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Original Research Article

Structural Packaging Designs for Exporting 'Nam Dok Mai' Mango by Air Freight

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ABSTRACT

'Nam Dok Mai' mango (*Mangifera indica* L.) is a famous product of Thailand that gains a great demand in the international markets. The top importers for Thai fresh mangoes are Malaysia, South Korea, Japan, and Vietnam. Furthermore, export rates to European countries, such as France and Switzerland, are growing. There are efforts to increase the fresh 'Nam Dok Mai' mango export by air freight. In addition to the pre- and post-harvest treatments of the mango, the packaging system contributes to the mango's quality during air transport. Therefore, this study aimed to design packaging prototypes for the 'Nam Dok Mai' mango to maintain satisfactory quality throughout the international air transport period. Existing commercial export boxes for the 'Nam Dok Mai' mango are BC-flute corrugated containers in the styles of regular slotted container (RSC) and full telescope design (FTD). The common pack size for exporting to South Korea and Japan is 5 kg, with varying box dimensions and vent hole designs. The packaging prototypes were aimed for the European countries with smaller but growing demands for the 'Nam Dok Mai' mango, and thus were designed as a 3-kg pack size. Nine B-flute and BC-flute corrugated tray prototypes with the outer dimensions of 360×260×90 mm were made. Vent holes and corner reinforcements were added to the designs to increase cold air ventilation and stacking strength, respectively. The commercial RSC and FTD boxes were rescaled to 360×260×90 mm and remade with the same corrugated board combinations as the prototypes. The peak force compressive strengths of one of the BC-flute tray prototypes and the B-flute FTD box were in the range of 3-4 kN and were not significantly different. For most of the B-flute tray prototypes, their peak force compressive strengths were comparable to that of the B-flute RSC box and were in the range of 1-2 kN. The experimental results will be beneficial as a packaging guideline for exporting the 'Nam Dok Mai' mango via air transport and can also be applied to other agricultural crops in the future.

INTRODUCTION

The epidemic situation of coronavirus disease 2019 (COVID-19) in the past few years caused global economic recession. For Thailand fruit exports, despite the decrease in the export quantity amidst COVID-19, the export value increased (Bank of Thailand, 2022; Thai PBS World, 2021). 'Nam Dok Mai' mango (*Mangifera indica* L.) is a famous product of Thailand that has gained a great demand in the international markets. This mango is known for its sweet flavor and abundance in essential antioxidants. At present, the top importers for Thai fresh mangoes are Malaysia, South Korea, Japan, and Vietnam (NNT, 2022; The Nation Thailand, 2022). Furthermore, export rates to European countries, such as France and Switzerland, are growing. The main export channel is air transport because it takes the shortest transit time. During transportation, fresh fruits still have

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biochemical activities such as ripening, respiration, dehydration, and release of ethylene (Paul, et al., 2019). Long transit time can lead to quality loss before the fruits reach the destination. In addition, physical damages encountered during transport, such as compression, shock, and vibration, must be considered. Packaging can help alleviate the loss and damages. The development of transport packaging takes into account the materials, styles, and dimensions. The package must function effectively in terms of absorbing forces from the outside to prevent physical damage to the mango. Proper air circulation inside the package helps to reduce temperature and maintain the mango quality. The dimensions (length × width × height) of the package affects how multiple packages are stacked on pallets and in unit load containers.

Existing commercial export boxes for air transportation of the 'Nam Dok Mai' mango are BC-flute corrugated containers in the styles of regular slotted container (RSC) and full telescope design (FTD) as shown in Figure 1. The common pack size for exporting to South Korea and Japan is 5 kg, with varying box dimensions and vent hole designs. The European countries (e.g., France and Switzerland) have growing demands for the 'Nam Dok Mai' mango, but their demands are smaller than those of Korea or Japan. Thus, smaller containers such as a 3-kg pack size are needed for mango exports to European countries. The aim of this research was to design corrugated packaging prototypes for the 'Nam Dok Mai' mango to maintain satisfactory quality throughout the international air transport from Thailand to Europe.

Figure 1. Existing commercial export containers for Thai fresh mangoes.

MATERIALS AND METHODS

Corrugated packaging prototypes

Corrugated boards were purchased from PNP Packaging Co., Ltd (Nonthaburi, Thailand) and were used as received. Nylon mesh, with mesh diagonal less than 1.6 mm, used for covering the vent holes was purchased from HSH Shop (Bangkok, Thailand). The structural design drawing was done using Adobe Illustrator (Adobe Inc., San Jose, CA, USA) version 26.0 and ArtiosCAD (Esko Software, Gent, Belgium) version 20. The prototypes were made with Mimaki CF2 series automatic sample cutter (Mimaki Co., Ltd., Bangkok, Thailand).

Compression test

Compression tests of the corrugated packages were performed by the Universal Testing Machine: Instron 5566 series 5000 (London, UK) according to ASTM D642 standard, with plate speed 12.7 mm/min. and plate size 50×50 cm. The tests were done in triplicate. The peak (maximum) force was recorded as the compression strength.

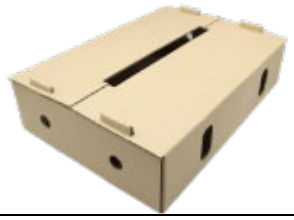
RESULTS AND DISCUSSION

Corrugated packaging prototypes

The corrugated packaging prototypes were designed in the forms of rectangular boxes and trays with different corrugated board combinations. The prototypes were aimed for the European countries, and thus were designed as a 3-kg pack size. The initial outer dimensions of the prototypes were 360×260×90 mm. The locations and sizes of the vent holes on the sides and bottom of the prototypes were based on the 5-kg commercial packaging designs (Figure 1). A piece of white nylon mesh with mesh diagonal less than 1.6 mm was used to cover each vent hole to prevent pests. According to the recent interview carried out with Thai mango exporters, the pest prevention which was a requirement for exporting mangoes to Japan would soon be applicable for European countries. Thus, the mesh was included in the package design. The designs of the prototypes are shown in Table 1 and the blank patterns are shown in Figure 2.

Table 1. Corrugated packaging prototype designs for exporting 'Nam Dok Mai' mango.

Code	Detail	Design	Paper Grade*
C-FTD	Commercial 1		B1

Code	Detail	Design	Paper Grade*
C-RSC	Commercial 2		B1
C-T1	Commercial 3		B1
P1	Prototype 1		B1
P2	Prototype 2		B1
P3	Prototype 3		B1
P4	Prototype 4		B2
P5	Prototype 5		B1
P6	Prototype 6		BC1

Code	Detail	Design	Paper Grade*
P7	Prototype 7		BC1
P8	Prototype 8		BX
P9	Prototype 9		BC1

* B1= B-flute grade KT125/CS110/CA125, B2 = B-flute grade KS170/CA125/KI150, BC1 = BC-flute grade KS170/CA125/CA125/CA125/KA125, BX = B-flute recycle grade.

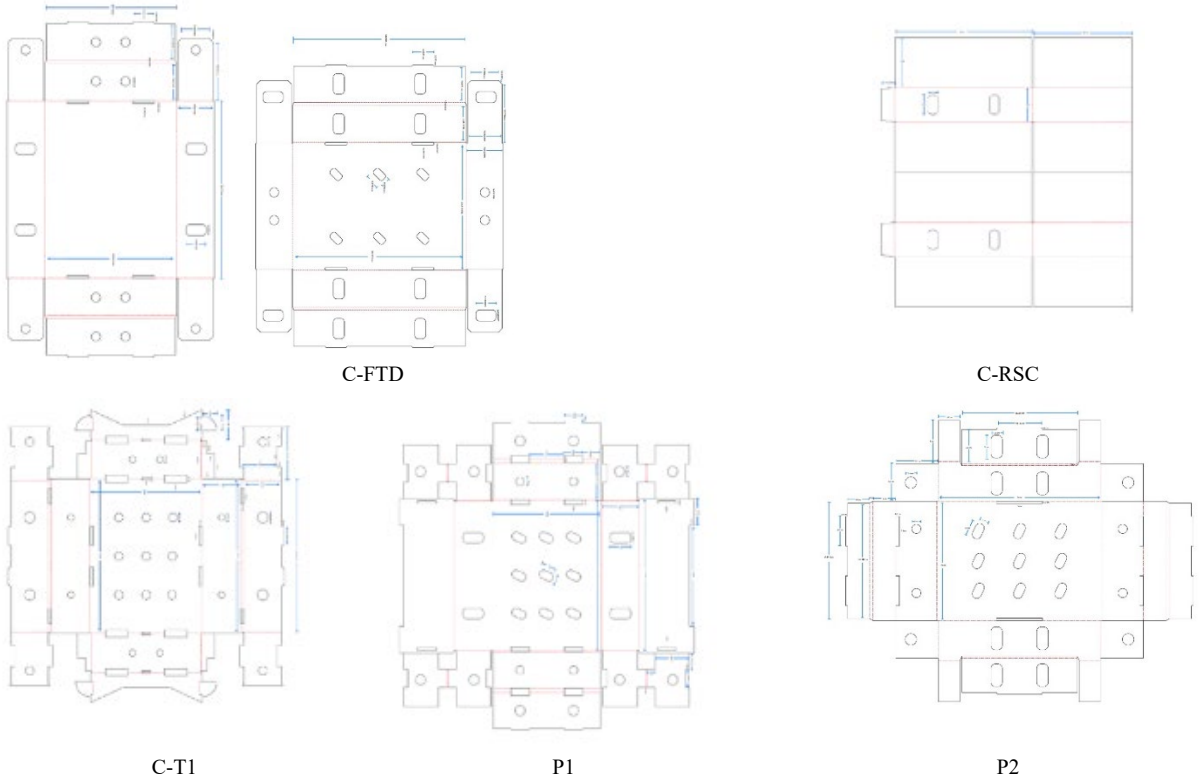


Figure 2. Blank patterns for the corrugated packaging prototypes, with red lines correspond to crease lines, black lines correspond to cut lines, and blue lines correspond to dimension lines.

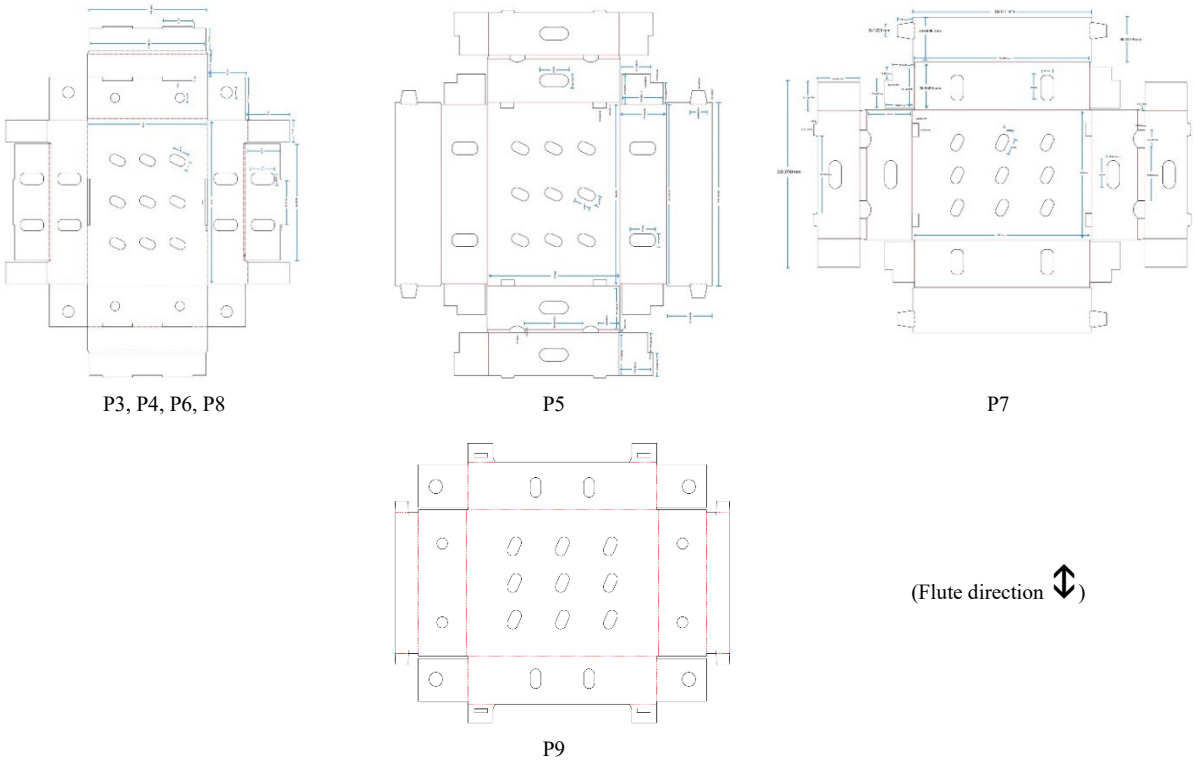


Figure 2 (cont.). Blank patterns for the corrugated packaging prototypes, with red lines correspond to crease lines, black lines correspond to cut lines, and blue lines correspond to dimension lines.

The C-FTD, C-RSC, C-T1 were designed based on the current commercial corrugated shipping containers for fresh mango export from Thailand, where FTD, RSC, and T1 were based on full telescope design (FTD), regular slotted container (RSC), and tray designs, respectively. These designs were rescaled from 5-kg pack size to 3-kg.

The nine packaging prototypes P1-P9 were designed as auto-locked trays. These auto-locked trays can be formed without using glue, which saves time and labor in the forming process. Prototype P1 was designed with flaps that covered the top part of the container. The flaps could be opened and closed as needed and were locked in place when closed. These flaps can provide extra stacking strength and theft-protection. Prototype P2 was designed with reinforced corners to increase compression and stacking strength. The flat-top design can increase loading efficiency. The design pattern for P2 was the simplest and required the shortest time to cut and form. Therefore, the same design was used for other prototypes using different paper grades, flutes, or flute orientations, as specified in Table 1. Prototype P3 used the same design pattern as P2 but with a difference in the direction of the flute orientation, where it changed from machine direction to cross direction. Prototypes P4 also used the same pattern as P2, but with a different paper grade. Prototype P5 was designed with flaps along the length of the package. The flaps could be opened and closed as needed and were locked in place when closed, but the locking mechanism was different from that of P1. Prototypes P1-P5 were made with B-flute corrugated board (liner-medium-liner) and board thickness of approximately 2.5 mm. Prototype P6 also used the same design as P2 but was made with BC-flute corrugated board (liner-medium-liner-medium-liner) with board thickness of approximately 6 mm. The comparison of B-flute and BC-flute boards was shown in Figure 3. The folding of the BC-flute board for P6 made the inside space of the box too small to fit 3 kg of 'Nam Dok Mai' mangoes. Prototype P7 used the same design pattern as P5, but with BC-flute board. Prototype P8 also used P2's pattern but was made with a recycle grade B-flute board. Prototype P9 used a modified design pattern based on P2 and was made with BC-flute board. The P9 pattern was designed to compensate for the board thickness, as the folding parts of the P2 design were too thick to pack 3 kg of fresh mangoes when using BC-flute board. The lock design for P9 could also be opened and closed as needed and fitted in place when closed.

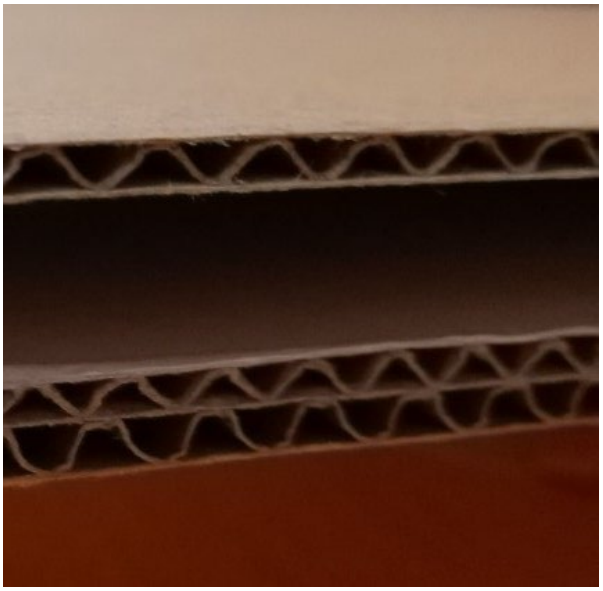


Figure 3. B-flute and BC-flute corrugated boards comparison.

Compression strength

As the P6 prototype did not have enough space inside the box to fit 3 kg of 'Nam Dok Mai' mangoes, it was not used for the compression strength test. The compression results are shown in Figure 4. Figure 4 shows the compression test results of the newly designed prototypes and the three commercial corrugated containers (C-FTD, C-RSC and C-T1). Among the commercial containers, the C-RSC has the

lowest strength (as can be seen from the lowest maximum force.) The C-FTD has the highest strength which can be attributed to the two pieces tray-style box where the top piece fully covers the bottom piece. The corner reinforcement in C-T1 contributes to better compression strength than that of C-RSC. The results show that the reinforcement in the tray-style box helps to increase compression strength. When comparing the compression results for different tray-style boxes made with B-flute corrugated board, the commercial box C-T1 and the new designs P1, P2, P4, and P8 are not significantly different. P3's compression strength is much lower when compared with C-T1 and most of the other boxes, showing that the flute orientation affects the strength of the box. For P3, the flute of the corrugated board on the force bearing panel (where the top flaps were folded) is paralleled with the bottom of the box. For the other prototypes, the flute on the force bearing panel is perpendicular to the bottom of the box. P5 design does not have as good compression strength as the C-T1. For prototypes made with B-flute boards with different board combinations such as P2 and P4, their compression strengths are not significantly different. For this P2 tray design, the flute orientation has greater effect to compression strength than the types of paper used in each layer of the corrugated board.

For the prototypes that are made with BC-flute, P7 has similar compression strength as C-FTD and P9 has higher compression strength than both P7 and C-FTD. Their compression strengths are in the range of 3-4 kN. Both P7 and P9 have significantly higher compression strength than the B-flute containers. All the B-flute containers, both commercial and prototype designs, have compression strengths less than 3 kN and mostly in the range of 1-2 kN. The results show the effect of the flute which corresponds to the board thickness. In this case, he thicker that board, the higher the compression strength.

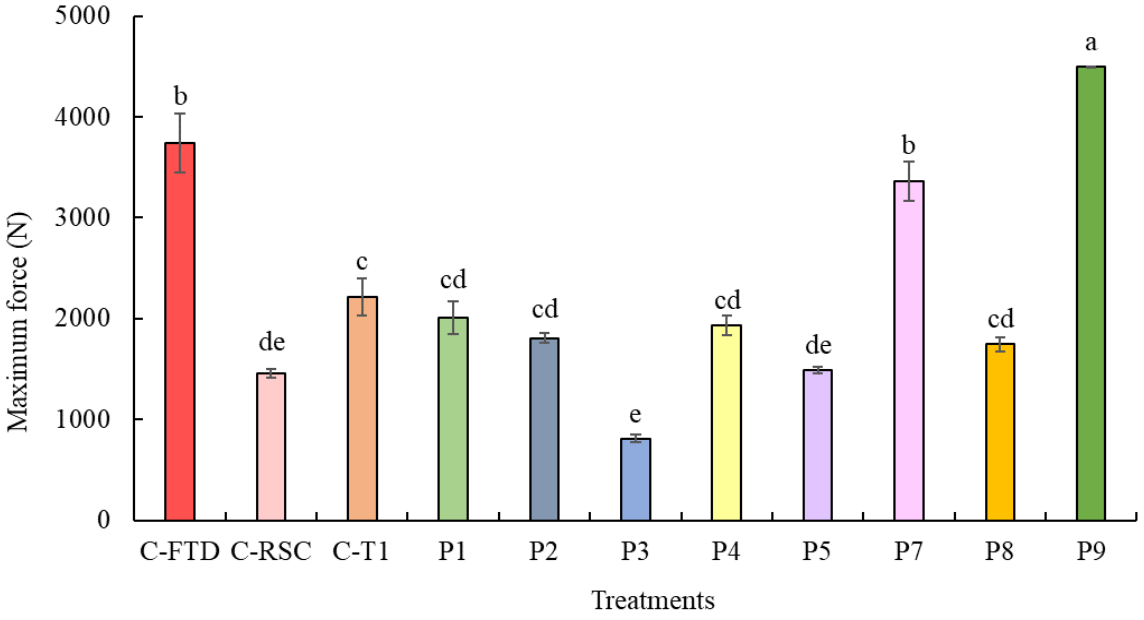


Figure 4. Compression test results of various types of corrugated packaging.

CONCLUSION

From the 9 designs of the corrugated prototypes, 8 of them had enough inside space to fit 3 kg of 'Nam Dok Mai' mangoes. The P2 tray design was found to be the easiest and fastest to form into a container. The compression tests showed that packaging designs affected the compression strength. The FTD design had the compression strength comparable to that of the BC-flute prototypes. The flute (i.e., B and BC) and the flute orientation also greatly affected the compression strength. The designs with corner reinforcement could contribute to higher compression strength. For the compression strength of the P2 tray design, the flute orientation had greater effect than the types of paper used in each layer of the corrugated board. The results obtained from this compression test demonstrated the stacking capability for packaging with different designs. This research will be beneficial as a packaging guideline for exporting the 'Nam Dok Mai' mango via air transport and can also be applied to other agricultural crops in the future.

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