# Reducing Transportation Damage

# To Grapes and Strawberries

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## Abstract

In-transit vibration damage to grapes and strawberries results in reduced quality for the consumer and reduced profits for the produce industry. To solve this problem, the first step is to determine which vibrational frequencies are causing the damage. In various tests, grapes and strawberries were subjected to different frequencies at constant force levels. The effects of the vibration treatments were evaluated on the basis of grading, color analysis, firmness, respiration rate and ethylene production rate. The critical frequency was found to lie between 7.5 and 10 Hertz for both commodities. Color change and respiration rate were shown to be good indicators of damage in grapes. Strawberries did not show a significant effect due to color. Firmness was not affected by vibration in either commodity.

## Introduction

The goal of this study is to reduce damage occurring during the truck shipment of grapes and strawberries. Both commodities are produced in large quantities on the West Coast and shipped to the East Coast. Frequently during transcontinental shipment, a significant portion of the load is damaged by highway-induced vibration.

During shipment, grape berries may be shattered from the clusters. (Although all varieties of grapes are susceptible to shattering, Thompson seedless are especially fragile.) The shattered grape berries are less salable than the full clusters and are often discarded. Shattering is one of the inspection criteria the USDA uses to determine whether table grapes meet grade requirements. More than 12 percent shattering in a box is grounds for reduction in grade (USDA, 1971). Shattering is also the most common defect found in grapes arriving in New York, occurring in nearly half of the shipments (Cappellini, 1986). Berries which are not shattered during transportation may be bruised, and this bruising results in discoloration and reduced shelf life.

With strawberries, in-transit vibration may cause skin abrasion and bruising. Under certain transport conditions, when the force of the vibrations approaches the force of gravity, the strawberries become virtually weightless in their containers. In this state, they bump together and rub against each other as they rotate. This contact results in a type of damage called "roller bruising." These abrasions and bruises provide a point of entry for micro-organisms, which reduces the berry's already short shelf life. One type of defect mentioned by the USDA inspection criteria for strawberries is "translucent, dull or watery appearance" (USDA, 1975). This defect is caused by juice oozing from abraded or bruised skin and can result in a reduction in grade.

According to a nationwide study conducted by the University of Michigan, transportation losses for these two commodities topped $18 million a year in the early 1980s (Pierson, 1982). Today, the figure is surely higher. According to shippers in the produce industry, the problem is so severe that some carriers are refusing to carry these commodities.

Highway-induced vibration damage is attributed to a combination of factors, including the roadbed, the suspension and the packaging. This problem may have been exacerbated in recent years by regulations allowing the use of longer trailers. Longer trailers have a greater proportion of their length behind the rear wheels. The increased distance acts as a cantilever, causing vibrations to be magnified at the rear of the trailer. Research has shown that this problem could be greatly reduced or even eliminated if trailers used air suspension (O'Brien, 1969). Unfortunately, air suspension is expensive to purchase and maintain; consequently, most trucks are equipped only with leaf springs.

There are several approaches which could reduce in-transit vibration damage occurring to strawberries and grapes and other commodities. These include altering the suspension of the truck, changing the pallet design, or packaging the fruit differently. The first step toward implementing any of these solutions is to determine which vibration frequencies are causing the damage. Research on other types of fruit has found that the majority of damage occurs in a very narrow range around the critical or resonant frequency (Chesson, 1971; Kawano, 1984).

Resonance occurs when the vibrations from the roadbed are at the same frequency as the natural frequency of the load. At the resonant frequency, the force of the vibrations is magnified and the vertical movement of the load also increases. The vertical motion is most severe at the top of the load. If the packaging or the suspension can be altered so that the force of vibrations going into the load at the resonant frequency is reduced or damped out, the produce will suffer less damage.

## Objectives

The research presented here was the first phase of a larger project designed to reduce in-transit vibration damage to fresh produce. The objective of this phase was to determine the critical frequencies for grapes and strawberries. Another related objective of the research was to develop practical and effective methods for evaluating quality loss during the transportation phase of distribution.

## Methodology

Three lots each of Thompson seedless grapes and Selva strawberries were obtained from a major shipper in California. The produce was transported to the USDA Transportation Research Facility in Beltsville, Maryland. To reduce the effect of this shipment on the results, the strawberries were graded for quality, and all shattered grapes were removed before the experiment began. The grapes were packed in 25-pound wooden and fiberboard lugs. The strawberries were packed in plastic pint baskets, with 12 pints to a flat.

The produce was vibrated at the frequencies and conditions shown in Table 1.

**Table 1**

Experimental Parameters

| | |
|---|---|
| *Grapes* | |
| Frequency (Hz) | 2-5, 5-10, 10-15, 15-20, 20-25 and 25-30 |
| Force level | 0.75 g for all frequency levels |
| Time period | 60 minutes for each frequency level |
| *Strawberries* | |
| Frequency (Hz) | 2-5, 5-10, 10-15, 15-20, 20-25 and 25-30 |
| Force level | 0.6 g for all frequency levels |
| Time period | 30 minutes for each frequency level |

Vibrational frequencies were chosen to fall within the range measured in trailers during over-the-road travel (Peleg, 1986). The force levels were increased over average values to allow a reduced vibration time (Kawano, 1984; Peleg, 1986).

The commodities were placed on the vibration table as they would normally be loaded onto a truck, except that only one stack was used for each treatment level. Figure 1 shows the vibration table and the wooden bracing used to hold the stacks upright. The experiment was conducted three times with each commodity to average out any effects due to maturity of the fruit or previous handling conditions.

VIBRATION TABLE AND CONTROL SYSTEM

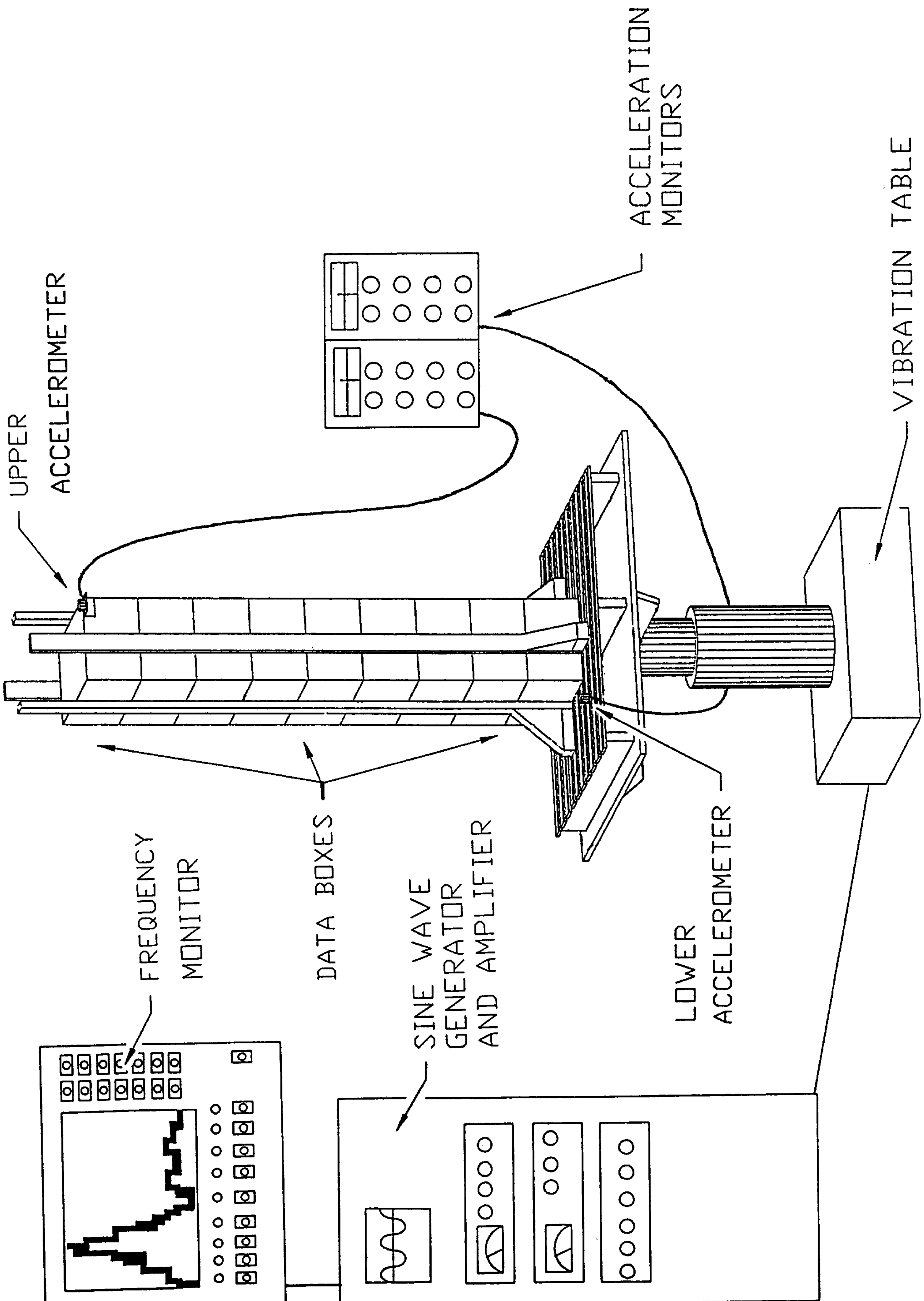


FIGURE 1

Preliminary results showed that the 5 to 10 Hz range caused the most damage to both commodities. To pinpoint further the critical frequency, two additional treatments at 5 to 7.5 Hz and 7.5 to 10 Hz were added to the experiment.

As Figure 1 shows, the sample boxes were in the top, middle and bottom positions. These positions were chosen to evaluate the effect of location in the stack on in-transit damage.

After vibration, the quality of the fruit in each frequency level and stack position was evaluated in several ways. In the case of the grapes, the shattered berries were removed and weighed. The strawberries were graded into five categories, ranging from unbruised to very severely bruised. The color and firmness of the fruit was also measured. Finally, the respiration rate and ethylene production of the fruit from each treatment level was measured using gas chromatography.

**Results of the Grape Trials**

Before treatment, the grapes had an average of 8 percent shattered berries due to previous handling and the trip from California. Figures 2 and 3 show the percentage of the total weight in each lug that was shattered by the different frequency treatments. The 5 to 10 Hz range clearly caused the most damage, with 16 percent of the fruit shattered. At 16 percent shattered, the grapes would have been downgraded, according to USDA criteria. The effect of position is also significant ($p \leq 0.05$) in the 5 to 10 Hz range. The top box received twice as much damage as the middle box and four times the damage of the bottom box.

Figure 3 shows the breakdown within the 5 to 10 Hz range. More damage occurred in the upper half, from 7.5 to 10 Hz, although there was 13.5 percent shattering in the lower range as well. Once again, the pattern due to position is evident.

Color analysis showed that the grapes that vibrated at the 5 to 10 Hz range became significantly ($p \leq 0.05$) darker after treatment. After one week of storage, the fruit in the 5 to 10 and 10 to 15 Hz treatments were significantly ($p \leq 0.05$) darker than those in other treatments. The darkening was probably due to sub-surface bruising. Firmness of the fruit was not affected by the vibration treatments at $p \leq 0.05$.

Figure 4 shows the rate of respiration for grapes from the various frequency treatments. The increased rate of carbon dioxide production by the grapes in the 5 to 10 Hz range is another indication that this range causes the most damage to the fruit. The vibrated grapes did not produce enough ethylene to draw any conclusions.

**Results of the Strawberry Trials**

Damage to the strawberries was evaluated by weighing the unsalable berries after each treatment. Berries were graded as unsalable if the skin was seriously abraded or the bruises penetrated deeply into the surface.

Figure 5 shows that more than 50 percent of the strawberries in the top box in the 5 to 10 Hz range were unsalable after the vibration treatment. Furthermore, Figure 6 shows that this damage was limited to the 7.5 to 10 Hz range.

Color and firmness measurements were not affected by the vibration treatments at the 95 percent confidence level.

**Conclusions**

The majority of damage for both commodities was caused by vibrations between 7.5 and 10 Hz. The data also shows that there is some damage in the 5 to 7.5 Hz range in the grapes. This difference between the two fruits is probably due to differences elasticity and mass of the fruit, and its packaging. By damping the force of the vibrations between 7 and 10 Hz, the amount of damage could be greatly reduced. It would be interesting to test other commodities to see if they also fall in this narrow range.

Color and respiration rate were shown to be good measures of quality in grapes, since the results for these parameters mirrored the weight of shattered berries. For strawberries, none of the parameters tests was an accurate, quantitative reflection of damage. Additional work in this area is needed.

The next phase of this project will involve testing new types of packaging both in the laboratory and over-the-road to reduce damage.

**References**

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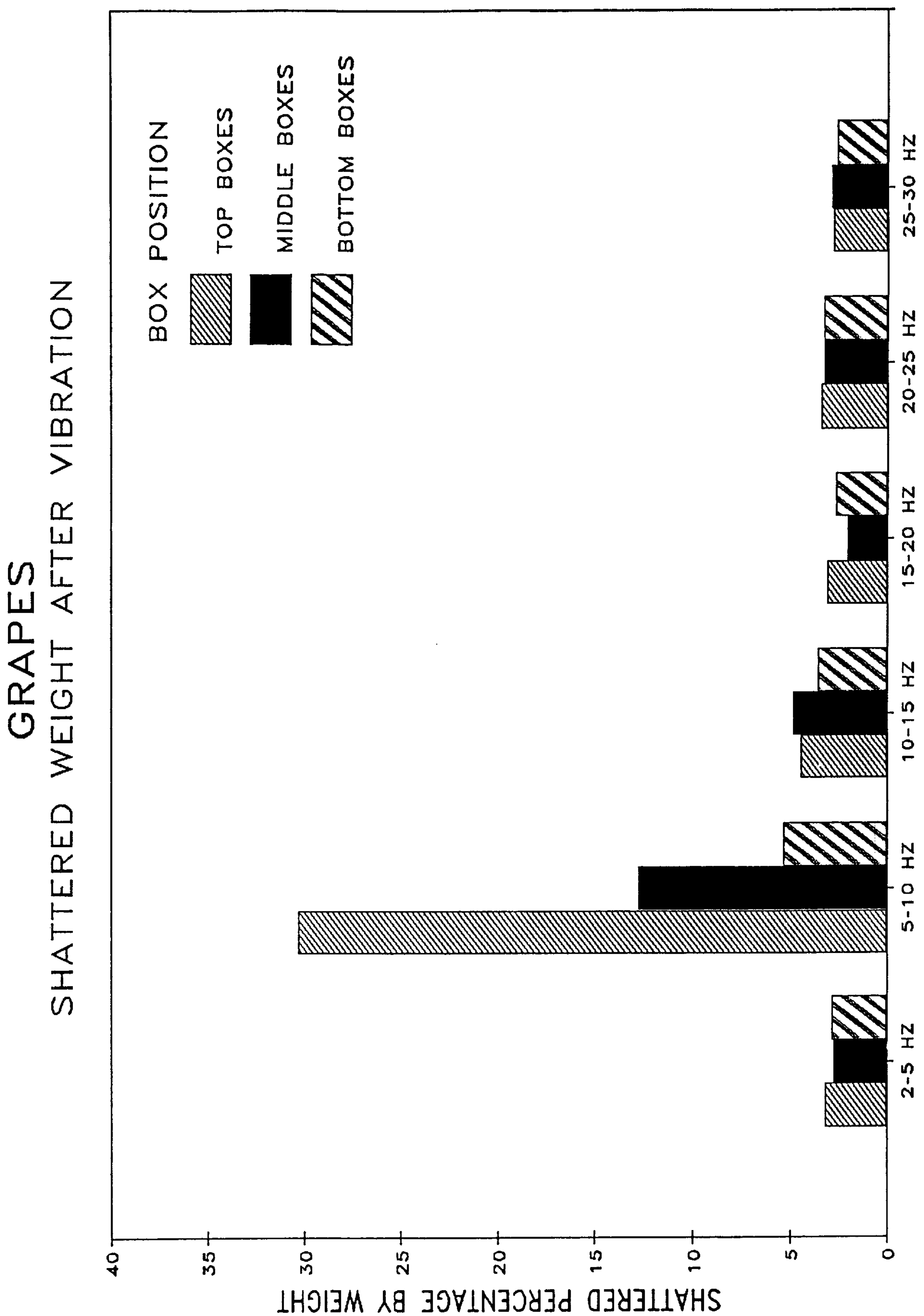

GRAPES
SHATTERED WEIGHT AFTER VIBRATION
BOX POSITION
TOP BOXES
MIDDLE BOXES
BOTTOM BOXES
SHATTERED PERCENTAGE BY WEIGHT
0
5
10
15
20
25
30
35
40
2-5 HZ
5-10 HZ
10-15 HZ
15-20 HZ
20-25 HZ
25-30 HZ
FREQUENCY TREATMENTS

FIGURE 2

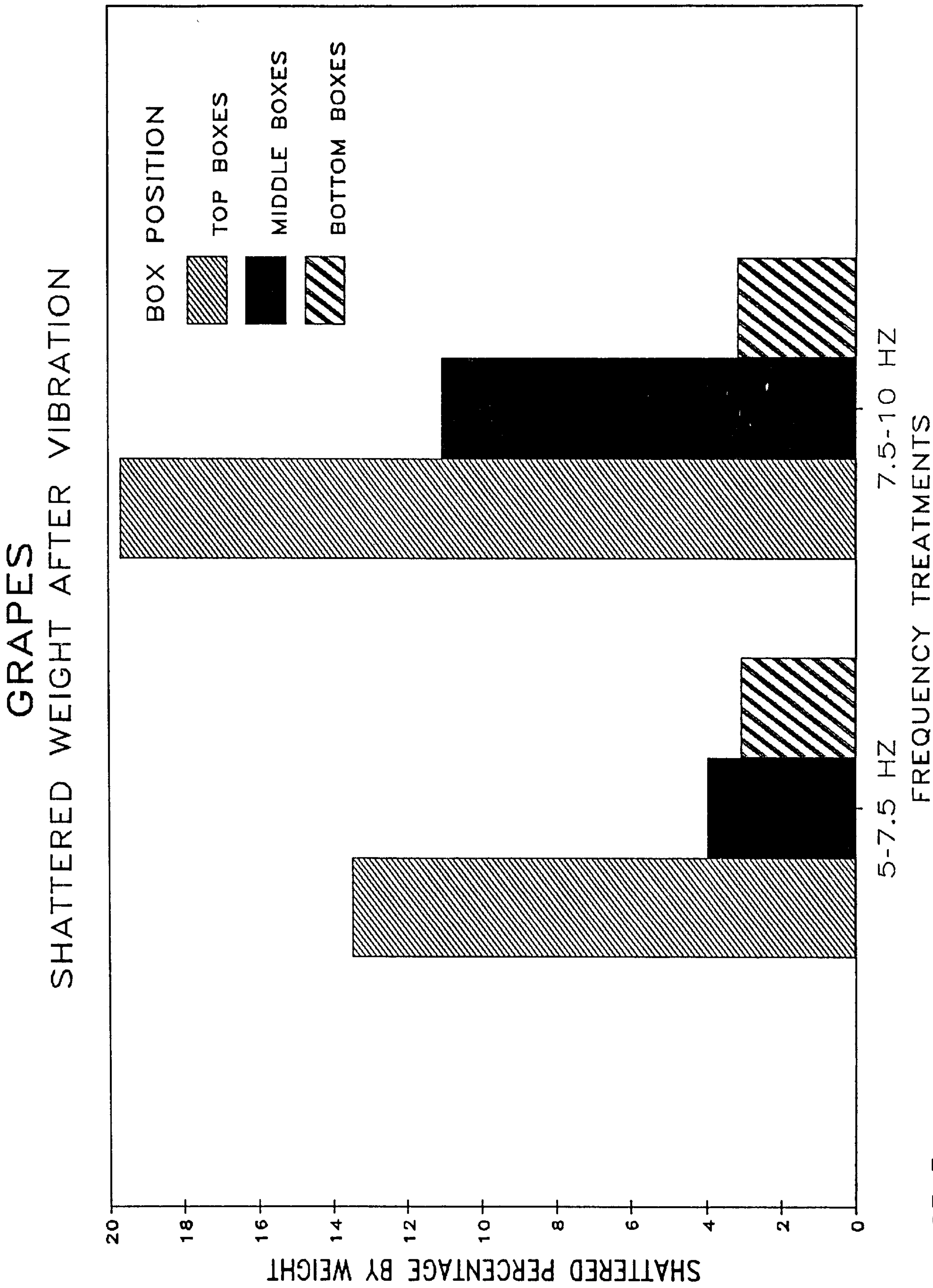

GRAPES
SHATTERED WEIGHT AFTER VIBRATION
BOX POSITION
TOP BOXES
MIDDLE BOXES
BOTTOM BOXES
SHATTERED PERCENTAGE BY WEIGHT
0
2
4
6
8
10
12
14
16
18
20
5-7.5 HZ
7.5-10 HZ
FREQUENCY TREATMENTS

FIGURE 3

## GRAPES

### CARBON DIOXIDE PRODUCTION RATE (TOP BOXES)

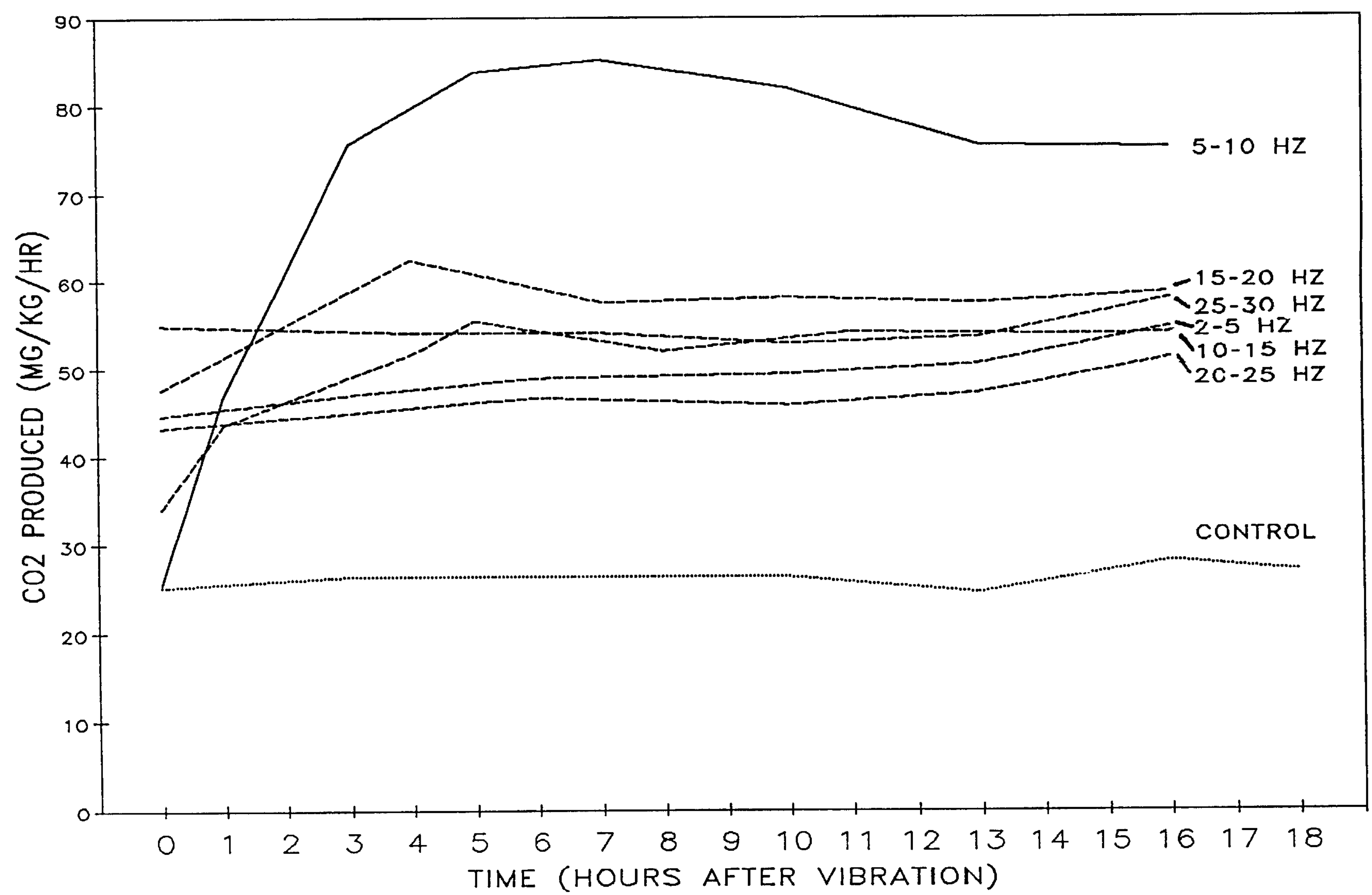
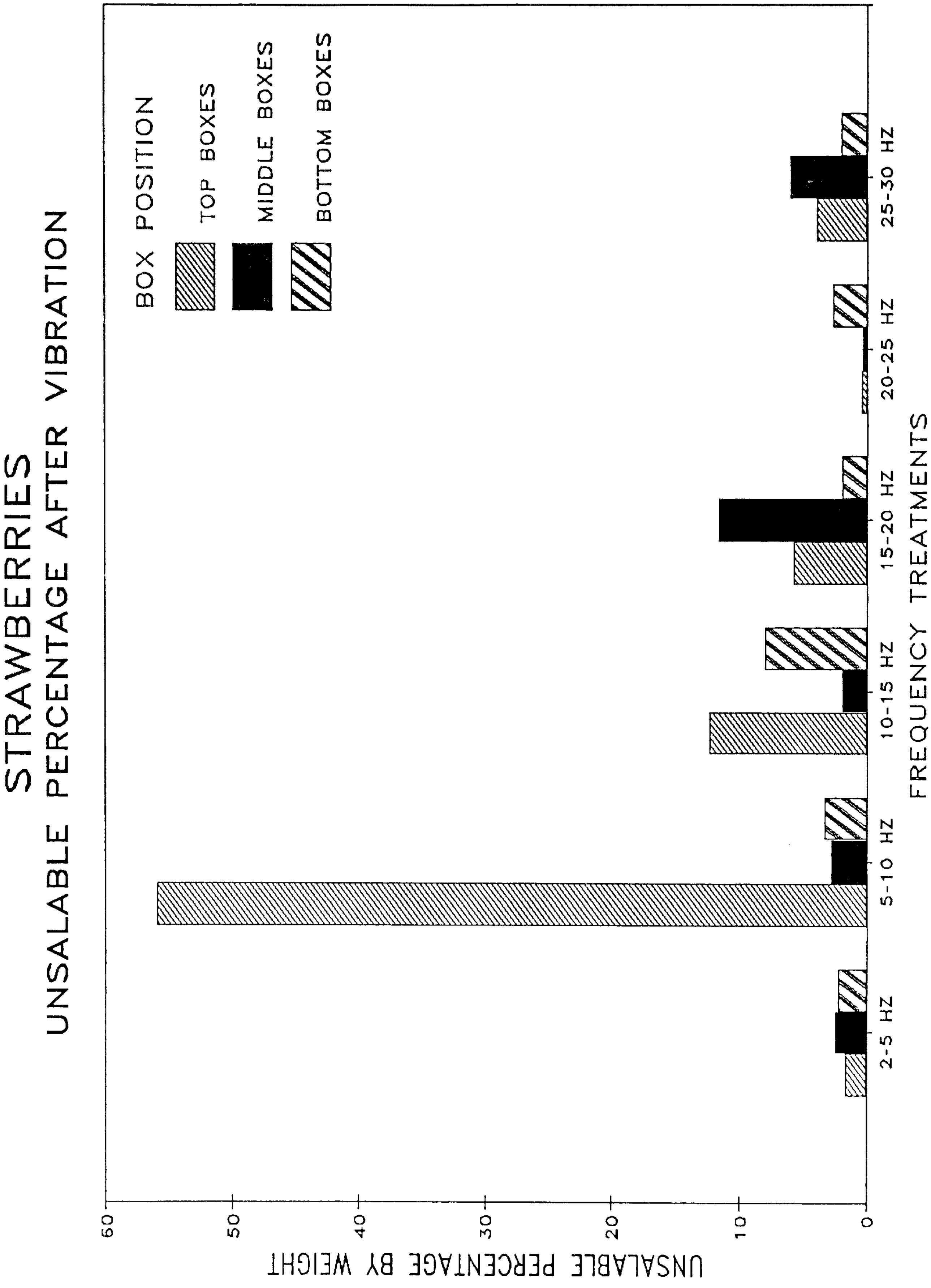



FIGURE 4



STRAWBERRIES
UNSALABLE PERCENTAGE AFTER VIBRATION
BOX POSITION
TOP BOXES
MIDDLE BOXES
BOTTOM BOXES
UNSALABLE PERCENTAGE BY WEIGHT
0
10
20
30
40
50
60
2-5 HZ
5-10 HZ
10-15 HZ
15-20 HZ
20-25 HZ
25-30 HZ
FREQUENCY TREATMENTS


FIGURE 5

STRAWBERRIES
UNSALABLE PERCENTAGE AFTER VIBRATION

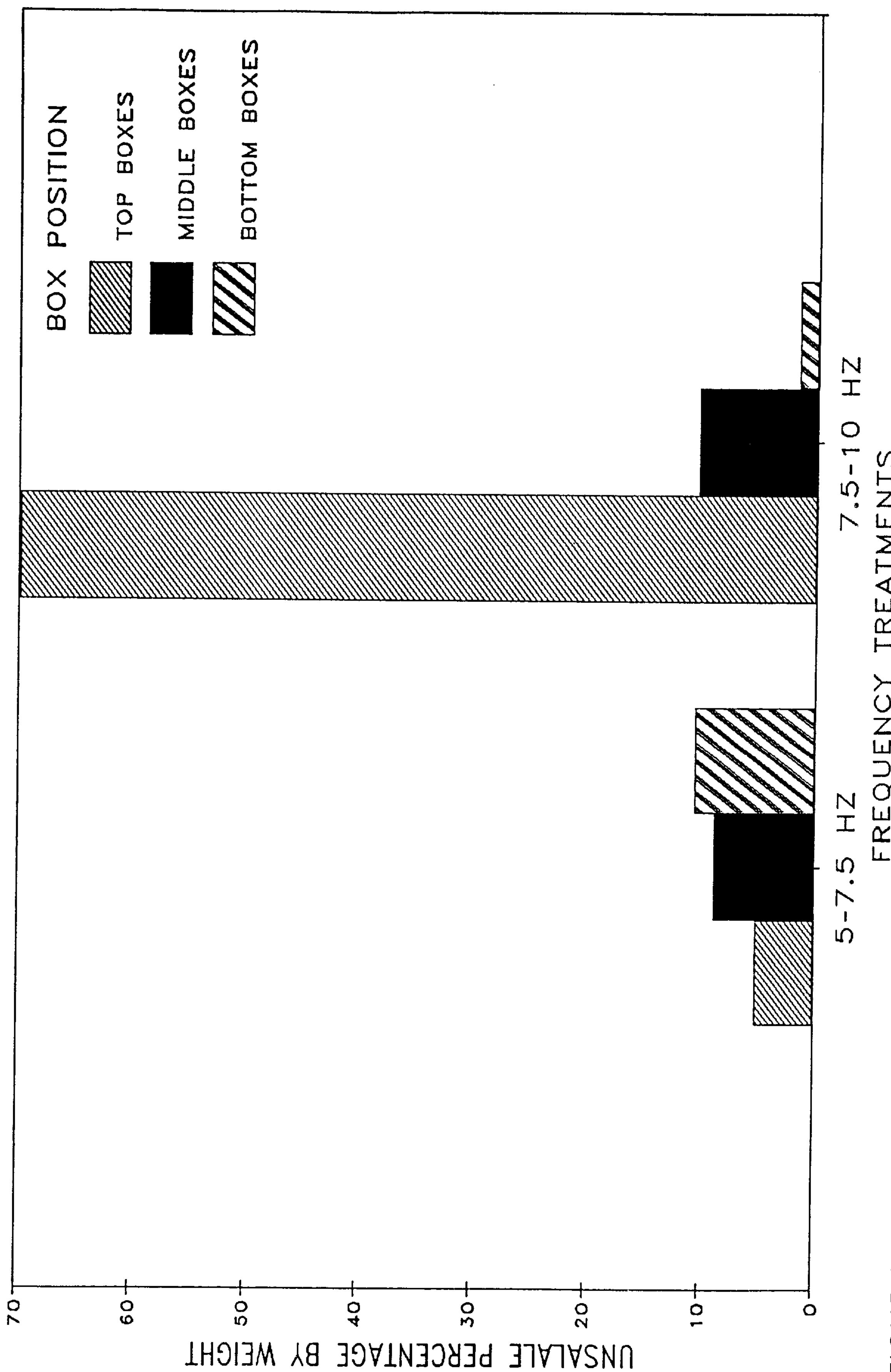



FIGURE 6

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