# Effect of Truck Vibration during Transport on Damage to Fresh Produce Shipments in Thailand

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**ABSTRACT**: The increase in global trade allows packaged products to be shipped across borders using inter-modal transportation. Trucks are still the most prevalent mode for surface shipments and time sensitive transport perishable products such as fresh produce. This study focused on measuring the transportation environment in truck shipments from various packing houses to major retail distribution centers in Thailand and then the subsequent distribution to regional stores in smaller trucks. Test measurements were compared to test methods used in North America and Europe. This study compared the quality of cabbage, lettuce, plums and pears after being shipped in truck transport by quantifying the level of bruises and cuts on fruit.

## 1.0 INTRODUCTION

THE effects of shock and vibration caused during shipping can result in serious product damage. Fresh produce (fruits and vegetables) are extremely sensitive to any physical or climatic changes after being harvested and during transportation and handling from the fields to ultimate purchased by the consumer at a retail store. Shipping and handling can cause various forms of bruises and cuts on the fresh fruit or vegetable which compromises its quality, aesthetic appeal and reduces its economic value to the grower and retailer. There are various modes of transportation in the growing international trade that requires inter-modal shipments over land, sea and air. However, trucks are still the most prev-

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alent mode for surface shipments and time sensitive transport perishable products such as fresh produce. This is also attributed to the fact that trucks are used in most cases as the first mode of transportation from the field or packing house to the retail distribution center.

Distribution data is therefore a significant factor in designing optimum product package systems. The dynamic levels measured in actual shipments can also be used to develop test methods to better simulate the shipping environment and avoid product quality loss or value at sales.

The primary objective of this study was to measure and analyze the distribution environment during truck transportation of fresh produce shipments in Thailand. The distribution measurement was focused on the major fresh produce regions to retail distribution centers and then downstream distribution to retail stores. In addition the amount of damage to the produce was also measured. Four different fresh produce items including cabbage, lettuce, pears and plums were shipped and monitored. In addition the measured vibration levels were compared to vibration data used in western countries to simulate truck transport environments.

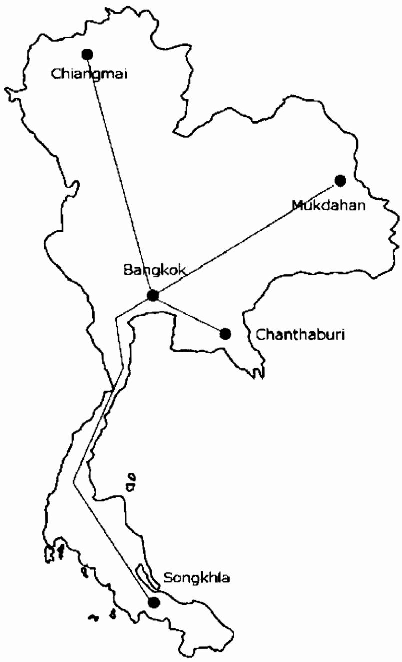


***Figure 1.*** *Thailand map indicating truck transportation routes investigated.*

***Table 1.*** *Truck Shipment Routes Studied.*

| Route | | Distance (km) |
|---|---|---|
| Truck | National Highway (NH) | |
| Bangkok-Chiang Mai (North) | 1 | 700 |
| Bangkok-Mukdahan (North-East) | 2 | 642 |
| Bangkok-Chanthaburi (East) | 3 | 245 |
| Bangkok-Songkhla (South) | 4 | 950 |

Thailand is the world's leading fruits and vegetables producer and exporter. The primary cause of produce loss is physical damage, attributed to vibration forces during handling and transportation. The most common method for shipping produce in many countries, including Thailand is truck transportation. Reusable plastic containers (RPC) are commonly used to package the produce for domestic shipping. The data in this study represents the major routes of produce distribution in Thailand from the growers to the distribution centers, and then onto retailers (Figure 1 and Table 1).

## 2.0 VIBRATION DATA MEASUREMENT AND ANALYSIS

The study measured vibration levels in various truck shipments from various regions of Thailand. A more comprehensive paper on this topic has been prepared that discusses both truck and rail shipments. The Shock and Vibration Environmental Recorder (SAVER) Model 3X90 developed by Lansmont, Corp. (Monterey, CA, USA) was used to quantify vibration levels (Figure 2). The SAVER consists of a piezoelectric


***Figure 2.*** *SAVER model 3X90 (Lansmont, Corp.).*

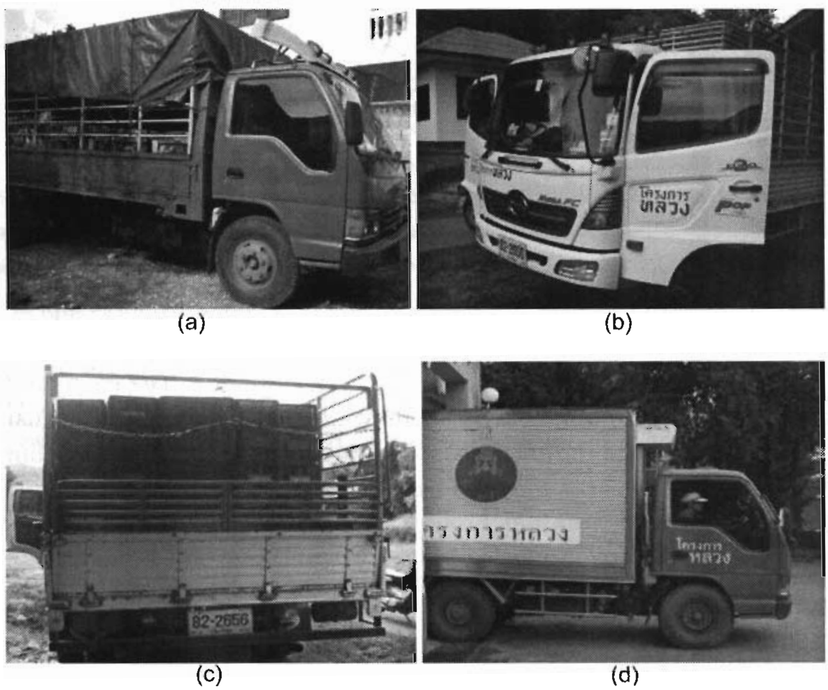

*Figure 3. Various trucks used in the vibration measurement study (a)–(d).*

tri-axial accelerometer, and is a battery powered instrument that measures shock (impact/drop), vibration, temperature, and humidity conditions that occur during shipping and handling. The recorders were mounted on platform base, at the rear floor position. This location produces the highest vertical vibration measurement.

Figure 3 shows the different types of leaf spring trailers used in the different sections of fresh produce distribution. Figure 4 shows the different road conditions that packaged fresh produce is shipped on from the farm to the final retail shelves.

To measure the vibration levels in the various sections of the distribution environment, the following settings were used on the SAVER's for the present study:

- Minimum time triggered sampling: 10 min
- Trigger threshold level: 2.4 G
- Minimum sampling rate: 500 samples per second
- Minimum recording window: 2.048 sec
- Sample size: 1024

## 2.1 Data Collection

The truck shipments in this study were conducted on the major distribution routes in the country. The details of the truck shipments routes are described in Table 2. The speeds of the measured trucks were in the range of 30–90 km/h, where the average speed on the good road conditions was 80–90 km/h, while on the poor road conditions (mostly two-lane roads) was 30–40 km/h. Truck shipment routes measured in this study are shown in Figure 1. The vibration data was analyzed using the SaverXware software (Lansmont Corporation, Monterey, CA, USA).

## 2.2 Data Analysis

The recorded acceleration amplitudes in the random vibration were analyzed as a function of frequency to determine the power density (PD)

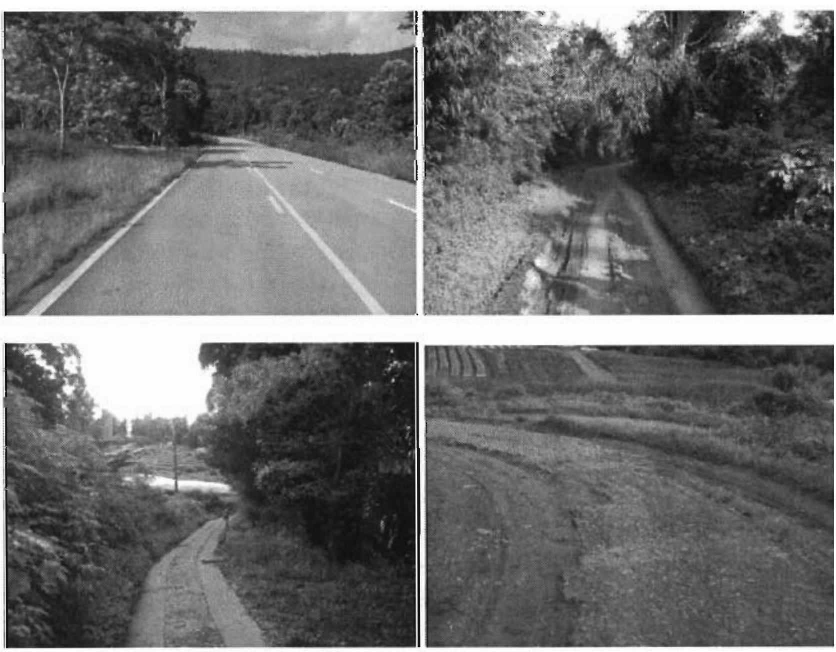

***Figure 4.*** *Various road conditions measured in this study.*

**Table 2.** *The Details of Produce Shipments Studied.*

| Origin | Destination | Average Distance (km) | Average Speed (km/h) | Truck | Load (kg) |
|---|---|---|---|---|---|
| Collecting Centers, Chiang Mai | Packing House, Chiang Mai | 80 | 50 | 6-wheel, unrefrigerated, 2 m × 4.8 m × 1.9 m | 7,200 |
| Packing House, Chiang Mai | Distribution Center, Bangkok | 700 | 70 | 6-wheel, refrigerated, 2.3 m × 7.1 m × 2.2 m | 15,000 |
| Distribution Center, Bangkok | Retailers, Bangkok | 15 | 60 | 4-wheel, refrigerated, 1.7 m × 4.7 m × 2.2 m | 5,000 |

levels. The average PD within a narrow band of frequencies of the spectrum is calculated as follows:

$$PD = \frac{1}{BW}\sum_{i=1}^{n}(RMS\ G_i^2)\ /\ N$$

where RMS $G_i$ is the root mean square acceleration value measured in g within a bandwidth (BW) of frequencies, and $N$ is the number of instants sampled. The corresponding *PD* levels are then plotted against the frequency of the bandwidth to develop the power spectrum density (PSD) plot.

The PSD plot is the variation of the vibration magnitudes as a function of frequencies. Data are presented from 1 to 100 Hz since this frequency band is the most accountable in causing package/product damage during transportation. Average power density spectra of the transport vibration measurement studied were computed and are presented similar to previous studies[1].

## 2.3 Produce Damage

Vibration during truck shipments has been known to be a critical cause of produce damage and loss due to bruising and cutting. Effect of vibration on mechanical damage of several fruits and vegetables such as apples[2], pears[3], peach[4] has been studied before in different regions. The effect of vibration levels and road conditions on damage to packaged tangerines during truck shipments in Thailand was also investigated by Jarimopas et al.[5] The produce distribution network for the Royal Project represented in this study is shown in Figure 5. The Royal Project has a large and extensive network of growers in the mountain areas in the northern region of Thailand. There are a number of fruit and vegetable products under the Royal Project ranging from tropical to temperate produce. The trucks used for produce pick-up from the collecting centers in the mountain areas to the packing house in Chiang Mai were six-wheel non-refrigerated trucks. To transport produce from the packing house in Chiang Mai to the distribution center in Bangkok, six-wheel refrigerated trucks were used. Produce was transported to the retailers by the 4-wheel or 6-wheel refrigerated trucks. All trucks used were a leaf-spring suspension type.

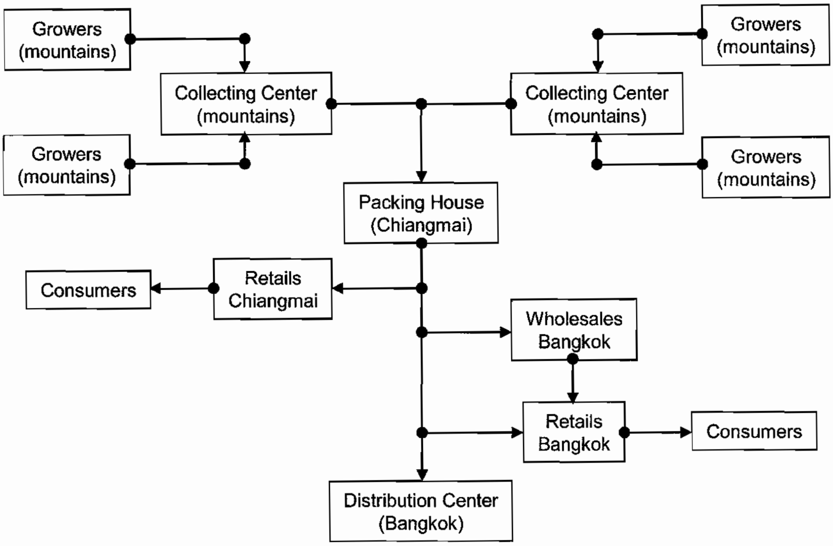


***Figure 5.** The produce distribution network measured in this study.*

The primary objectives of this study were as follows:

1. To measure the vibration levels in the truck shipments of the major produce distribution routes in Thailand.
2. To measure the damage levels attributed to transportation and handling to various produce (cabbage, lettuce, plums and pear).
3. To compare highway vibration levels to inner city transportation from distribution centers to retail stores.

## 3.0 RESULTS AND DISCUSSION

### 3.1 The Truck Vibration Measurement

The average PSD plot developed for Thailand truck shipments in all axes is shown in Figure 6. The data for lateral and longitudinal vibrations is also shown. Since produce items vary in shape from spherical to elliptic, the damage caused to each produce item is a combination of vibration movement in all three orientations and rotational effects caused to the individual fruit, accompanied with dynamic compression. Figure 7 shows the vibration power density spectrums measured from smaller inner city trailers used to move produce from distribution centers to retail stores. These data spectrums were compared to composite vibration

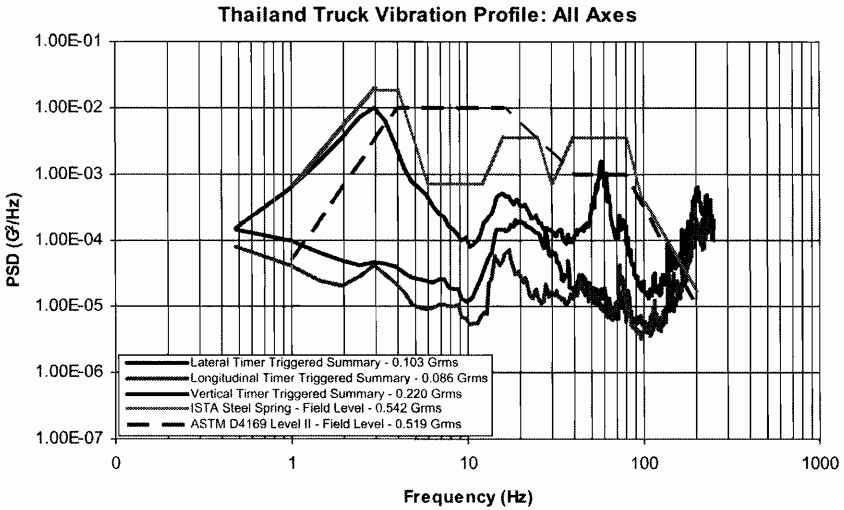


***Figure 6.*** *PSD plot for truck vibration in Thailand in all axes compared with ASTM and ISTA.*

spectrums for vertical vibration that are used for vibration testing and recommended by the American Society of Testing and Materials International[6] (ASTM) and the International Safe Transit Association[7] (ISTA).

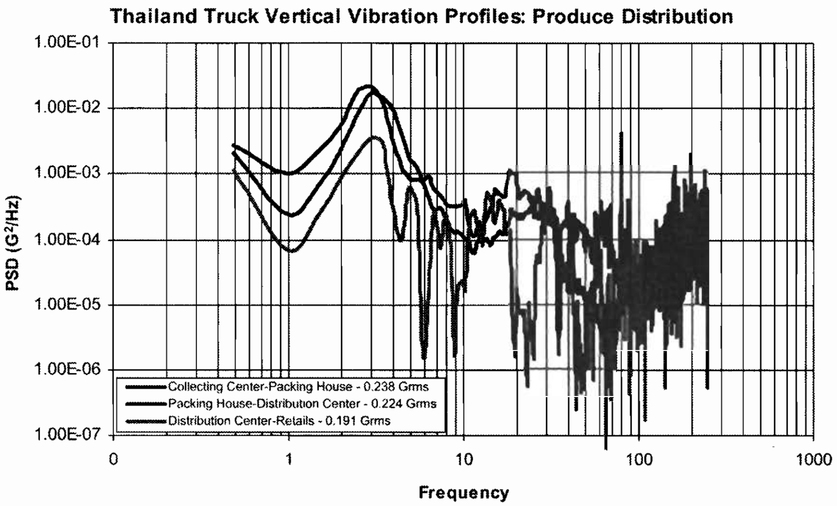


***Figure 7.*** *PSD plot for vertical vibration of different truck shipments for produce distribution in Thailand.*

The results in Figure 6 and 7 show that the measured vertical vibration levels for highway shipments were similar to that of ASTM and ISTA in the low-frequency range (1–5 Hz). However in the higher frequency range the vertical vibration levels for truck highway transport are much lower. These higher frequencies represent the structural response of the trailer and effect of speed. Vibration levels measured in the smaller vehicles from distribution center (IDC) to retail stores are generally higher in the higher frequency regions (Figure 7). The highest vibration levels occurred from the field to packing house (PH), followed by PH to DC's. The lowest overall vibration levels occurred between DC's to retail stores. Table 3 shows Grms levels for the vertical, lateral and longitudinal orientations.

### 3.2 The Produce Distribution Study

In addition to the vibration data, the different produce was also inspected for physical damage due to cuts and bruises. A bruise was identified if it measured more than 1 $cm^2$ and a cut was identified to be 1 cm long with a minimum depth of 5 mm. These levels are generally known to make the sale of fresh produce ineffective at the desired retail price. The data and results from inspecting damaged produce (Figure 8) is presented in Table 4. The produce received at the retailers from the distribution center had the least damage, corresponding to the lowest vibration levels (Figure 7). Higher percentage and intensity of produce damage was observed at the packing house as compared to those at the distribution center. This was due to poor road conditions between the collecting center and the packing house. Bruising and cutting were shown to be the

***Table 3.*** *Average Grms Levels for Different Truck Shipments for Produce Distribution.*

| Spectrum | Route | Orientation | Level (Grms) |
|---|---|---|---|
| 1 | Collecting Centers— | Vertical | 0.238 |
| 2 | Packing House | Lateral | 0.106 |
| 3 | | Longitudinal | 0.061 |
| 4 | Packing House— | Vertical | 0.224 |
| 5 | Distribution Center | Lateral | 0.079 |
| 6 | | Longitudinal | 0.050 |
| 7 | Distribution Center— | Vertical | 0.191 |
| 8 | Retailers | Lateral | 0.072 |
| 9 | | Longitudinal | 0.054 |

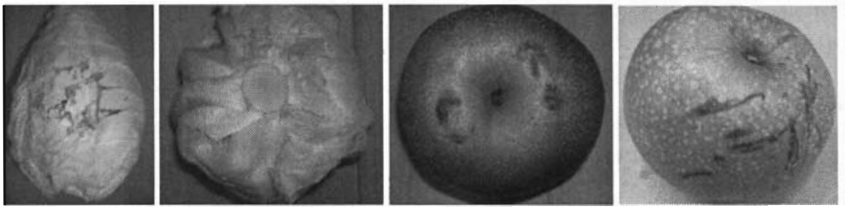

***Figure 8.*** *Physical damage of selected produce after truck transportation.*

primary causes of damage. Mechanical injury is a known cause of rapid deterioration of produce. This is a significant parameter in produce packaging design. It is therefore critical to develop better produce protective solutions for post-harvest handling of produce to reduce the amount of downstream packaging materials, and reduce the burden of packaging materials in today's requirements to reduce packaging and be more sustainable. Reduction in damage delivers more product with less packaging in the entire supply chain.

## 4.0 CONCLUSIONS

- Vibration levels measured in truck shipments in Thailand showed the highest levels in vertical direction, followed by lateral and longitudinal orientations.
- The highest level of vibration occurred from the grower to packing houses, due to the poor road conditions.
- The highest level of damage occurred between the fruits and vegetables being transported to the packing houses.

## ACKNOWLEDGEMENTS

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***Table 4.*** *Percentages Loss of Various Produce After Actual Shipments.*

| | Percentages Damage | | |
|---|---|---|---|
| **Produce** | **At Packing House** | **At Distribution Center** | **At Retailers** |
| Head lettuce | 45 | 30 | 10 |
| Cabbage | 50 | 40 | 15 |
| Chinese pear | 39 | 29 | 21 |
| Chinese plum | 15 | 10 | 5 |

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