Phytosanitary hot water treatment for fruit fly control in West African mango exports

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Issues/Challenges

- Fruit flies (Diptera: Tephritidae) are among the most important regulated pests affecting international mango trade. Market access for West African mango exports to the European Union depends largely on the effective implementation of systems approaches. However, post-harvest chemical control options are extremely limited.
- Hot water treatment (HWT) is internationally recognized as an effective phytosanitary treatment for fruit fly control. While HWT is technically well established, its suitability for West African mangoes shipped by sea had not been validated under commercial export conditions. Concerns remained regarding fruit tolerance to heat and the ability to maintain commercial quality throughout transport, ripening and shelf-life.

Actions taken

This work was carried out through an international cooperation framework coordinated by COLEAD under the EU-funded Fit for Market Plus programme. The initiative brought together scientific, export and import partners to generate evidence under commercial conditions. The partnership included:

- **Greenbean Scientific Ltd** – experimental design, statistical analysis and quality assessment;
- **APEX-KO (Côte d'Ivoire)** – hosting of experimental hot water treatment (HWT) facilities and field trials at exporter level;
- **Ripe Now Ltd (United Kingdom)** – support to commercial sea freight trials and post-arrival quality evaluations.

The study was conducted over two export seasons (2020–2021) on Kent and Keitt mangoes produced in Côte d'Ivoire. Hot water treatment trials were implemented under commercial conditions.

The USDA–APHIS reference protocol (46.1 °C for 75–90 minutes, depending on fruit size) was used as the reference treatment. Alternative protocols were tested to reduce heat damage while maintaining phytosanitary efficacy, including:

- Lower temperatures (45.1 and 45.6 °C);
- Higher temperatures (50, 52 and 55°C) to control post-harvest diseases;
- Shorter treatment durations;
- Different post-treatment cooling methods.

Two cooling approaches were also evaluated:

- Conventional air cooling in a cold room (12–17 °C);
- Hydrocooling by immersion in water, either at ambient temperature (~27 °C) or chilled (~16 °C).

Fruit fly mortality was assessed by counting live and dead larvae following treatment. Fruit quality was evaluated through external, internal and sensory assessments. Treated fruit were shipped by sea from Côte d'Ivoire to the United Kingdom under commercial export conditions and assessed on arrival, after ripening and at the end of shelf-life.

Key results

The standard hot water treatment protocol at 46.1 °C achieved complete fruit fly larval mortality, confirming its phytosanitary effectiveness (Fig. 1). However, this treatment caused severe external and internal heat damage to the fruit (Fig. 2). Observed defects included:

- Scalding
- Lenticel darkening
- Pitting
- Development of internal cavities

Quality deterioration intensified during ripening and shelf-life, resulting in fruit that was commercially unacceptable after sea freight. Alternative protocols using lower temperatures reduced the severity of heat damage but resulted in incomplete fruit fly control (one larvae survived). Even the survival of a single larva is sufficient to trigger consignment rejection under phytosanitary regulations.

Reducing treatment duration at 46.1 °C did not significantly reduce fruit damage, indicating that temperature was the main factor driving heat injury. Post-treatment cooling methods also influenced outcomes:

- Hydrocooling (ambient or chilled water) increased the incidence of defects
- Conventional cold-room air cooling resulted in fewer defects (Fig. 4)

The nature and severity of symptoms varied across fruit sizes and between seasons. Differences were observed between the two export seasons (2020-2021) in the susceptibility of Kent mangoes sourced from the same farms, suggesting an influence of growing conditions and fruit maturity at harvest. The study further demonstrated that, given the high temperatures required to control post-harvest diseases (>50°C), achieving simultaneous control of fruit flies and post-harvest pathogens through Hot Water Treatment (HWT) was not feasible under the tested conditions.

Conclusions

Hot water treatment is technically effective for fruit fly control in mangoes. However, the high susceptibility of Ivorian Kent and Keitt mangoes to heat injury, combined with seasonal and size-related variability, makes a standard HWT protocol commercially unviable under sea-freight export conditions.
A single fixed protocol cannot reliably ensure both phytosanitary efficacy and marketable fruit quality across seasons or even within a single export campaign. Protocols requiring continual adjustment would be operationally impractical and economically unsustainable. These findings underline the importance of:

- science-based validation of phytosanitary treatments under commercial conditions;
- realistic assessment of trade-offs between phytosanitary efficacy and product quality;
- continued international cooperation under the IPPC framework to identify alternative solutions and strengthen system approaches for safe trade.

Figure 1 – Phytosanitary efficacy of hot water treatment

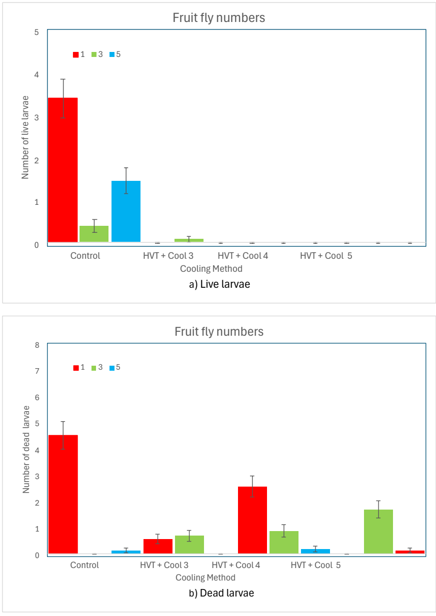

Fig. 1. Average effect of hot water treatment (HWT) and cooling method on number of (a) live and (b) dead larvae for all fruit (2021 season). Bars show means ± standard errors for two-way analysis of deviance. Heat treatments: 1 = 46.1 °C for standard durations; 3 = 45.1 °C for standard durations; 5 = 46.1 °C for short durations (10 min less than standard). Cool 3 = hydrocooling with ambient water; Cool 4 = hydrocooling with chilled water; Cool 5 = cold room.

Figure 2 – Visual evidence of heat damage and commercial unacceptability

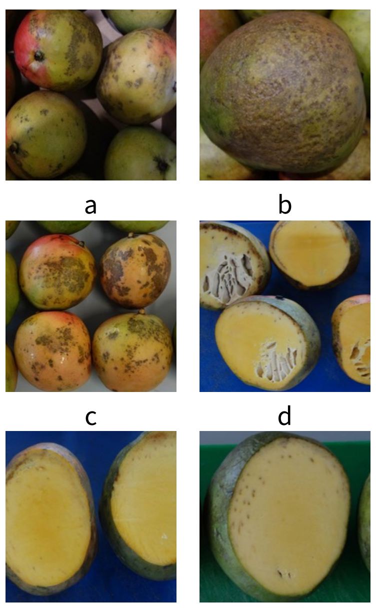

Fig. 2. Heat damage on Kent mangoes treated at 46.1 °C for 90 min, on arrival in UK after sea freight in 2021. (a,b) Count 7 size mango on arrival in the UK showing pitting; (c–f) count 7 mango post-ripening: (c) pitting, (d) internal cavities, (e) discoloured pulp around rim, (f) discoloured resin canals.

Figure 3 – Quantified impact of HWT on fruit quality along the supply chain

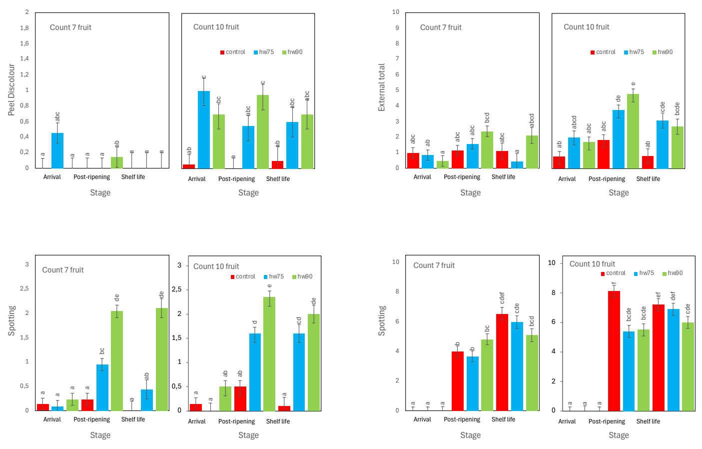

Fig. 3. Effect of hot water treatment (HWT) (46.1 °C for 75 or 90 min) on quality measures of count 7 and count 10 size fruits assessed at arrival, post-ripening, and end of shelf-life (5 days), 2020 season. (a) Peel discoloration ("scalding"); (b) total external defects; (c) darkened lenticels; (d) total sensory score. Bars show mean ± SE from three-way ANOVA model. Compact letter display (CLD): bars with the same letter are not significantly different (Tukey HSD test). Control = untreated fruits; hw75 = HWT for 75 min; hw90 = HWT for 90 min.

Figure 4 – Effect of temperature and cooling method on defect severity

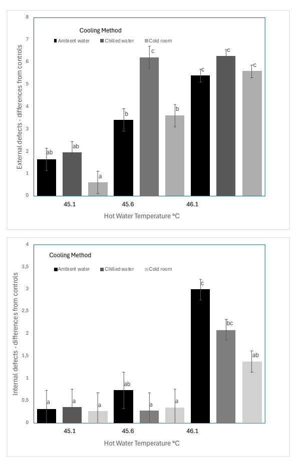

Fig. 4. Effect of hot water treatment (HWT) temperature and cooling method on (a) total external and (b) total internal defects in Kent mangoes, 2021 season. Compact letter display (CLD) shows groups of means that are not significantly different following a Tukey multiple comparison test.