Research Article

Role of Sorting Efficiency at Packing Stations in Reducing Fruit Fly-Infested Mangoes at Post-Harvest Stage in Western Burkina Faso

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Abstract | Mango is one of the economically important fruits of Burkina Faso, being exported to many European and American countries. Interception and rejection of mango exports at ports and airports can be reduced by improving their supply chains, particularly at the packing stations, through efficient sorting and detection of fruit infestations by fruit flies. In Burkina Faso, fruit flies are a major constraint on the mango industry. They cause substantial losses at different levels of the mango value chain. The objective of this study was to enhance the post-harvest management of fruit fly infestation in mangoes intended for export. This entailed evaluating the incidence of fruit fly infestation in mangoes received at the packing station and after sorting, and determining the extent to which in-station sorting mitigates fruit fly infestation on exported mangoes. This was achieved by taking random samples of 40 mangoes from each batch at the reception and post-sorting stages of the mango supply chain. Three packing stations selected in the city of Bobo Dioulasso, Burkina Faso, were New Ranch Koba (SN Ranch Koba), Agro Burkina (Agro B), and Fruit Terminal Management Companies. Following incubation in the laboratory, the infested mangoes were counted to determine the average number of infested fruits and the percent infestation rates. The results showed that fruit infestations in samples at both levels of the packing chain did not differ significantly among the packing stations. However, during the 2022 and 2023 seasons, about 97.7 and 87% of the fruit infestations were not eliminated by the prevailing sorting techniques, respectively, demonstrating the inefficiency of the sorting stage, and hence resulting in a high risk of interception and rejection of mango containers intended for export.

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Keywords | Mango export, Postharvest sorting, Fruit fly infestation, Pest detection, Africa, Packing stations, Quarantine measures

Introduction

Mango cultivation is one of the major agricultural production sectors in Burkina Faso and generates annually more than 17.6 million USD revenue (MASA, 2014; APEMA-B, 2018). In 2021, national mango exports totaled 12 thousand tons, generating about 13.9 million USD (APROMAB, 2018). During the 2021 campaign, the total quantity of fresh mangoes produced was estimated at 199 thousand tons, equating to an average yield of about 9.51 tons per hectare, and it was 27% less than the 2020 campaign, with an estimation of 271 thousand tons (UNPEM-B, 2021). This decline in mango production can be attributed to several factors, including abiotic, biotic, and socio-economic constraints faced by this sector (Bota *et al.*, 2018).

The main biotic constraint encountered by the mango production sector is the incidence of fungal diseases and insect pests (Ngamo *et al.*, 2010; Ouedraogo *et al.*, 2011; Song-Naba, 2017; Karim *et al.*, 2025). Among insect pests, fruit flies are the most significant pest affecting mango fruits (Ekesi *et al.*, 2009; Lloyd *et al.*, 2010; Ouédraogo, 2011; Gomina, 2015; Isabirye *et al.*, 2015; Zida *et al.*, 2023; Babar, 2025). In the context of the export market, the financial impact of these insect pests is considerable, as they are categorized as destructive quarantine pests (N'Depo *et al.*, 2009; CTA, 2013; Opoku *et al.*, 2025). Losses incurred by the fruit flies are reflected in the interception and incineration of mango containers at the exporter's expense upon the detection of at least one fruit fly larva in the mango fruit (Pouillès-Duplaix, 2008; CTA, 2013). During the 2022 mango season, about twenty mango containers from Burkina Faso were intercepted due to the presence of fruit fly larvae (EUNSPH, 2022), inflicting about 1.0 million USD loss. This situation gives rise to questions regarding the efficiency of sorting operations at packing stations.

A variety of control measures have been developed and implemented at the orchard level, utilizing fruit fly trapping methods with pheromones and food baits (Nanga Nanga *et al.*, 2022; Zida *et al.*, 2023; Opoku *et al.*, 2025). While this control method is effective in reducing pest infestations, it is important to note its limitations. Later on, the larval populations that escape these control measures are then detected at the fruit sorting stations. It is vital to develop the technical capacities required to effectively monitor and identify the infested mango fruits. To date, there has been limited research conducted on the detection and management of fruit fly infestation in fresh mango packing stations, to identify responsibilities along the packing line and develop suitable solutions (Parrot *et al.*, 2022).

As the protection of export-quality agricultural produce, including mango fruits depend on the integrated pest management and precision agricultural techniques (Kebe *et al.*, 2023), this study was initiated at New Koba Ranch Company (3828 Bobo Dssoifu, Burkina Faso) during the 2022 season. The study was repeated at three packing stations during the 2022 and 2023 seasons. The objective of the study was to enhance the post-harvest management of fruit fly-related issues in mangoes, with a view to minimizing interceptions and augmenting mango exports from Burkina Faso. The study objectives were threefold: firstly, to assess the importance of fruit fly infestations on mango consignments received at the packing station; secondly, to assess the importance of fruit fly infestations in mangoes after sorting at the packing station; and thirdly, to measure the contribution of sorting step at the packing station in reducing fruit fly infestations in post-harvest mangoes destined for export.

Materials and Methods

Study site and mango export companies

The study was conducted in the western part of Burkina Faso in the city of Bobo Dioulasso, where the majority of fresh mango packing facilities are located. The companies involved in this study were New Koba Ranch Company, Burkina Agro Company, and Fruit Terminal Management Companies, targeting the markets of France, Germany, Belgium, Spain, England, Libya, Morocco, Kuwait, and the USA. The fruit products of these companies are collected from different regions of Burkina Faso and are usually certified according to the standards of Organic, Ecossert, Global-GAP, BSCI, HACCP, and NOP. All mango growers, whether organic or conventional, are well registered and coded in the traceability system.

Fruit and pest sampling protocol

The Kent and Keitt varieties of mango were used as the plant material. It is important to acknowledge the appreciation of these varieties by the importing countries. One category of these fruits was subjected

to post-harvest sorting in the field, while the other was subjected to further sorting at the packing station. The insect pest material comprised eggs and different larval stages of fruit flies found in the infested fruit, and pupae collected during the incubation period. For the incubations, plastic basins with a capacity of 10 liters were used, in which sterilized sand was filled and were closed with coarse-mesh netting, muslin cloth, plastic rings, and an incubation cage. Pupae were placed in labelled glass Petri plates.

Mango fruits sorting at the packing station was based on the relevant sanitary and phytosanitary standards and requirements. These requirements include major quality issues such as disease (e.g. anthracnose, bacteriosis, rot, and mold around the mango stalk), insect pests (e.g. fruit flies and mealybugs), and soft noses. The sorting process was conducted manually, with the mango anomalies being identified by women labor with training in their recognition. From a fruit fly management point of view, the sorting process was based on the observation of the ovipositioning points by female flies. At the sorting table, each mango was carefully inspected to ascertain any potential ovipositioning points, and those that do not meet the required standards were then discarded.

Mangoes sampling

Mango samples were taken at two levels of the packing line. Frist at the reception of fruits at the dock, sourced from various orchards and delivered by trackers to packing stations. These fruits have been meticulously sorted in the field to ensure adherence to rigorous sanitary, phytosanitary, and quality standards, with no evidence of fruit fly infestation. Secondly, the post-sorting fruits were taken, which were ready to be exported. In accordance with the regulatory and commercial requirements of the destination market, these have been sorted and are considered to be free from fruit fly infestation.

At the packing station, forty mangoes from each of the two levels were selected on a random basis depending on their geographical origin. In accordance with the established rhythm of mango supply, three samples were collected from each packing station on a weekly basis. During the 2022 campaign, a total of 30 samples were collected from each station, with 15 samples being collected from each level of the packing line. During the 2023 campaign, 36 samples were taken from each packing station, including 18 at each level of the packing line. The mango samples collected were labelled and transported to the laboratory for incubation, monitoring, and fruit fly pupal collection.

Fruit incubation and infestation assessment procedure

The fruits were incubated in a shaded facility. This enabled the progression of the tephritid immature stages in mangoes, facilitating the identification of affected mangoes. The process involved placing the batches of mangoes in plastic pots (10 L capacity) containing sterilized sand and a coarse-mesh screen placed beneath. The label pot is covered with a muslin cloth fabric, held in place by an elastic ring. The set is placed in incubation cages. For monitoring of pupae, the pots were removed from the cages at 5-day intervals, and sand was sieved to collect the pupae. The identification of mango infestations has been based on descriptions provided by Zida *et al.* (2023). The Petri plates were used to collect the pupae, and the fruits containing larvae were again placed under incubation for further detection.

The infestation levels of mangoes were evaluated at the reception and again after sorting at the packing station. At both levels of the supply chain, the assessment was based on determining the average number of infested mangoes. The infestation rate (%) was obtained using the following formulae:

$$Average\ number\ of\ infested\ fruits = \frac{\sum Mangoes\ infested\ in\ all\ repetitions}{Number\ of\ replications}$$

$$Infestation\ rate\ (\%) = \frac{Number\ of\ infested\ fruits}{Total\ number\ of\ fruits\ in\ sample} \times 100$$

Statistical analysis

Data regarding the fruit infestation was processed in MS Excel. This facilitated the calculation of the average number of infested mangoes and the infestation rates. The statistical analysis was conducted using Genstat® Discovery Edition 4 software. A student Newman-Keuls test was carried out to compare the mean infestation rates of fruit samples at the reception with those of the sorted samples in packing stations. The test was conducted at a confidence level of 95% in order to assess the efficiency of the sorting process at the packing stations.

Results

Fruit fly infestations recorded at the reception stage

According to the results of the 2022 season (Figure 1),

the average number of infested fruits at the SN Ranch Koba varied between zero and four mangoes, with the former recorded in the week of 16 May and the latter in the week of 23 May. For SGTF, one mango throughout the study period was recorded. Agro B samples recorded zero infestation for the week of 25 April and two mangoes for the week of 23 May. In the 2023 campaign, the average number of infested fruits was one mango throughout the study period at the SN Ranch Koba, while it was zero and one at station SGTF. The average number of infested fruits at the Agro B station varied between one mango for the 24 April and first May and two mangoes for the samples of weeks of 8, 15, 22, and 29 May, respectively (Figure 2).

Fruit fly infestations recorded at the post-sorting stage

During the 2022 season, the average number of infested fruits among the samples of mangoes taken after sorting was found as follows: In the SN Ranch Koba packing station, it was zero for the week commencing from 2 May, and three for the weeks of 16 and 23 May. In SGTF station, the average number of infested mangoes varied. For the week of 9 to 16 May, one mango was found infested, and for the weeks of 25 April, 2 May, and 23 May, two infested mango fruits were recorded in the post-sorting stages. Regarding the samples from Agro B packing station, there had been a variation in the number of infested mangoes, ranging from one infested mango for the

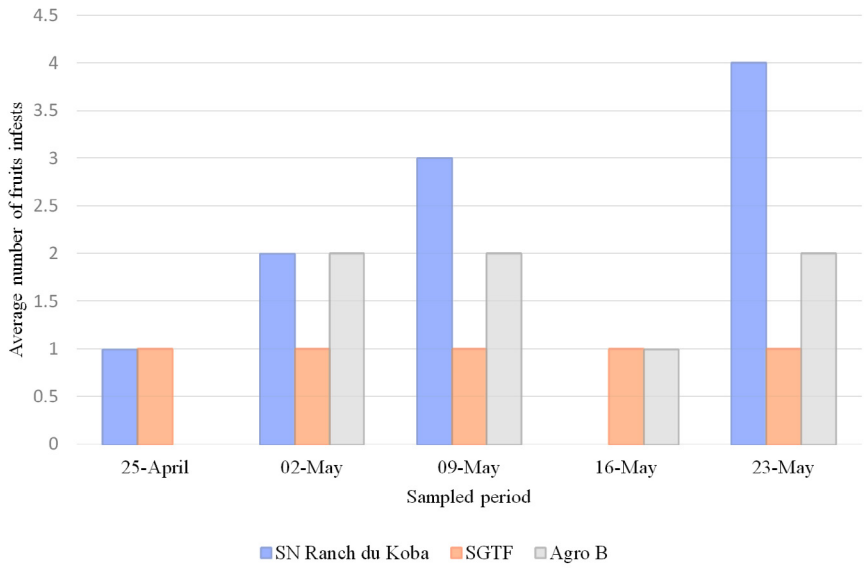

Figure 1: *Average number of infested mango fruits in samples taken before sorting at the packing stations during the 2022 season in Bobo-Dioulasso, Burkina Faso.*

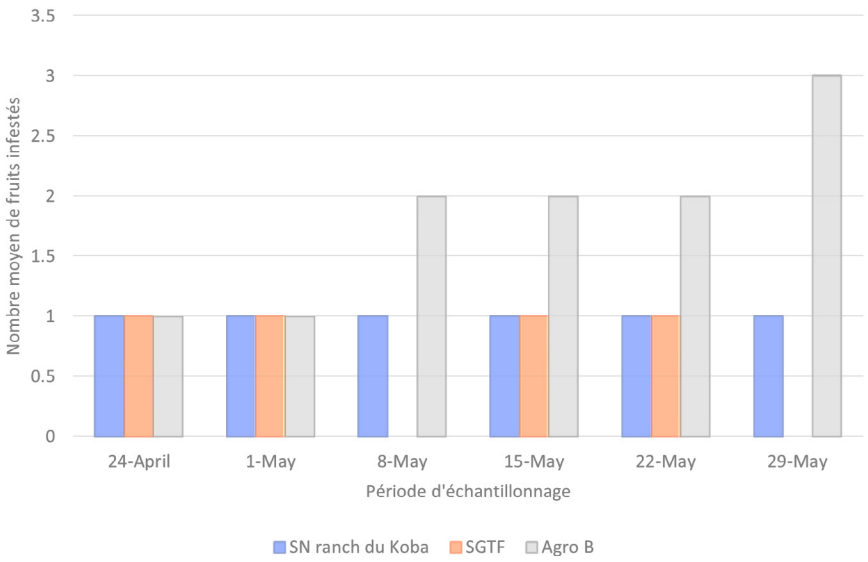

Figure 2: *Average number of infested mango fruits in samples taken before sorting at the packing stations during the 2023 season in Bobo-Dioulasso, Burkina Faso.*

weeks of 25 April, 9 May, and 16 May to two for the weeks of 2 May and 23 May (Figure 3).

Regarding the average number of infested fruits in 2023 (Figure 4), at the SN Ranch du Koba packing station, there was one mango for samples for all weeks except for the week of 8 May, where two infested mango fruits were recorded. In the SGTF packing station, the quantity of infested mangoes varied between zero for the week commencing from 8 May and one mango for the weeks of 24 April, 1 May, and 15 May. Regarding the Agro B packing station, the number of mangoes present in the samples has varied. During the weeks of 24 April, 1 May, and 15 May, there was zero fruit infestation, while in the week of 29 May, three mango fruits were found infested (Figure 4).

Role of sorting at the packing station in the reduction of fruit fly infestation

Table 1 presents the statistical analysis of the infestation rates for mango samples. This analysis was done for the fruit sampling period and source of supply for each of the three packing stations, and overall, for all packing stations combined. The results regarding the infestation rates of mangoes sampled at reception showed slightly higher average infestation rates at the SGTF station than those for the mangoes

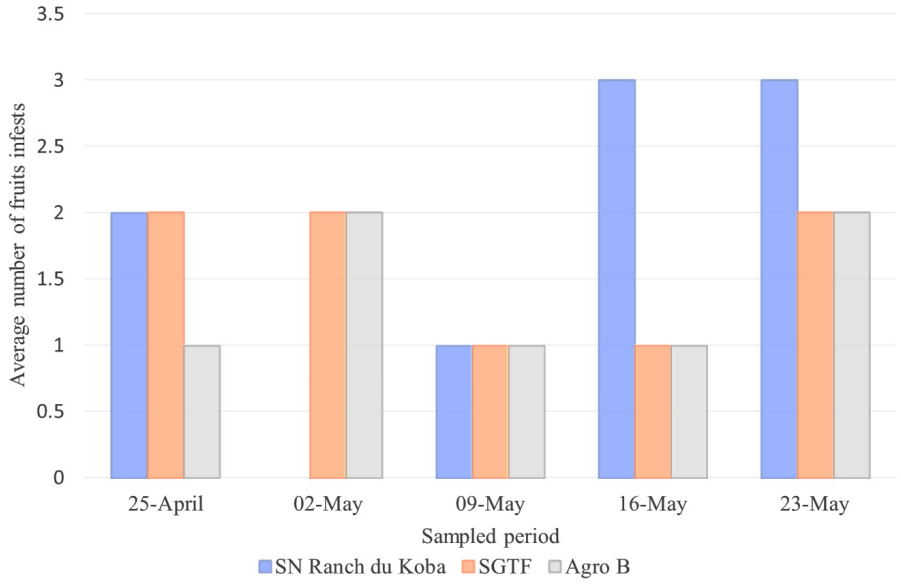

Figure 3: *Average number of infested mango fruits in samples taken after the sorting stage at the packing stations during the 2022 season in bobo-dioulasso, burkina faso.*

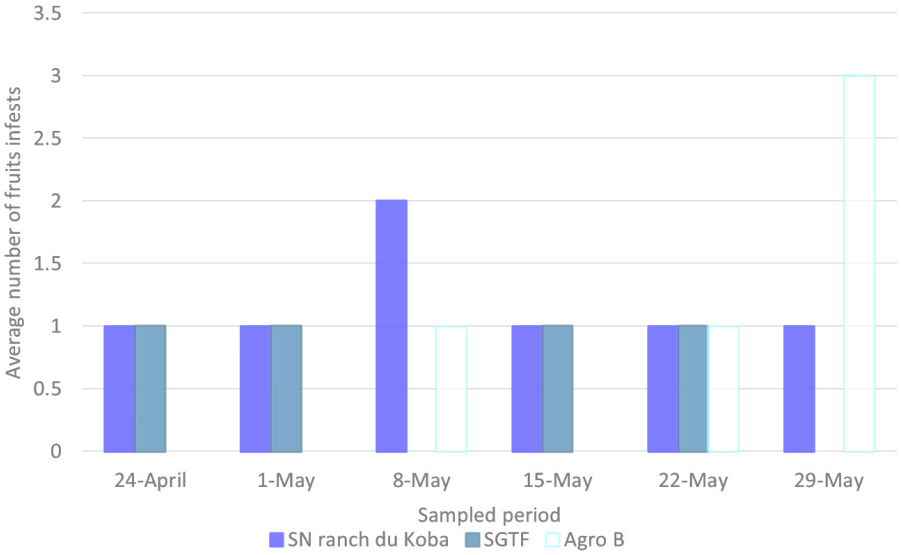

Figure 4: *Average number of infested mango fruits in samples taken after the sorting stage at the packing stations during the 2023 season in bobo-dioulasso, burkina faso.*

sorted at SN Ranch Koba and Agro B. In contrast to the two stations previously tested, SGTF has achieved a higher average infestation rate for mangoes sampled after sorting than for those sampled at reception. In all stations, average infestation rates remained consistent for mango samples of both levels. Statistical analysis revealed no significant difference in infestation rates among the mango fruits at packing stations.

Role of sorting at the packing station in the reduction of fruit fly infestation during the 2023 season

Similarly, in the case of the 2023 season, mango fruits infestation rates were slightly higher at the SGTF packing station than those for mango fruits sorted at SN Ranch Koba and Agro B packing stations (Table 2). In contrast to the two stations previously tested, SGTF exhibited a higher average infestation rate for mangoes sampled after sorting than for those sampled at the reception stage. In all stations, average infestation rates remained consistent for mangoes of both levels. Moreover, statistical analysis revealed no significant difference in infestation rates between the fruits sampled at reception and those sampled at the post-sorting stage (Table 2).

Overall, the post-sorting infestation rates of mango fruits by fruit flies varied, on average, from 2.1% for SN Ranch du Koba and Agro B packing stations to 1.0% for SGTF packing stage. Our statistical analysis revealed no significant differences in infestation rates of mango fruits between the samples received at the reception and post-sorting stages for all packing stations.

Discussion

Extensive use of synthetic insecticides has been inevitable and common practice in fruit and vegetable production around the world, particularly in the developing countries, including Burkina Faso (Srinivasan *et al.*, 2022). This results in risks of disruption of beneficial arthropods, environmental contamination, and human health hazards (De Bon *et al.*, 2014; Ahmed *et al.*, 2025; Majeed *et al.*, 2025). This situation necessitates the search for alternative, more selective management steps in the value chain of fruits and vegetables (Lefèvre *et al.*, 2020). This study assessed the prevailing scenario of fruit fly infestation in mangoes and the importance of practical implications of sorting efficiency at fruit packing stations.

Mango fruit samples were taken and inspected for fruit fly infestation at the reception facility and after routine sorting at different fruit packing stations in western Burkina Faso for the mango fruit seasons of 2022 and 2023. Results showed that the mangoes received at the packing stations were equally infested with those ready to be exported. Infestation in mango fruits overlooked by the field technicians gets detected at the reception stage, while those that

Table 1: *Average infestation rates (means ± SE) of mango fruits sampled at the reception and after sorting at the packing stations during the 2022 season in bobo-dioulasso, burkina faso.*

Sampling Station	Samples period			Supply source		
	Reception	Sort	Reception # Sort	Reception	Sort	Reception# Sort
SN Ranch du Koba	4 ± 4	3 ± 3	p = 0.53 t = 0.64 df = 14	4 ± 4	3 ± 4	p = 0.3 t = 0.64 df = 14
SGTF	1.2 ± 2	3 ± 2	p = 0.95 t = -1.72 df =14	2 ± 2	3 ± 2	p = 0.93 t = -1.52df = 14
Agro B	3 ± 8	2 ± 2	p = 0.63 t = 0.49 df = 14	3 ± 2,6	2 ± 2	p = 0.63 t = 0.49df = 14
Overall (for all stations)	3 ± 1	3 ± 3	p = 0.86 t = -0.18df =44	3 ± 3,2	3 ± 2.6	p = 0.54 t = -0.09 df = 44

Table 2: *Average infestation rates (means ± SE) of mango fruits sampled at the reception and after sorting at the packing stations during the 2023 season in Bobo-Dioulasso, Burkina Faso.*

Sampling Station	Samples period			Supply source		
	Reception	Sort	Reception # Sort	Reception	Sort	Reception #Sort
SN Ranch du Koba	2 ± 0.04	2 ± 0.1	p = 0.68 t = -0.42 df = 17	2 ± 0.1	2 ± 0.1	p = 0.84 t = 0.21df = 17
SGTF	2 ± 0.1	3 ± 0.03	p = 0.3 t = 1.08df = 14	2 ± 0.1	1 ± 0.03	p = 0.3t = 1.08df = 14
Agro B	0.4 ± 0.1	2 ± 0.1	p = 0.17t = 1.41df = 17	4 ± 0.1	2 ± 1	p = 0.17t = 1.41df = 17
Overall (for all stations)	6 ± 0.3	1 ± 0.1	p = 0.81t = 1.78df = 50	0.03 ± 3.2	0.03 ± 2.6	p = 0.54t = -0.09df = 50

escaped this stage were detected at the sorting stage and the packing stage. This explains why the infested mangoes that have escaped sorting in the field are either freshly infested by the fruit flies during the fruit supply chains and therefore are difficult to detect at this particular stage and often would cause substantial economic loss (Ouedraogo *et al.*, 2011; Muriithi *et al.*, 2016; Manrakhan, 2026), or the result of the careless attitude of the fruit sorting labor at the packing station (Bantayehu, 2025).

The lower number of infested fruits recorded at both levels of the packing line could be explained by a number of factors. There would be the effect of sorting carried out in the orchards and packing stations, the pre-rainy season of the study period, which reduces the risk of fruit fly populations' expansion and infestation of mangoes (Vayssières *et al.*, 2009). The application of good preventive and control practices against the fruit flies and other insect pests, such as ploughing, elimination of alternative host plants, and sanitation contribute to reducing infestations of mangoes (Muriithi *et al.*, 2016). In the world, studies were effect on the ecology, knowledge and assessment of fruit fly infestations on fruit orchards or natural formations have showed that the population explosion of this insect correlates with humidity conditions and the period attractiveness of is host plants, and therefore the rainy season beginning (Ouedraogo *et al.*, 2011; Konta *et al.*, 2015; Zida, 2019).

Moreover, the statistical analysis revealed no significant differences in fruit infestation levels between the reception and post-sorting stages. Fresh mangoes during export can show fruit fly infestations, which explain the potential risk of larval detection at ports and airports and subsequent shipment interception and destruction (Kwasi, 2009). In fact, the study during the 2022 season showed that sorting performed at the sorting station reduced only 2.3% of the infested mangoes that arrived at the reception facility of the packing stations. During the 2023 season, it was found that the sorting at the station reduced only 13% of the infested mangoes that arrived at the reception. Therefore, about 97.7 and 87% of the infested mangoes that arrived at the reception decks were not eliminated by sorting at the packing stations for the 2022 and 2023 seasons, respectively. This means that visual detection during the manual sorting technique may not be efficient, and sufficient for the complete elimination of infested mangoes, demonstrating the inefficiency of the sorting stage.

Conclusions and Recommendations

It is concluded that mango fruits were found infested by fruit flies both at the reception facility and at the post-sorting stage for all three packing stations and for both mango seasons, resulting in 80 to 90% fruit infestation not detected and eliminated by the prevailing routine reception and sorting practices of the mango packing and exporting stations. It shows the inefficiency and inadequacy of the sorting techniques of the parking stations because the presence of insect infestation in mangoes ready for export maintains the risk of containers being intercepted at phytosanitary control facilities of the ports and airports. This opens a reflection on the possibility of improving the sorting of mangoes at packing stations. The development or adaptation of control methods regarding post-harvest management of fruit fly infestations, and new detection techniques for the infested fruits, are the future perspectives of this study.

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Novelty Statement

This study evaluated the effectiveness of current fruit sorting practices at the packing stations regarding the fruit fly infestation detection in export-quality mangoes in Burkina Faso. Results exhibited significant fruit infestation both before and after sorting, with no significant differences among the stations and sorting stages. Notably, the existing sorting techniques failed to eliminate more than 95% infested fruits, indicating poor efficiency and a constant risk of export rejection.

Author's Contribution

Sylvain Nafiba Ouédraogo: Conceived the idea and contributed to the drafting of the manuscript.
Jérémy Kaboré: Collected and analyzed the data, wrote the first draft.
Rémy Anogmain Dabiré: Designed and supervised the study.
Lucien Sawadogo: Financed the research work and technically reviewed the draft.
Muhammad Zeeshan Majeed and Muhammad Umair Ajmal: Prepared the results and technically revised the manuscript.
Issaka Zida: Supervised the study, elaborated the intellectual content, and technically proofread the draft.
Hervé Bama: Contributed to the drafting of the manuscript.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors declare no conflict of interest regarding the publication of this work.

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