Measurement and analysis of vibration and mechanical damage to bananas during long-distance interstate transport by multi-trailer road trains

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Abstract

Mechanical damage induced by vibration is a known cause of quality deterioration and wastage of fresh produce in post-harvest supply chains. The need to minimize visual defects in fruits, such as bananas, is being driven by the growing consumer preference for high quality produce. Transport of produce interstate and internationally from the growing regions to major retail markets, however, increases the risk of exposure of fruits to injurious vibration excitation. This study measured the vibration, and consequential mechanical damage, to bananas stacked at different stack heights and positions in a multi-trailer road train during an interstate road transport of over 3000 km in distance. Significantly different damage levels in bananas were observed in different pallet positions of the road train with the highest damage propensity revealed at the most rear pallet position. The damage levels in each pallet position were found to closely correspond with the Root-Mean-Square (RMS) acceleration of the vibration excitation on the trailer floor. The highest energy Power-Spectral Density (PSD) peaks were revealed to be concentrated in the lower frequency range (0.1–5 Hz). The cartons stacked in the top tiers of each pallet showed significantly increased mechanical damage followed by the bottom tiers with the middle-tiers exhibiting minimal damage. Palletized banana cartons subjected to simulated vibration, on a laboratory vibration simulator, demonstrated that vibration in the high frequency range (>30 Hz) was attenuated with the height of the carton in the pallet. However, the transmissibility of vibration energy in the range of 3–20 Hz was the greatest in the top-tier cartons, resulting in excessive mechanical damage to the bananas. The characterization of damage to bananas at different stack positions\heights of multi-trailer road trains is an integral step for the development of damage reduction mechanisms. These would require the design, optimization, and simulation testing of better packaging alternatives targeted at minimizing the occurrence of mechanical injury in-transit.