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Single packaging design of papaya (*Carica Papaya L.*) variety IPB 9 (calina) for transportation and distribution

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Abstract. Papaya Calina (*Carica Papaya L.*) is one of the favorite fruits. The thin skin and soft flesh of the papaya, easily cause the damaged of papaya mainly due to mechanical damage at the distribution process. The distribution of papaya generally carried out in bulk and arranged on the vehicles without packaging. Improvements in packaging for distribution that combined with retail packaging will reduce mechanical damage and increase consumer appeal. The research objective is to design retail and distribution packaging. Retail packaging is designed for individual fruits made from polypropylene plastic bags and corrugated board. Distribution packaging are made from corrugated board. The weight of papaya is selected in the range of 700 g -1000 g with a diameter of 90.5 mm - 110 mm and a length of 225 mm -240 mm. Based on these data, retail packaging is designed in the form of fruit units of 250x125x 250 mm for plastic bags and 90x90x140 for corrugated. The distribution packaging is designed with half telescopic container type using the flute BC with two different positions, both of vertical and horizontal positions. The packaging with the horizontal position contains of 4 fruit per packaging, the dimensions are 410x250x115 mm (KS1) and for vertical contains of 6 fruit per packaging with dimensions 330x230x70 mm (KS2). Corrugated board packaging dimensions is designed by considering the efficiency of pallets or generally vehicles that used in product distribution. The efficiency of the packaging that arranged on the pallet with the size of 1200x1100 mm are 85.41% for KS1 and pallet with the size of 1067x1067 are 80% for KS2, while for M5 vehicle with the size of 2200 x 1585 mm the efficiency is 82.56% for KS1 and M2 vehicle with the size 2630x1460 mm the efficiency is 90,92% for KS2.

1. Introduction

Papaya (*Carica Papaya L.*) is one tropical fruit that has a high economic value. The Center for Tropical Horticulture Studies (LPPM-IPB) has produces superior varieties of products produced by research innovations in papaya commodities based on market demand criteria. The criteria for papaya desired by consumers for fresh consumption include sweet taste, oval shape, weight range from 500-1000 g, red orange fruit flesh, and long shelf life. Currently, the most desirable varieties of papaya are papaya IPB9 or papaya calina [1].

Papaya calina has some properties such as perishable and rapid weight loss due to its thin fruit skin and soft flesh. In addition, papaya also easily subjected mechanical damage caused by transportation and distribution activities [2]. Papaya is generally distributed without packaging. Fruit taken from farmers, directly arranged on pickup truck. However the distribution is carried out for supermarkets, fruit shops and other cities, papaya is packaged in bulk using plastic containers or boxes wrapped in newspaper. This packaging makes papaya in the hands of consumers experiencing a low quality and consumer under expectations .

The transportation process also results in quality degradation during postharvest. The vibration occur during transportation on the highway or railroad can cause weight loss and shorten self life. Damage during transportation occurs mostly in bulk conditions or improper use of packaging,



resulting in damage to the product when arriving at the destination reaches 30-50% [3]. In addition, mechanical damage that occurs in the process and distribution will accelerate physiological damage when the papaya is stored [2].

One way to reduce mechanical damage to papaya fruit during transportation and distribution is packaging use. Packaging has an important role, among others, to improve the appearance of the product, help prevent or reduce damage, and protect the fruit from contamination and other physical disorders. Good packaging is not only minimize damage and maintain fruit quality, but also reduce transportation and distribution costs [4].

Research conducted in an effort to reduce mechanical damage to papaya using corrugated packaging for distribution has been carried out by Tawakal [2]. Tawakal said the provision of corrugated cardboard packaging with foam net combination and wrapping during transportation is the best treatment because it is able to maintain the quality of papaya before sold. Packaging that is commonly used is bulk packaging, while single packaging that is ready to display (display) has not been widely done. In addition to better protecting the fruit during transportation, single packaging is used for retail that are readily to be displayed when they arrive at fruit shops / fruit outlets. Therefore in this research, a single packaging (retail) made from PP plastic and corrugated cardboard will be conducted. Retail packaging is designed with regard to the convenience of consumers in carrying papaya fruit such as handholes for plastic packaging and ropes for cardboard packaging. In the process of transportation and distribution, retail packaging is packed again in a carton box made of corrugated cardboard.

Based on the description above, the main objectives of this study are: 1) designing single / retail packaging made of PP plastic and corrugated cardboard and distribution packaging made from corrugated cardboard for papaya; 2) Analyzing the strength of packaging and; 3) simulate the preparation of the distribution package design for various transport sizes and pallets to get the best efficient arrangement.

2. Material and Methods

2.1. Material

The materials used in this study were papaya with 1 tier maturity level (papaya weight 700 - 1000g), individual retail packaging made from flute wave C (double face) and BC (double wall) flute type packaging, and polypropylene plastic packaging 0.08 mm. The equipment used consists of scales, meters, sealers, measuring ruler, and UTM (Universal Testing Machine).

2.2. Methods

2.2.1 Preparation of fruit samples includes sorting based on weight.

The weight of the papaya chosen was 700-1000 g based on the heavy information demanded by the export market. This information was obtained from exporters who have made export sales of papaya fruit. The results of fruit sorting based on the weight range measured fruit dimensions, namely length and diameter to determine the inner dimensions of the designed package.

The weight of one papaya is measured using a digital scale (Mettler PM-4800) with accuracy of 2 numbers behind the comma. Measuring the diameter of papaya fruit was done using a measuring tape by measuring the circumference of the width and the height of the papaya using equation 1.

$$D = 2 \times (K / (2 \times \pi)) \quad (1)$$

Information

K = circumference of circle (mm)

D = circle diameter (mm)

2.2.2. Designing the dimensions of retail packaging

2.2.2.1. Polypropylene plastic packaging

Plastic packaging for papaya fruit that will be designed is a polypropylene (PP) plastic packaging 250x250 mm with a thickness of 0.08 mm. The number of fruits in one plastic package is 1 fruit with the position of the fruit sleeping horizontally. The package is given a round perforation hole with a width of 5 mm. The number of holes perforated as many as 20 (twenty) holes. Determination of retail packaging dimensions is calculated by equations 2 and 3.

$$P_p = P_b + 1 \quad (2)$$

$$T_p = T_b + 1 \quad (3)$$

Information :

P_p = Plastic package length (mm)

P_b = length of papaya fruit (mm)

T_p = plastic packaging height (mm)

T_b = height papaya fruit (mm)

2.2.2.2. Corrugated cardboard packaging

Corrugated cardboard packaging for papaya fruit that will be designed is made from double face using flute C 0.3 cm thickness type RSC (Regular Selotted Carton) which is given a rope for ease of carrying. The number of pieces in one carton package is 1 fruit with vertical standing fruit position. Packaging is given a round vent with an area of 2% of the packaging area. The number of ventilation is 2 (two holes). The stages for designing cardboard primary packaging are determination of inner dimensions, design dimensions and outer dimensions.

Table 1. Calculation of corrugated cardboard packaging design

Information	Length (mm)	Wide (mm)	Height (mm)
Inner dimension	DP_b	DL_b	T_b
Design dimension	$P_{kd} + T_f$	$L_{kd} + T_f$	$T_{kd} + (2 \times T_f)$
Outer dimension	$P_{kdes} + (2 \times T_f)$	$L_{kdes} + (2 \times T_f)$	$T_{kdes} + (2 \times T_f)$

information :

D = diameter

P_b = length of papaya (mm)

L_b = width of papaya (mm)

T_b = height of papaya (mm)

P_{kd} = length of inner dimension (mm)

L_{kd} = width of design dimension (mm)

T_{kd} = Height of outer dimension (mm)

P_{kdes} = length of packaging design (mm)

L_{kdes} = width of packaging design (mm)

T_{kdes} = high of packaging design (mm)

T_f = thick *flute C*

2.2.3. Designing the packages for distribution

Packaging distribution for papaya fruit designed was made from double wall flute corrugated cardboard BC type RSC (Regulated Slotted Container) and HTC (Half Telescope Container). For one horizontal distribution package, 4 packets of papaya were packaged in PP plastic retail packaging with horizontal ground position, while vertical distribution packages packed 6 papaya packaged in carton packaging with vertical standing position.

Table 2. Calculation of distribution packaging design horizontal position

Information	Length (mm)	Width (mm)	Height (mm)
Inner dimension	$N_p \times P_{lr}$	$N_L \times L_{lr}$	T_{lr}
Design dimension	$P_{kd} + T_f$	$L_{kd} + T_f$	$T_{kd} + T_f$
Outer dimension	$P_{kdes} + (2 \times T_f)$	$L_{kdes} + (2 \times T_f)$	$T_{kdes} + (2 \times T_f)$

Table 3. Calculation of distribution packaging design vertical position

Vertical position	information	Outer dimension	Design dimension	Outer dimension
<i>Body</i>	Length (mm)	$N_p \times P_{lr}$	$P_{kd} + T_f$	$P_{kdes} + (2 \times T_f)$
	Width (mm)	$N_L \times L_{lr}$	$L_{kd} + T_f$	$L_{kdes} + (2 \times T_f)$
	Height (mm)	T_{lr}	$T_{kd} + T_f$	$T_{kdes} + (2 \times T_f)$
<i>Cover</i>	length (mm)	-	$P_{Kdesbody} + (2 \times T_f)$	$P_{Kldescorver} + (4 \times T_f)$
	width (mm)	-	$L_{Kdesbody} + (2 \times T_f)$	$L_{Kldescorver} + (4 \times T_f)$
	Height (mm)	-	$\frac{1}{3} \times (T_{Kdes body} - T_f)$	$T_{Klcover} + T_f$

Keterangan

n_p = length number of retail packaging (mm)

P_{lr} = outer retail packaging length (mm)

n_L = wide number of retail packaging (mm)

L_{lr} = outer retail packaging width (mm)

T_f = thickness *flute* BC (mm)

P_{kd} = inner packaging length (mm)

L_{kd} = inner packaging width (mm)

T_{kd} = inner packaging height (mm)

P_{kdes} = packaging design length (mm)

L_{kdes} = packaging design width (mm)

T_{kdes} = packaging design height (mm)

$P_{Kl cover}$ = outer packaging length cover (mm)

$L_{Kl cover}$ = outer packaging width cover (mm)

$T_{Kl cover}$ = outer packaging height cover (mm)

2.2.4. Perform packaging strength tests and analyze the strength of packaging stacking

Calculation of the number of packing stacks is done with equations 4 and 5

$$SF = \frac{P}{f} \quad (4)$$

$$\text{Number of stack packs} = \frac{SF}{\text{Berat total box}} \quad (5)$$

Information

SF = maximum safe load

P = compressive strength (N / m²)

f = safety coefficient value

2.2.5. Simulating the preparation of packaging on the pallet and like a transport car (pick up)

2.2.5.1. Packaging arrangement efficiency on pallet

The packaging design results are structured simulations on a pallet. The size of the pallet with the most efficient packaging arrangement is the best pallet size, namely with the most packaging arrangement. Determination of packaging arrangement efficiency on a pallet using equation 6.

$$E_k = \frac{\text{---}}{\text{---}} \quad (6)$$

Information

E_k = Efficiency of packaging on a pallet

P_p = Compilation pattern

L_k = The area of the packaging floor

L_b = Pallet area

2.2.5.2. Efficiency of packaging arrangement in transport car (pick up)

The efficiency of packaging arrangement efficiency above the conveyance was intended to determine the freight charge that can affect the quantity of fruit and shipping costs. Determination of the efficiency of packaging arrangement above transport car using equation 7.

$$E_b = \frac{L_b}{L_k} \quad (7)$$

Information

E_b = Body efficiency

L_k = packaging area

L_b = Tub area

3. Result and Discussion

3.1. Measurement of Dimensions of Papaya Fruit

The dimensions of papaya measurements included fruit weight, fruit diameter and fruit height. Papaya fruit obtained in this research was varying size because it comes from several different trees. The results of measurements of 30 samples of Calina papaya fruit were obtained as shown in table 4.

Tabel 4. Measurement results of dimension papaya

Packaging	Part	Average
Plastic	weight (g)	883,54±74,53
	Diameter (mm)	29,31±0,52
	Height (mm)	23,70±1,23
Corrugated cardboard	Weight (g)	808,63±66,74
	Diameter (mm)	26,35±1,66
	Height (mm)	22,85±0,57

The results obtained from the dimensions of papaya measurements were used to determine the dimension retail and distribution packaging design.

3.2. Retail packaging

3.2.1. Polypropylene plastic packaging

Based on the results of measurements of the weight and dimensions of papaya fruit, plastic packaging design were obtained (table 5 and figure 1 and 2).

Tabel 5. Dimensions of designed plastic packaging

Parameter	Hasil rancangan
Plastic thickness (mm)	0.08
Number of perforation holes	20
Area of perforation hole (mm)	5
Percentage perforation (%)	1.6
Plastic length (mm)	250
Plastic width (mm)	125
Plastic height (mm)	250
Packaging area (cm ²)	2187.5
Handhole length (mm)	100
Handhole height (mm)	20

The use of perforated plastic packaging is to prevent condensation from occurring so as to minimize moisture condensation in the package. The use of plastic packaging without perforation on fruits and vegetables can cause decay and anaerobic reactions that cause unpleasant odor decay occur, so it is necessary to have a perforation hole that can get rid of respiration through the perforation hole [5].

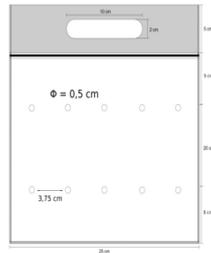


Figure 1. Design dimension plastic packaging

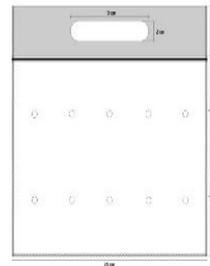


Figure 2. Design plastic packaging

3.2.2. *Corrugated cardboard packaging*

Based on the results of measurements of the weight and dimensions of papaya fruit, corrugated cardboard design were obtained (table 6 and figure 3 and 4).

Tabel 6. Dimension of corrugated cardboard packaging

Parameter	Dimension packaging		
	Inner dimension	Design dimension	Outer dimension
Length (mm)	81	84	90
Widht (mm)	81	84	90
Height (mm)	231	234	240
Packaging area (mm ²)	656.1	705.6	810
Packaging volume (mm ³)	15155.9	16511	19440

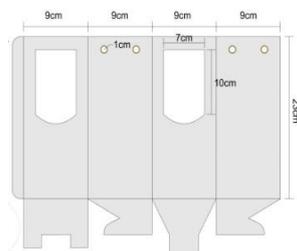


Figure 3.dimension corrugated cardboard packaging design



Figure 4. corrugated cardboard packaging design

Corrugated cardboard was a type of packaging that was often used to package products such as fruit, vegetables and industrial goods. The use of corrugated cardboard packaging was chosen because, easy to formed, easy to obtained, can be recycled [6]. Corrugated cardboard packaging was

also very efficient for shipping, and the use of this packaging had been used in general for distribution, transportation and storage [7].

3.3. Design distribution packaging

The type of packaging designed for this distribution package is a double wall flute BC corrugated cardboard with RSC (Regular Slotted Container) and HTC packaging type (Half Telescope Container) which consists of body parts and cover. This material was chosen because it could reduce vibration well and has a smooth surface. Horticultural product packaging has several properties that are more profitable than wood, including having a smooth surface, easy to assemble, and the most important is having good vibration-reducing properties [8]. The use of BC flute type corrugated cardboard packaging was chosen because it has the best flat compressive resistance so that it is expected to maintain the quality of fruit during distribution [9].

Each distribution package was ventilated. Ventilation on horizontal packaging (KS1) is 12 ventilation and for vertical packaging (KS2) there are 8 ventilation, where the hole diameter of each ventilation is 2 cm. Ventilation serves to maintain adequate air distribution according to product needs so that the heat transfer of the product to cold air will be optimal, this can reduce product damage during transportation [10]. Ventilation was circle shaped, because ventilation of this circle results in having air circulation and good temperature distribution [11].

Packaging distribution of design results for horizontal packaging (KS1) is 41x25x11.5 cm and for vertical packaging (KS2) is 33x23x7 cm. The results of calculation of inner dimensions, design dimensions and external dimensions could be seen in tables 7 and table 8. Packaging design and secondary packaging design results in Figures 5,6,7,8 and 9.

Tabel 7. Horizontal packaging design (KS1)

Parameter	Dimension packaging		
	Inner dimension	Design dimension	Outer dimension
Length (mm)	399	396	410
Width (mm)	229	236	250
Height (mm)	94	100.1	115
Packaging area (mm ²)	9137.1	9345.6	10250
Packaging volume (mm ³)	85888,7	93549.4	117875

Tabel 8. Vertical packaging design (KS2)

Parameter	Part of packaging	
	Bottom (Body)	Top (Cover)
Inner dimension		
Length (mm)	289	
Width (mm)	189	
Height (mm)	229	
Design dimension		
Length (mm)	296	316
Width (mm)	196	216
Height (mm)	236	56
Outer dimension		
Length (mm)	310	330
Width (mm)	210	230
Height (mm)	250	70
Packaging area (mm ²)	6510	7590
Packaging volume (mm ³)	162750	53130

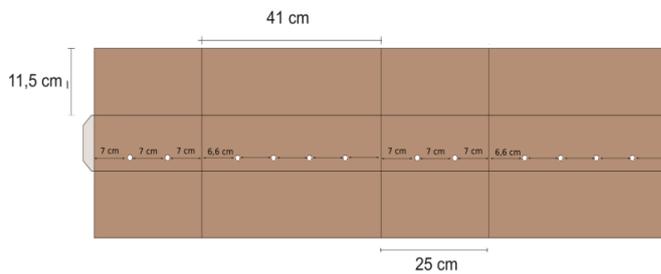


Figure 5. Dimension horizontal packaging (KS1) design



Figure 6. horizontal packaging (KS1) design



Figure 7. Vertical packaging design (KS2)

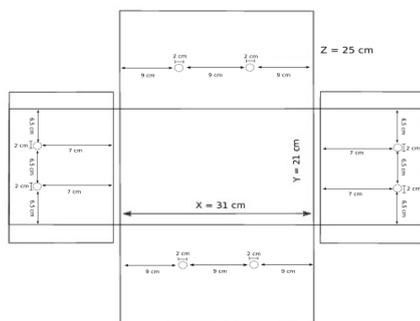


Figure 8. vertical packaging (KS2) design body

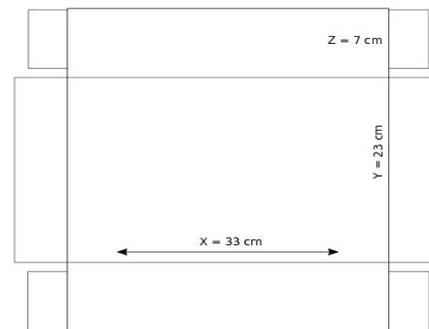


Figure 9. vertical packaging (KS2) design cover.

3.4. Packaging Strength and Number of Stacks

The compressive strength test is very important to do on corrugated cardboard packaging to find out the maximum strength of the carton when stacked during distribution using containers and when storing in a warehouse. This piles causes pressure from top to bottom, commonly called top to bottom compression. In addition, the compressive strength value could be used to calculate the maximum number of piles that can be used as a consideration for choosing the appropriate packaging design for papaya [2]. In the real condition in the field the stack height is arranged so that the packaging in the lowest position does not suffer damage caused by the static load from the packaging above [12]. The results of the calculation of the packaging strength test and the maximum number of stack packs in table 9.

Table 9. Packaging Strength and Number of Stacks

Design packaging	Dimension (PxLxT) cm	Fruit capacity	Compressive strength (N/m ²)	Number of stacks
KS1	41 x 25 x 11,5	4	16623,99	23
KS2	31 x 21 x 25	6	6673,97	7

3.5. Packaging arrangement efficiency for transportation packaging

3.5.1. Packaging arrangement efficiency on pallet

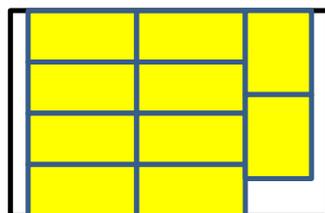
The packaging arrangement on the pallet is intended for export so that it is known that the pallet size matches the design package. In the papaya export-import trade the efficiency of product distribution would be maximized if the producing country and importing countries use the same pallet size [2].

The optimal efficiency of pallet used consists of pallet load efficiency of 90%, namely good fit, 80% efficiency, namely average fit and 70% efficiency, namely poor fit. The highest efficiency value for the package designed is a pallet with dimensions of 1200x1000 mm with efficiency of 85.41% for horizontal packaging (KS1) and dimensions of 1067x1067 mm with 80% efficiency for vertical packaging (KS2). According to [14], the presence of residual space on the pallet can provide air circulation space between packages and facilitate the preparation and dismantling during distribution.

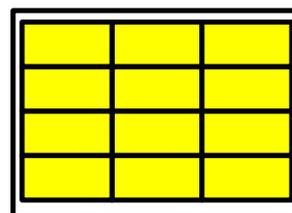
The results of calculating the efficiency of using various sizes of pallet based on ISO pallet standards for packaging design results are presented in table 10. The composition of distribution packaging on the pallet with the best efficiency can be seen in Figure 10 and 11.

Table 10. Value of efficiency of use of pallets for design packages

Pallet size (mm)	Country	Pallet efficiency (%)	
		Horizontal packaging	Vertical packaging
1200 x 800	Europe, Singapore, Chinese	74,73	71.15
1140 x 1140	Several european country, Chinese, Germany, Netherlands, Taiwan,	78.87	70.08
1200 x 1000	Singapore, Thailand, Chinese, Indonesia USA, Chinese	85.41	75.9
1219 x 1016	USA and Canada	82.76	73.54
1067 x 1067	Japan, Taiwan, Korea,	72.02	80
1100 x 1100	Singapore, Thailand	84.71	75.15



1200x1000

Figure 10. efficiency on pallet for horizontal packaging (KS1)

1067x1067

Figure 11. efficiency on pallet for vertical packaging (KS2)

3.5.2. Efficiency of packaging arrangement in transport cars

The efficiency of packaging arrangement on transport cars is intended to find out shipments that could affect fruit quantity and shipping costs. Some of the transport vehicles that were often used for transportation could be seen in table 11 and in Figure 12.

Table 11. Efficiency of packaging arrangement horizontal packaging (KS1) and vertical packaging (KS2) in various types of transport vehicles

Type of packaging	Types of transport vehicles	Size transport cars (mm)		Large transport cars (mm ²)	Number of packages	Packaging area (mm ²)	Efficiency (%)
		Length	Width				
Horizontal packaging	M1	2200	1480	3256000	25	2562500	78,70
	M2	2630	1460	3839800	30	3075000	80,08
	M3	2350	1585	3724750	30	3075000	82,56
	M4	2425	1600	3880000	33	3385200	87,17
	M5	2200	1585	3487000	30	3075000	88,18
Vertical packaging	M1	2200	1480	3256000	36	2732400	83,91
	M2	2630	1460	3839800	48	3643200	94,87
	M3	2350	1585	3724750	42	3187800	85,58
	M4	2425	1600	3880000	42	3187800	82,16
	M5	2200	1585	3487000	36	2732400	78,36

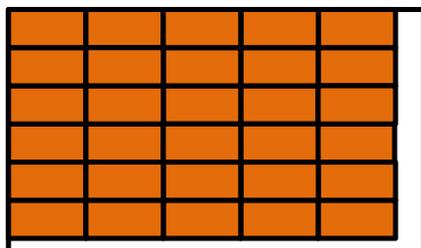


Figure 12. efficiency on pallet for horizontal packaging (KS1)

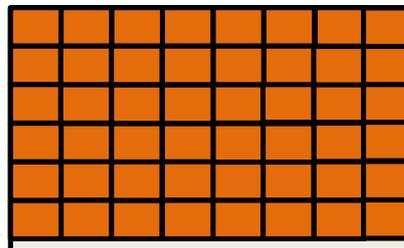


Figure 13. efficiency on pallet for vertical packaging (KS2)

Product distribution efficiency will be maximized if horizontal packaging (KS1) uses the type of M5 transport vehicle that is for 88.18% and for vertical packaging (KS2) using M2 type of car that is for 94.87%.

4. Conclusion

The average dimension of one papaya was the average weight of 808.63-883.54 g, the average diameter is 26.35-29.31 cm and the average height is 22.85-23.70 cm. The PP plastic packaging was 25x12.5x25 cm and carton packaging was 9x9x24 cm. Horizontal packaging was 41x25x11.5, while vertical packaging was 33x23x7 for top /cover packaging, and 31x21x25 for bottom / body packaging. The packaging strength test results, for horizontal packaging amounted to 16623.99 N / m² with a maximum number of packing stacks of 23 piles, and for vertical packaging of 6673.97 N / m², with a maximum number of packing piles, namely 7 stacks. The efficiency of packaging preparation will be

better using a pallet size of 1200x1000 mm (85.41%) for horizontal packaging and pallet sizes of 1067x 1067 mm (80%) for vertical packaging. For horizontal packaging, the efficiency of packaging preparation on a transport vehicle would be better to use a size of 220x158.5 cm or M5 (88.18%) and 263x146 cm or M2 (90.92) for vertical packaging.

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