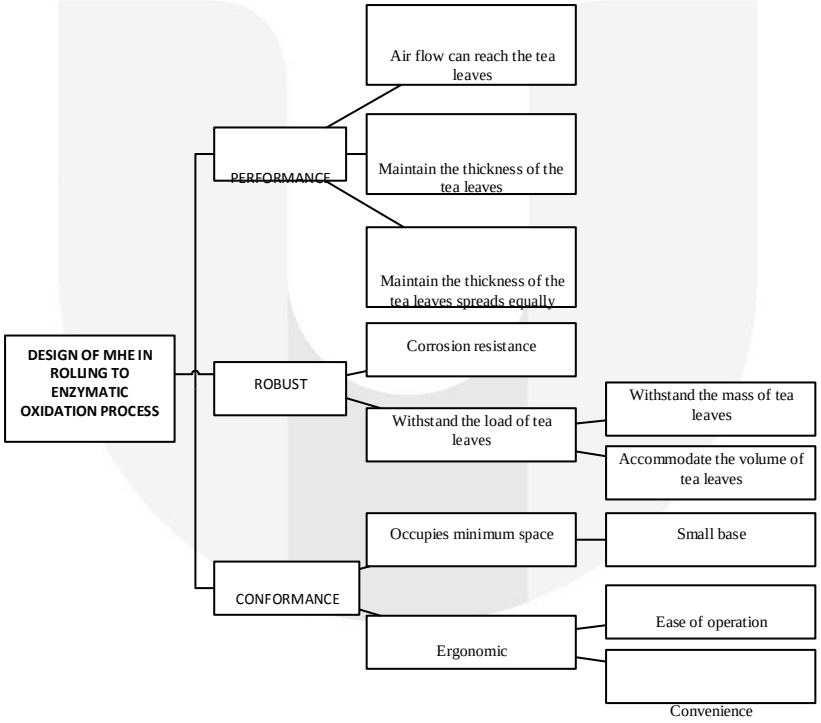

Figure 3 Objectives Tree

Following is the objectives tree of the initial design purpose material handling equipment (MHE) in rolling process to oxidation is presented in Figure 3. These objectives will then be used to guide the design process of the material handling equipment, in other words the design solution has to meet the needs or objectives of the design.

3.2.2 Establishing Function

The second stage in the design process of the proposed MHE is establishing the function that sets the functions performed and the limits of the design system. At this stage of the method used is the Function Analysis Method which describes the input-output system of a process that will be experienced in the design of the proposed four-wheel hand truck. Following black box models of the proposed MHE on Figure 4.

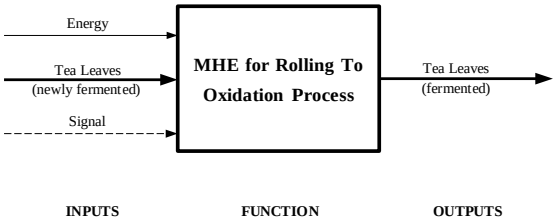

Figure 4 Black Box

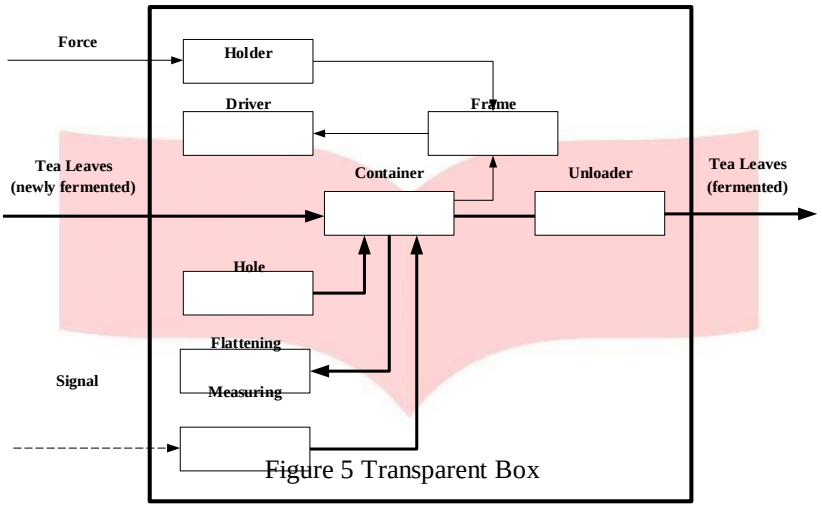

Figure 5 Transparent Box

3.2.3 Setting Requirements

After the function of the design of the proposed material handling equipment is set, it is done later in the design process is the set requirements aimed at making an accurate design specifications for designers [3]. Determination of needs carried out by Performance Specification Model of the proposed four-wheel hand truck for rolling to enzymatic oxidation process presented in Table 2. Performance specification can then be used as a measure in the sixth stage, namely Evaluating Alternatives to see if a solution has been designed in accordance with the prescribed criteria.

Table 2 Performance Specification

	Criteria	Parameter	Limits
1	Air flow can reach the tea leaves	Temperature of tea leaves	24°-28°C
2	Maintain the thickness of the tea leaves	Thickness of tea leaves	10 cm
3	Maintain the thickness of the tea leaves spreads equally	Flatness of tea leaves	-
4	Corrosion resistance	Corrosion resistance	-
5	Withstand the mass of tea leaves	Capacity /MHE	5 tray
6	Accommodate the volume of tea leaves	Capacity /tray	> 12 kg
7	Small base	Base dimension	80 x 103 cm
8	Ease of operation	Number of operating steps	< 15 steps
9	Convenience	Convenience	-

3.2.4 Determining Characteristics

The relationship between characteristics and attributes is in fact a very close one. Designer makes decisions about the physical properties of the products specified technical characteristics of the product, the characteristics are then determined from the product attributes that can meet customer needs. Therefore, it needs interpretation or definition of the attributes of the product to the technical characteristics of products to help designers in designing the four-wheel hand truck. Determination of the design characteristics of the proposed four-wheel hand truck for rolling to enzymatic oxidation process is done by using Quality Function Deployment (QFD) can be seen in Figure 6 and Table 3.

Table 3 The targets of engineering characteristics

Engineering Characteristics	Targets	Units
Hole dimension	d = 4	mm
Distance between the holes	2	cm
The limit height	10	cm
Flatten dimension	Depth < 1,5	Cm
Oxidation rate	-	-
Kekuatan rangka MHE	≥ 60	kg
Capacity of the container	≥ 12	kg/tray
Frame Dimension	150 x 100 x 75	cm
Number of operation steps	< 15	steps
Unloader dimension	45	degree
Number of operator	≤ 2	Operator(s)
MHE dimension	150 x 100 x 105	cm

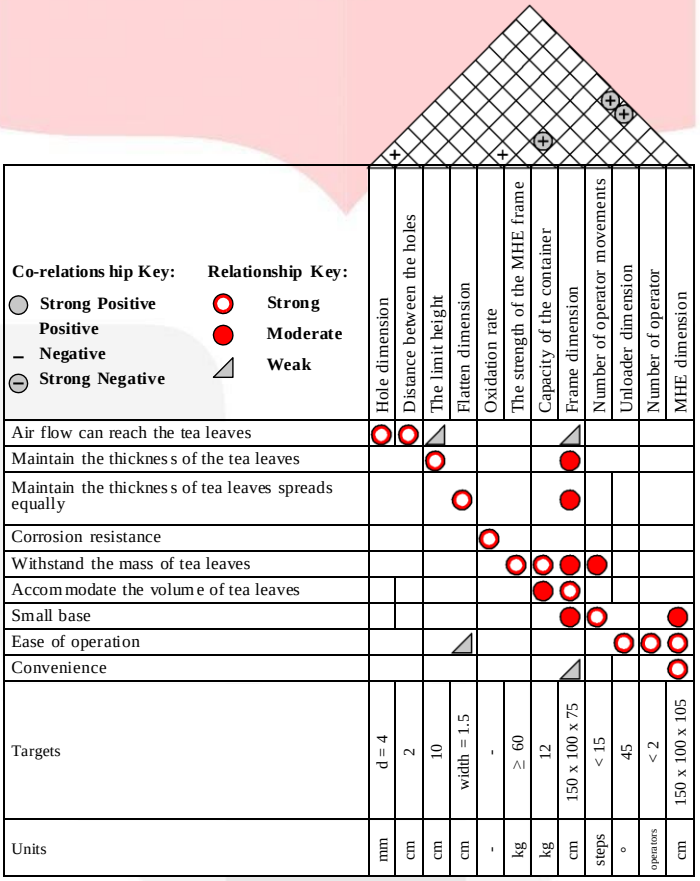

Figure 6 Quality Function Deployment

3.2.5 Generating Alternatives

Stage of Generating Alternatives is a logical process of solving the problem that resulted in some concept alternatives/solutions that does not exist. The method used in this stage, namely Morphological Chart Method. Morphological chart lose its usefulness when the number of columns exceeds three or four [4]. Morphology Chart of the proposed four-wheel hand truck for rolling to enzymatic oxidation process design can be seen in Table 4. From the morphological chart in Table 4, the initial number of possible concept combinations theoretically is 3x3x3x2x3x3x3x3x3 = 13.122 combinations. In most cases, an effective development team will generate hundreds of concepts, of which 5 to 20 will merit serious consideration during the concept selection activity [4], so the number of combination concept should be reduced. Then do the reduction of the sub-solutions, resulting in 10 feasible concept of the 12 concepts that exist in Table 5.

Table 4 Morphological Chart

Features		Sub-solutions		
1	**Container**	Rectangular	Circle	Half slot
2	**Frame / Support**	1 Layer	> 1 Layer	Lifting mechanism
3	**Unloader**	Shovel	Sloping sides	Hole
4	**Driver**	Castor	Pneumatic wheel	-
5	**Holder**	Side by side	Front side	One point
6	**Hole**	Circle	Square	Hexagon
7	**Flattening**	Flat	Curve	Hand
8	**Measuring**	Ruler	Tape measure	Indicator
9	**Prevent**	Material tray: Aluminium	Material tray: Stainless Stell	-

Table 5 Concept combination

No	Features									Concept
	Container	Frame	Unloader	Driver	Holder	Hole	Flattening	Measuring	Prevent	
1	Rectangle	1 Layer	Sloping Sides	Castor	Side by side	Circle	Flat	Indicator	Stainless Stell	A
2	Rectangle	1 Layer	Sloping Sides	Castor	Front side	Circle	Flat	Indicator	Stainless Stell	B
3	Rectangle	1 Layer	Hole	Castor	Side by side	Circle	Flat	Indicator	Stainless Stell	C
4	Rectangle	1 Layer	Hole	Castor	Front side	Circle	Flat	Indicator	Stainless Stell	D
5	Rectangle	> 1 Layer	Sloping Sides	Castor	Side by side	Circle	Flat	Indicator	Stainless Stell	E
6	Rectangle	> 1 Layer	Sloping Sides	Castor	Front side	Circle	Flat	Indicator	Stainless Stell	F
7	Rectangle	**> 1 Layer**	**Hole**	Castor	Side by side	Circle	Flat	Indicator	Stainless Stell	Eliminated
8	Rectangle	**> 1 Layer**	**Hole**	Castor	Front side	Circle	Flat	Indicator	Stainless Stell	Eliminated
9	Rectangle	Lifting Mech.	Sloping Sides	Castor	Side by side	Circle	Flat	Indicator	Stainless Stell	G
10	Rectangle	Lifting Mech.	Sloping Sides	Castor	Front side	Circle	Flat	Indicator	Stainless Stell	H
11	Rectangle	Lifting Mech.	Hole	Castor	Side by side	Circle	Flat	Indicator	Stainless Stell	I
12	Rectangle	Lifting Mech.	Hole	Castor	Front side	Circle	Flat	Indicator	Stainless Stell	J

3.2.6 Evaluating Alternatives

Evaluating alternatives is the stage of selecting the best design alternative among other designs formed at the stage of generating alternatives. The evaluation of alternatives can only be done by considering the objectives that the design is supposed to achieve. The method used in this stage is the Weighted Objectives Method. The aim of the weighted objectives method is to compare the utility values of alternative design proposals with respect to the design objectives, on the basis of performance against differentially weighted objectives [3]. Following the evaluating results of the tenth concept in Table 7 and Table 8 that produces the selected concept which is the concept H for the four-wheel hand truck.

Table 6 Relative Weights of The Objectives

The Objectives	Importance	Relative Weights (%)
Air flow can reach the tea leaves	5	16.12
Maintain the thickness of the tea leaves	5	16.12
Maintain the thickness of the tea leaves spreads equally	5	16.12
Corrosion resistance	3	9.67
Withstand the mass of tea leaves	3	9.67
Accommodate the volume of tea leaves	3	9.67
Small base	1	3.22
Ease of operation	4	12.9
Convenience	2	6.06
Total	31	100 %

Table 7 Screening concept

Selection Criteria	Concepts										
	A	B	C	D	E	F	G	H	I	J	Reference
Air flow can reach the tea leaves	0	0	0	0	0	0	0	0	0	0	0
Maintain the thickness of the tea leaves	+	+	+	+	+	+	+	+	+	+	0
Maintain the thickness of the tea leaves spreads equally	+	+	+	+	+	+	+	+	+	+	0
Corrosion resistance	-	-	-	-	-	-	-	-	-	-	0
Withstand the mass of tea leaves	+	+	+	+	+	+	+	+	+	+	0
Accommodate the volume of tea leaves	+	+	+	+	0	0	+	+	+	+	0
Small base	-	-	-	-	0	0	-	-	-	-	0
Ease of operation	-	-	-	-	0	0	+	+	-	-	0
Convenience	-	+	-	+	-	0	-	+	-	+	0
Sum +'s	4	5	4	5	3	3	5	6	4	5	0
Sum 0's	1	1	1	1	4	5	1	1	1	1	9
Sum -'s	4	3	4	3	2	1	3	2	4	3	0
Net Score	0	2	0	2	1	2	2	4	0	2	0
Rank	8	2	8	2	7	2	2	1	8	2	8
Continue?	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No

Table 8 Scoring concept

	(%)	Concepts							
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Air flow can reach the tea leaves	16.12	3	0.45	3	0.45	3	0.45	3	0.45
Maintain the thickness of the tea leaves	16.12	3	0.45	3	0.45	3	0.45	3	0.45
Maintain the thickness of the tea leaves spreads equally	16.12	3	0.45	3	0.45	3	0.45	3	0.45
Corrosion resistance	9.67	3	0.3	3	0.3	3	0.3	3	0.3
Withstand the mass of tea leaves	9.67	2	0.2	2	0.2	3	0.3	3	0.3
Accommodate the volume of tea leaves	9.67	4	0.4	4	0.4	1	0.1	3	0.3
Small base	3.22	1	0.5	1	0.5	4	2	3	1.5
Ease of operation	12.9	3	0.375	2	0.25	1	0.125	5	0.625
Convenience	6.06	1	0.075	1	0.075	3	0.225	4	0.3
Total Score		3.2		3.075		4.4		4.675	
Rank		4		5		3		1	
Continue?		No		No		No		Develop	

4. Results and Analysis

From the design objectives, the type of material handling equipment that has the characteristics that most closely with the design objectives, namely industrial truck especially four-wheel hand truck. The data processing which refers to the rational design process, obtained a type of manual material handling equipment is industrial truck with Concept H in Figure 7, which has been evaluated based on the criteria of selection. Those selection criteria are derived from the design objectives that have been defined at the beginning of the design process tailored to the technical provisions of enzymatic oxidation process, user requirements, and the existing circumstances. By improving the design of the proposed four-wheel hand truck based on these provisions is expected to improve the quality of the resulting tea leaves. The four-wheel hand truck has a two layer as a direct order for the container that could accommodate the tea leaves out of the sieve. Each tray has a height limit for powders were accommodated and have air holes, so that air flow can reach the tea leaves in the container and undergo enzymatic oxidation process with better and more evenly.

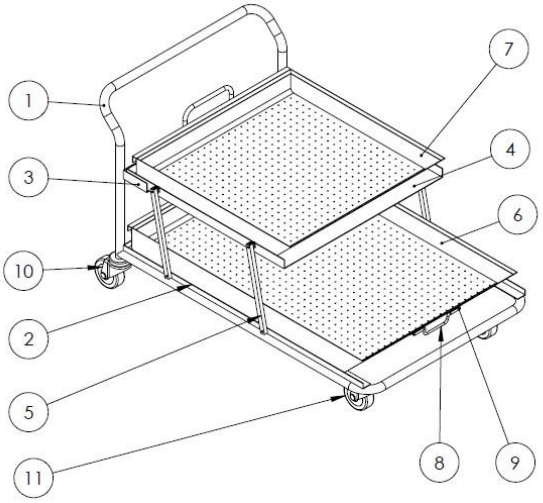

Figure 7 Design proposal of four-wheel hand truck in rolling to enzymatic oxidation process

ITEM NO.	PART NUMBER	QTY.
1	Frame	1
2	Bottom Support	1
3	Top Support	1
4	Lifting Support	1
5	Link Support	4
6	Tray 1	1
7	Tray 2	1
8	Handle for Tray 1	1
9	Assembly for handle	2
10	Break castor	2
11	Free Castor	2

Figure 8 Bill of material four-wheel hand truck proposal

5. Conclusion and Suggestion

5.1 Conclusion

From the results of data processing, data analysis, and proposals have been made, it could be concluded that refers to the purpose of resolving the issues raised in the research. Type of material handling equipment that is suited to the rolling process to the enzymatic oxidation is the kind of four-wheel hand truck. To achieve the design goal, then four-wheel hand truck designed with size 160 x 105.2 x 105 cm, has 2 container layer using a lifting mechanism, the powder height limit of 10 cm, has a flattening tools are accommodated tea leaves, air holes of 4 mm with the distances between holes 2 cm, unloader form of sloping sides, and the operation can be performed by one operator.

5.2 Suggestion

1. Consider the deeper aspects of ergonomics in the design process.
2. Using anthropometric data of the company operator as a reference in the required dimensions.
3. Evaluate the results of the design is better than existing MHE.
4. Using material handling equipment that is designed on the process of rolling to enzymatic oxidation.

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