Packaging Development to Support Export Supply Chain of Mangosteen Fruit

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Abstract

The changes of the quality of mangosteen fruits for export market occur during the distribution handling from production center to the shipment port and then to the destination market countries. This research was carried out to develop optimum packaging design of mangosteen fruit for export market using corrugated carton material which enable to be stacked in maximum load. The result showed that compressive strength of C-flute packaging type with inner package was 474.5 kgf, while the BC-flute packaging type was 663.2 kgf. The maximum stacking was determined based on the capacity, compressive strength of packaging and safety/environment factor in ASTM D4269 standards. The designated packaging of C-flute and BC-flute type could be maximally stacked up to 29 units and 35 units of packaged fruits, respectively. Compressive strength decreased higher under storage at 13^{o}C (RH approximately at 90-95%) than 8^{o}C with 60-75% RH i.e. 40.04-41.64% and 6.75-30.31%, respectively. Mechanical damage symptom occurred in C-flute type with 2x2 and 2x3 inner model during transportation was broken calyx at 1.39 and 1.67%, respectively. Packaging model under different capacity did not significantly influence firmness and TSS but significantly influence weight loss.
Keywords: mangosteen, packaging design, compressive strength, mechanical damage

Introduction

Mangosteen, The Queen of Fruit, has become one of the most popular tropical fruit in the world because of its exotic shape, taste and color. The largest import markets of mangosteen from Indonesia are China (44.4%), Hongkong (35.47%), Singapore (8.54%), expand to Middle Eastern (6.14%) and Europe (0.39%). For Indonesia, mangosteen has become the main export fruit commodity. Meanwhile, it is reported that a big shrinkage occurred in exported fruit of which only 35%-40% was accepted by importing countries (Sutrisno *et al.*, 2009).

Packaging is conducted to maintain the safety of a product during transportation and to protect it from pollution and quality degradation as well as to make it easy in handling. The advantages of using appropriate packaging are efficiency in handling, ease in storage and distribution as well as reducing transportation and marketing cost (Hardenberg, 1986).

Box which is made of corrugated carton is a type of packaging which mostly used for transportation of goods including fruits, vegetables and other industrial goods. Corrugated carton box is very functional because of its practical for retail sale, needs little stock room and is made from material which is environmentally friendly. This type of carton box can also be designed for application which have various strengths and forms needed. However, the compressive strength of packaging box depends on various design factors. The factors affecting the design are board component, dimension, design, dispatch condition and storage environment. Jinkarn *et al*. (2006) stated that corrugated board lost its compressive strength when subjected to distribution hazards such as high relative humidity, excessive stacking load, long term storage and uneven stacking pattern.

Transportation is an important link in the mangosteen agribusiness activities. In the process of transportation, fresh mangosteen damage can be caused by environmental and physical risks. Mechanical damage that occurs in agricultural products during transport can reach 32%-47%. Products experiencing mechanical damage will be more vulnerable to physiological and biological damage (Satuhu, 2004).

The objective of this research was to develop a design of mangosteen packaging for export purposes and determine the change in compressive strength and quality changes during cold storage as well as mechanical damage during transportation simulation.

Materials and Methods

Materials

Fruits used were mangosteen which was classified as export quality (major size at 61 mm - 63 mm and 100-120 gram individual weight) and 6.53 kgf bio-yields with 5.2 mm deformation. The material used for packaging was corrugated carton of BC and C-flute types for the construction of prototypes of outer packaging and B flute type for inner packaging with grammature 150.

Methods

Design of packaging was carried out based on packaging requirement with some conditions, i.e., number of fruits per package, dimension and weight, number of stacks, characteristics and type of carton material. Design testing was conducted on the compressive strength as indicated in Figure 1. Eight prototypes were designed in this research, conforming to the criteria previously mentioned and listed as follow: A1B1C1, A1B1C2, A1B2C1, A1B2C2, A2B1C1, A2B1C2, A2B2C1 and A2B2C2 (A1: 2x2 inner model; A2 2x3 inner model; B1: C-flute type; B2: BC-flute type; C1 without inner; C2: with inner). The samples of design are presented in Figure 2.

Compressive strength test was carried out using two wooden plates with smooth surfaces which were attached to the upper and the lower compressive jaws of the machine to evenly distribute the compressive load on the corrugated board panel. Each wooden plate weighed 4.6 kg and sized at 48 cm x 40 cm x 4 cm. The crosshead speed was set at 10 mm/min.

The value of compressive strength in the test was used to calculate the number of stacks using the following equations (Twede *et al*., 2005).

$$C_s = \frac{P}{f} \qquad (1)$$

$$S = \frac{C_s}{W_b} \qquad (2)$$

where: C_s is compressive strength; P is compressive load, S is number of stacks and f is a coefficient.

Transportation simulation was carried out by converting time needed for transporting mangosteen from production center to the collector which was held at 2.23 hours of truck with speed of 60 km/hour. The result was approximately at 3.295 Hz and 3.88 cm for 2 hours which equal with 133.878 km of road in outer city.

Observation on the mechanical damage was visually conducted by calculating the occurrence of broken calyx, fruits cracking and bruising. Fruit was considered to be dented if its skin surface was not smooth. This condition was known by means of touching and examining the skin surface. Measurement of the fruit damage was calculated by the following equation.

$$Y_b = \frac{S_r}{S_b} \times 100 \qquad (3)$$

whereas: Y_b is percentage of fruit damage; S_r is number of damage fruits (broken calyx, fruits cracking and bruising); and S_b is total number of fruits.

The observation of quality change i.e. weight loss, firmness and total soluble solids (TSS) was conducted after 10 days storage at 8 and 13^{o}C and transportation simulation. Control treatment which was conditioned to be un-packaged and un-transported was also developed for comparison.

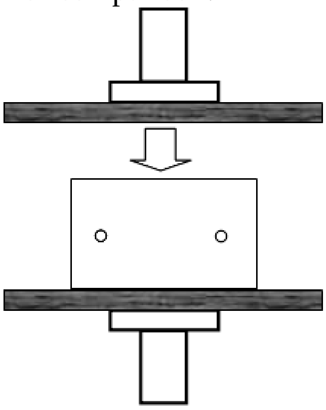
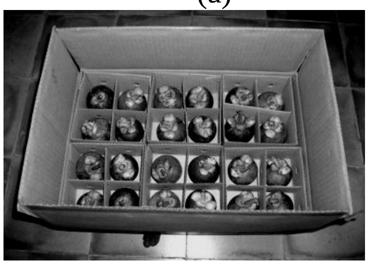


Figure 1 Compressive strength test (Jinkarn *et al.*, 2006)

(a)



(b)

Figure 2 Model mangosteen packaging (a) inner packaging, (b) outer packaging

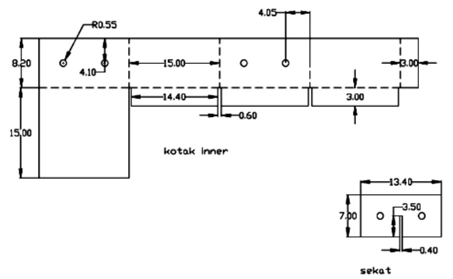
Statistical Analysis

To examine the significance influence of packaging capacity towards quality of objected mangosteen fruits i.e. weight loss, firmness and TSS, completely randomized design with significance level at 0.05 was used. When significance influence was found, Duncan multiple test was carried out.

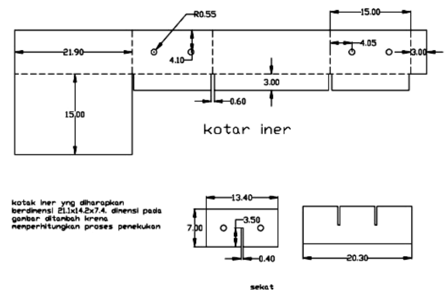
Result and Discussion

Model of packaging design

Supply chain of mangosteen export in Indonesia involved farmers, small middle man, packing house and exporters. In this supply chain the product distribution was conducted by the use of packaging of plastic basket or wooden crate. The mechanical damage of mangosteen during the transportation simulation for wooden crate with Styrofoam partition was 5.2 %, which was higher compared to the plastic basket packaging with 3.7 % damage. The difference was because the size of the wooden crate was bigger than that of the plastic basket, so the stacking load among the fruits became bigger (Sutrisno *et al.*, 2009). To reduce the mechanical damage during transportation, a development in packaging of mangosteen fruit was carried out using corrugated carton material. In this research, C-flute and BC-flute type with average capacity at 4.8 kg and 6.0 kg were used. Figure 3 shows the dimension of the packaging design developed.



(a) Model inner 2x2



(b) Model inner 2x3

Figure 3 Dimension of the packaging design

Compressive strength and maximum stack of the designed package

Compressive strength test under number of stacks was carried out during distribution using container or in warehouse during storage. Stacking caused top to bottom compression. Based on the magnitude of compressive strength, the maximum stack could be calculated. Peleg (1985) stated that there are two factors affecting the compressive strength, i.e., material of the box, like flute type carton used and type of packaging.

Compressive strength test of the packaging design with A2B2C2 experienced the highest compressive strength of 790.89 kgf (Figure 4). It also revealed that packaging using BC-flute type and 2x3 inner model had higher compressive strength than C-flute type and 2x2 inner model, respectively. Based on the Equation 3, the number of maximum stack could be calculated, i.e., 29 stacks for 2x2 inner model with C-flute material and 35 stacks for BC-flute material. The compressive strength of the BC-flute material was higher than that of the C-flute so that the estimated number of stacks was also higher (Figure 5).

Change in compressive strength during cold storage

After 10 days storage, test showed that storage at 13^{o}C with high RH (approximately at 90-95%) experienced higher rate in reducing compressive strength than storage at 8^{o}C with 60-75% RH i.e. 40.04-41.64% and 6.75-30.31%, respectively in each packaging (Table 1). In order to explain the effect of cold storage condition towards the compressive strength, the hygro-instability properties of corrugated board was best could define the phenomenon since there was no control in RH in storage room and investigated in different temperature. Hygro-instability of material is defined as the capability of material to absorb water from the ambient air which caused the deflectance of the material. The material which in this case was represented by corrugated carton would continue to absorb water from the ambient air until reach equilibrium where it was not capable to absorb water anymore. In this research, high RH caused higher decreasing rate which could be described that higher RH had higher water content so the possibility to water absorbed was also relatively high.

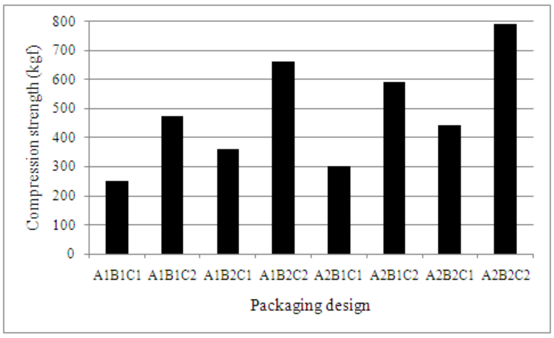


Figure 4 Compressive strength of packaging design

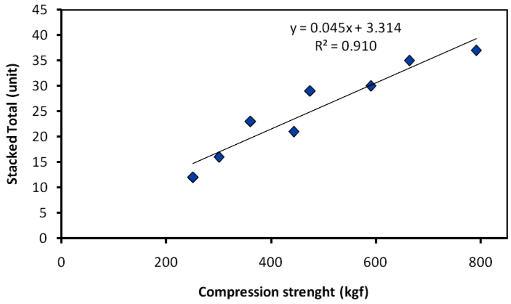


Figure 5 Relationship of compressive strength and number of maximum stacking

Mechanical damage and change in quality of mangosteen

The main symptom of mechanical damage in C-flute type with 2x2 and 2x3 inner model was broken calyx at 1.39 and 1.67% respectively which occurred because unfitted inner space of fruits which led to free movement and impact between fruits and the wall area. Position of fruits inside the package experienced 45^o and 90^o sliding which accounted at 2.77 and 1.67%, respectively. While the mechanical damage such as breaking, cracking and bruising were not found.

Darmawati *et al*. (2009) used 8 kg capacity packaging design with fcc pattern resulting in 3.1% and 2.3% damage with jumble pattern. While 15 kg packaging design for each pattern were 7.5% and 2.5%, respectively. So that packaging design using corrugated carton of C-flute type and partition with a capacity of 4.8 kg and 6.0 kg could reduce the damage of mangosteen fruit during transportation.

Lower weight loss was encountered in packaged fruits than control i.e. 24.14% (A1B1C2), 25.04% (A2B1C2) and 27.68% (control). Statistically, weight loss in A1B1C2 was not significantly different with control, while A2B1C2 was significantly different with A1B1C2 and control. Different result was found for two others quality parameters. Three treatments did not significantly influence firmness and TSS (Table 2).

Table 1 Change in compressive strength during cold storage

Storage duration (days)	Compressive strength (kgf)							
	A1B1C2		A1B2C2		A2B1C2		A2B2C2	
	8°C	13°C	8°C	13°C	8°C	13°C	8°C	13°C
0	474.50	474.50	663.23	663.23	590.19	590.19	790.89	790.89
1	372.89	292.25	619.26	427.11	558.12	367.24	605.85	481.50
5	337.31	285.90	622.65	402.75	549.41	338.36	630.46	469.35
10	330.66	280.64	618.45	397.67	548.75	344.46	625.88	474.08

Table 2 Quality changes of mangosteen

Treatment	Weight loss	Firmness	TSS
A1B1C2	106.5573 b	0.7983 a	17.9503 a
A2B1C2	99.8307 a	0.8053 a	17.9507 a
Control	108.0493 b	0.7841 a	18.0433 a

Means followed by the same letter within a column is not significantly different as determined by Duncan test $P<0.05$.

Conclusions

In this research, two types of packaging material were used and then were compared by applying B-flute as inner packaging to determine the quality of mangosteen under transportation and cold storage for export purpose. BC-flute type had higher compressive strength than C-flute which resulted in higher number of stacks. Mechanical damage symptom occurred during transportation simulation was broken calyx. Packaging model under different capacity was not significantly influence firmness and TSS but significantly influence weight loss in which A2B1C2 was significantly different with A1B1C2 and control.

Acknowledgments

This research was supported by Asia Invest project from Europe Union Commission program and Institutional Prime Research from Directorate General of Higher Education, Ministry of National Education Republic of Indonesia.

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