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*Full Length Research Paper*

# Insect pests of corn (*Zea mays* Linné, 1753) stocks and impact on storage and preservation in the Bagoué region, Northern Côte d'Ivoire

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**In Côte d'Ivoire, corn is one of the most widely consumed foodstuffs. However, this product suffers from pest damage during storage and preservation, mainly caused by insects. The aim of this study is to identify the insects associated with corn cobs and evaluate their effect in Tengrela, Bagoué region. Three sub-prefectures were selected: Kanakono, Debeté, and Papara. In each sub-prefecture, three batches of 30 cobs of corn were collected in three different storage facilities. Insects collected after shelling and sieving were counted and identified. Corn damage was assessed using the counting and weighing method (CWM). Results show that 12 species were identified, grouped into 10 families and 4 orders. These species are divided into harmful and beneficial insects based on their diet. The average attack rate recorded at the end of 12 months of storage is estimated at 82.53% of stocks. This study reveals for the first-time the establishment of *Prostephanus truncatus*, a large grain borer beetle in northern Côte d'Ivoire. Among with *Sitophilus zeamais, P. truncatus* is the most abundant destructive species in corn stocks. This study shows the urgent need to implement methods to protect and preserve the quality of corn cobs in Côte d'Ivoire.**

**Key words:** Corn, post-harvest, storage, insect pests, *Prostephanus truncatus*, Côte d'Ivoire.

## INTRODUCTION

Corn (*Zea mays* Linné, 1753) is one of the most widely consumed cereals in the world (Statista Research Department (SRD), 2019). Cultivated over vast areas (Isengildina-Massa et al., 2020), its global production is

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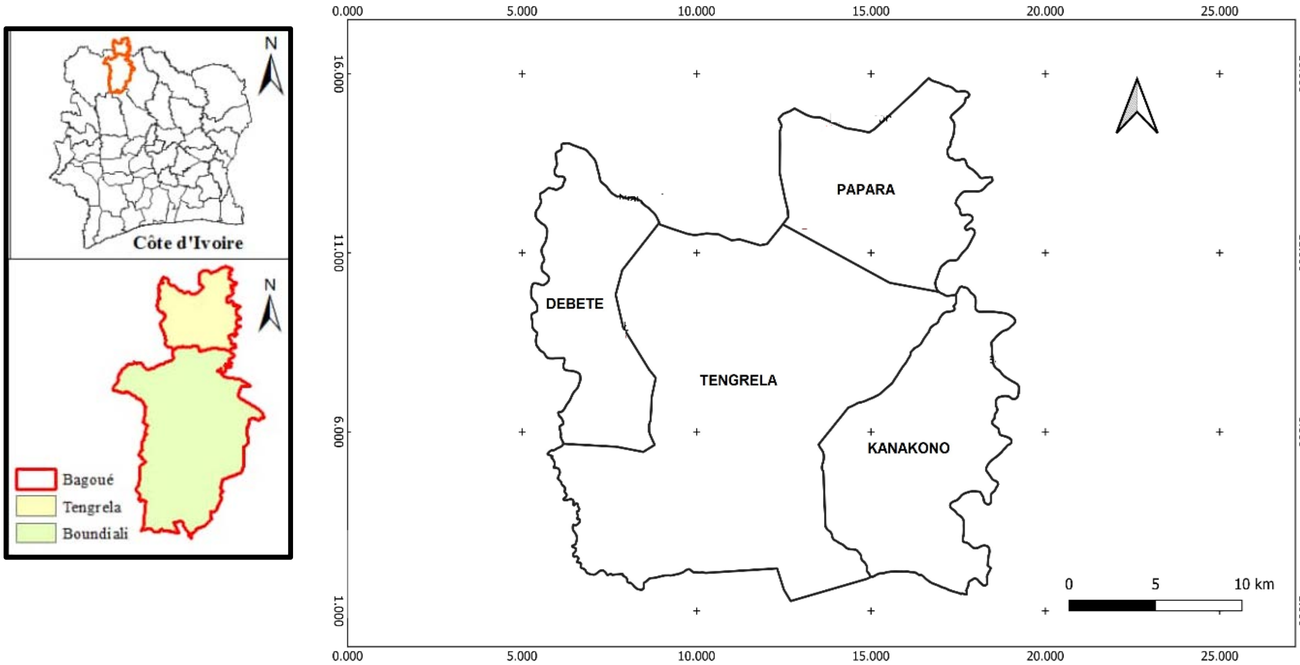


**Figure 1.** Map of Tengrela Department (Bagoué Region, Northern Côte d'Ivoire).

estimated at 193 billion tons and is expected to reach 1,315 billion tons over the next decade (OCDE/FAO, 2020). Corn is the staple food of the populations of sub-Saharan Africa. It is also used in livestock farming for animal feed (poultry, pigs, cattle) and as a raw material in certain brewing, soap-making and oil industries (Zhang et al., 2021). Despite its important role in food security, corn is exposed to numerous damages during storage and preservation (Glodjinon et al., 2019). These constraints are linked to the constant depredation caused by numerous bio-aggressors including insect pests (Semako et al., 2021). The damage caused by these pests can result in crop losses of between 30 and 100% during storage (Ngom et al., 2020; Stathers et al., 2020). These pests are capable of causing total loss of stock after seven months of storage, if no protective measures are taken (Sankara et al., 2017). In Côte d'Ivoire, most of the country's corn production, estimated at 1,025,000 tons in 2017 (FAOSTAT, 2017), comes mainly from the Bagoué, Poro, and Tchologo regions (Dedi and Diomande, 2017). This production remains insufficient to meet the ever-growing needs of Ivorians, hence the importation of corn every year. Indeed, strong demand from livestock breeders and industries has forced import of corn to meet people's needs (USDA, 2011). Furthermore, this insufficient production is subject to significant losses caused by numerous pests that include insects during storage (Johnson, 2009). Recently, farmers in the Bagoué region have been complaining of increasing damage resulting in the loss of all their stocks. Insect damage is making it increasingly difficult to store corn over long periods. Therefore, effective control methods are urgently needed to clean up the region's corn stocks. It begins with knowledge of the insect species that colonize these stocks. This is the context in which this study was initiated. Its aim is to identify the insects responsible for damages on corn stocks and their impact during storage.

## MATERIALS AND METHODS

### Study environment

This study was carried out in the Bagoué region more precisely in the Tengrela department (10° 29′ 13″ longitude North and, 6° 22′ 48″ latitude West), in the north of Côte d'Ivoire (Figure 1). Surveys were carried out in 3 sub-prefectures which are Debeté; Papara and Kanakono.

### Composition of corn cob samples

In this region, corn is generally stored as spathed cobs in farmers' granaries. In each sub-prefecture, samples were taken from 3 granaries. The granaries were chosen according to the availability of corn cobs, accessibility and with the agreement of the farmers. In each granary, 5 sampling zones were predefined. For each of these 5 sampling zones, 6 cobs were collected to form a batch of 30 cobs. This process was repeated 3 times to assess variability within the granaries and ensure the reliability of the results. Hard-to-reach cobs were sampled using a non-automated mechanical arm, to cover the entire surface and depth of the storage structure.

**Table 1**. Number of insects collected according to sub-prefecture after 12 months of storage in the Bagoué region.

| Sub-prefectures | Number of insects/samples | p |
|---|---|---|
| Papara | 1789.3 ± 220.0[a] | |
| Kanakono | 1686.0 ± 151.7[a] | 0.001 |
| Debeté | 1239.0 ± 149.1[b] | |

Means within a column followed by the same letter do not differ significantly from each other in a Newman-Keuls test at 5% threshold.

Samples were labelled according to sub-prefecture, granary, and sampling date. In this study, the corn cobs were 12 months old.

### Collecting and identifying insects

For insect collection, each batch of 30 sampled corn cobs was dehulled and then shelled in a white-bottomed tray. The shelled corn kernels were sieved using a 2 mm square-mesh sieve. Insects were collected using entomological forceps and stored in labelled pillboxes containing 70% ethanol. In the laboratory, the collected insects were identified under binocular magnifying glass using determination keys (Delobel and Tran, 1993). Insects were classified based on their trophic regime, thus determining their agronomic status in corn cobs (Huchet, 2017). Two main groups of pests and beneficial insects were identified. Regarding pests, insects that can attack healthy grains are primary pests (I); those that consume already damaged grains are secondary pests (II), and those that consume crumbs are tertiary pests (III). Beneficial insects were classified into two categories: parasitoids (Pa) and predators (Pt) (Huchet, 2017).

To assess attack rates, each corn sample, after sieving for insects, was divided into two (2) groups: attacked and healthy kernels. A kernel is said to be attacked when it has a perforation or has been eaten away by insect pests. Each fraction was then counted and weighed. Grain attack rate (TA) and corresponding losses (P) were determined using the counting and weighing method defined by (Boxall, 1986) and improved by (Johnson, 2009), and calculated using the following formulas:

$$TA\ (\%) = (NGA/NGT) \times 100$$

where NGA = number of attacked grains and NTG=total number of grains.

$$P\ (\%) = [(NGA \times PGS) - (NGS \times PGA)/(PGS \times NTG)] \times 100$$

where NGA = number of attacked grains, NGS = number of healthy grains, NTG = total number of grains, PGA = weight of attacked grains and PGS = weight of healthy grains.

### Data analysis

#### *Diversity indexes*

Biodiversity indices such as relative Abundance and frequency of occurrence were determined. relative Abundance (rA) is the ratio of the number of individuals of a given species to the total number of individuals of all species combined (Dajoz, 2006). This index indicates the abundance of a species in a population. Depending on the value of relative abundance (rA), the species considered is said to be very abundant (rA>10%); abundant (5% ≤ rA < 10%); fairly abundant (1% ≤ rA < 5%) and not very abundant (rA < 1%).

The frequency of occurrence (C) of a species is the ratio between the number of samples containing the species and the total number of all samples taken. It is used to study the constancy of a species in a given environment (Dajoz, 2006). Depending on its value, the species considered is said to be ubiquitous (C = 100%); constant if (75% ≤ C < 100%); frequent (50% ≤ C < 75%); incidental (25% ≤ C < 50%); accidental (5% ≤ C < 25%) or rare (C < 5%).

### Statistical analysis

To assess the robustness of the data obtained, they were subjected to statistical analysis. After checking the normality and homogeneity of the data using the Shapiro-Wilk test and Levene's test, respectively, a one-way ANOVA was used to compare the means obtained. Data were separated using the Newman-Keuls test. The Pearson correlation test was used to identify dependent variables. These analyses were performed using XLSTAT software version 2016.

## RESULTS

### Number of insects collected in corn stocks by sub-prefecture

In the sub-prefectures sampled, the average number of insects collected per sample ranged from 1239 ± 149.1 to 1789.3 ± 220 individuals. The abundance of insects obtained per sample varied from one sub-prefecture to another (P = 0.001). Papara and Kanakono recorded significantly (P) the highest numbers of insects compared to Debete (Table 1).

### Specific composition of insects associated with corn cobs in the sub-prefectures surveyed

As a result, 42,429 insects were collected from the corn samples studied. They were classified into 4 orders, 10 families, 11 genus and 12 species. Coleoptera was in the main order, with 9 species. Only one species per order was identified for the other orders, that is Hemiptera, Hymenoptera and Lepidoptera. About the specific composition of insects according to the sub-prefectures visited, Kanakono recorded the highest number of species with 11 identified. The sub-prefecture of Debeté

**Table 2.** Relative Abundance, frequency of Occurrence and agronomic status of insect species collected (pest/natural enemy) in 270 cobs from each sub-prefecture surveyed in Tengrela, northern Côte d'Ivoire.

| Order | Family | Species | Debete | | Kanakono | | Papara | | AS |
|---|---|---|---|---|---|---|---|---|---|
| | | | rA (%) | C (%) | rA (%) | C (%) | rA (%) | C (%) | |
| Coleoptera | Bostrichidae | *Prostephanus truncatus* (Horn, 1878) | 19.93 | 100 | 73 | 100 | 88.24 | 100 | I |
| | Curculionidae | *Sitophilus zeamais* (Motschulsky, 1855) | 32.12 | 100 | 6.83 | 77.77 | 0.03 | 11.11 | I |
| | Tenebrionidae | *Tribolium castaneum* (Herbst, 1797) | 25.9 | 100 | 8.07 | 88.8 | 7.88 | 100 | II |
| | | *Tribolium confusum* (Jaquelin, 1868) | - | - | 0.07 | 11.11 | - | - | III |
| | Nutidulidae | *Carpophilus dimidiatus* (Fabricius, 1792) | - | - | 3.24 | 66.66 | 0.07 | 22.22 | II |
| | Cucujidae | *Cryptolestes pusillus* (Schönherr, 1817) | - | - | 5.45 | 77.77 | - | - | II |
| | Silvanidae | *Cathartus quadricollis* (Guérin-Méneville, 1844) | - | - | 0.43 | 11.11 | - | - | II |
| | | *Oryzaephilus surinamensis* (Linnaeus, 1758) | 5.81 | 100 | 0.82 | 33.33 | 2.25 | 77.77 | III |
| | Histeridae | *Teritrius nigrescens* (Lewis, 1891) | 16.22 | 100 | 0.40 | 11.11 | 1.117 | 77.77 | Pr |
| Lepidoptera | Pyralidae | *Plodia interpunctella* (Hübner, 1813) | - | - | - | - | 0.35 | 55.55 | I |
| Hemiptera | Anthocoridae | *Xylocoris sp* (Reuter, 1875) | - | - | 1.49 | 55.5 | 0.03 | 11.11 | Pr |
| Hymenoptera | Pteromatidae | *Lariophagus distinguendus* (Forster, 1797) | - | - | 0.11 | 11.11 | - | - | Pa |

rA (%): Relative Abundance; C (%): frequency of occurrence; AS: agronomical status. Pest: I: primary pest; II: secondary pest; III: tertiary pest. Natural enemy (Beneficial insects): Pa: parasitoid; Pr: predator.

recorded poor diversity, with 5 species identified. In the Papara sub-prefecture, 8 species were collected. Five species are common to all the 3 sub-prefectures visited: *Prostephanus truncatus* (Horn, 1878); *Sitophilus zeamais* (Motschulsky, 1855); *Oryzaephilus surinamensis* (Linnaeus, 1758); *Tribolium castaneum* (Herbst, 1797) and *Teretrius nigrescens* (Lewis, 1891) (Table 2).

**Relative abundance, frequency of occurrence and agronomic status of corn-infested insects in Tengrela department**

Among the main species collected, *P. truncatus,* a primary pest, was very abundant, with relative abundance values ranging from 19.9% in Debeté to 88.8% in Papara. This species was omnipresent (C = 100%) in all the sub-prefectures surveyed.

*S. zeamais*, a primary pest, is present in all sub-prefectures, but is not very abundant in Papara. Conversely, in Debeté, *S. zeamais* is very abundant (rA = 32%) and omnipresent (C = 100%). *T. castaneum, a* secondary pest of corn grains is constant (C = 89%) in Kanakono and omnipresent in the other sub-prefectures. However, apart from Debeté where it is very abundant (rA = 25.9%), *T. castaneum* is abundant in the other sub-prefectures (7.8% < rA < 9.3%). *O. surinamensis, a* tertiary pest, is omnipresent only in Debeté and constant in the other sub-prefectures. This species recorded relative abundances ranging from 0.82 to 5.81%. *T. nigrescens, a* predatory species, is very abundant in Debeté (16.2%). However, it recorded low relative abundance at Kanakono (0.11) and Papara with a value of 1.12% (Table 2).

**Damage and losses after 12 months' storage**

The average rate of insect attacks on corn stocks

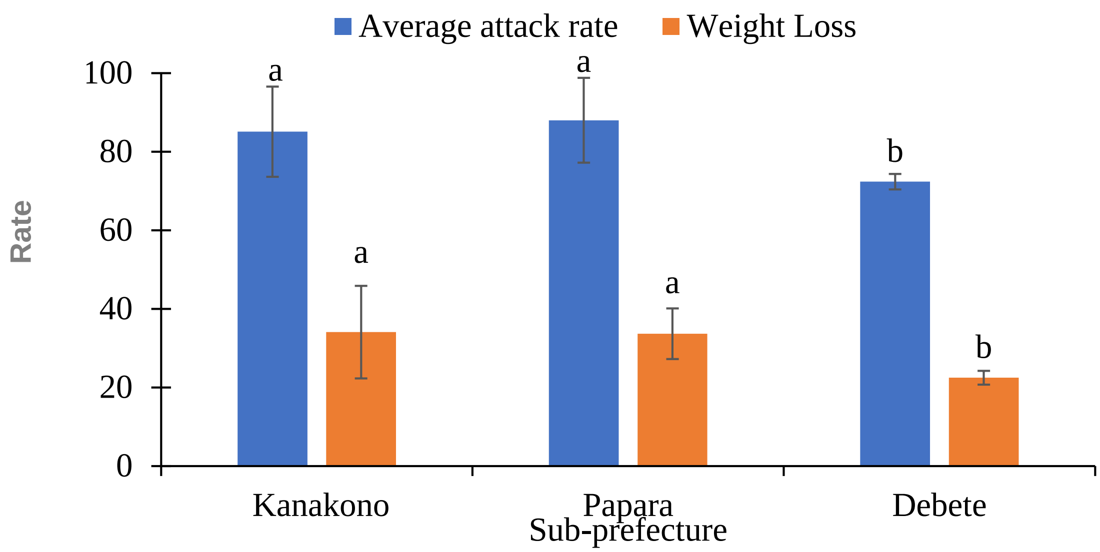


**Figure 2.** Attack rate and weight losses recorded in maize stocks after 12 months' storage in Tengrela department, northern Côte d'Ivoire.The histogram bars of same color with the same letter are not significantly different in a Newman-Keuls test at 5% threshold. Average attack rate p=0.001; Weight loss p=0.001.

and weight losses due to damage follow the same trends. The sub-prefecture of Debeté recorded the lowest attack rate (72.37 ± 1.97%) and weight loss (22.47 ± 1.76%) compared with the other sub-prefectures. In Kanakono and Papara, attack was statistically not significant. Corn kernel weight losses followed the same trends as attack rates. Weight loss values recorded in Kanakono and Papara are statistically not significant (Figure 2).

## Correlation between incidence of insects and attack rate

The number of insects collected in each sample was positively correlated with recorded grain attack ($p = 0.002$; $r = 0.505$).

Thus, the abundance of insects in storage structures induces an increase in damage (Figure 3). However, no correlation was recorded between weight loss and recorded attack rates ($p = 0.66$).

## DISCUSSION

The results of the present study revealed a high specific composition of insects in corn cobs in the Tengrela department. A total of 12 insect species were recorded (Table 2). This high diversity could be explained by the physico-chemical characteristics of corn, which are conducive to insect proliferation (Johnson, 2009). These results are similar to those of Oura et al. (2022)**,** who recorded 15 insect species in their study of corn stocks in Burkina Faso. The latter, who worked on millet, sorghum and corn grains in Burkina Faso, showed in their work that corn stocks host more insect species than other cereals.

Corn cob samples taken from storage structures were used to collect insects associated with this product. Comparison of the average number of insects collected revealed that the number of insects present in a storage structure depended on the sub-prefecture. These results could be explained by the abundance of different species collected in the various sub-prefectures. Indeed, natural enemies (predators) are more abundant in Debeté, which could regulate pest populations in this locality compared to Papara and Kanakono. Indeed, the abundance of insects in an environment is a function of the presence and abundance of natural enemies, which play a role in regulating pest populations, thus reducing their numbers (Huchet et al., 2017).

The relative abundance of *P. truncatus*, the great grain capuchin, was highest in this study in all the sub-prefectures visited apart from Debeté. This suggests its sedentarization in Côte d'Ivoire. Indeed, the work of N'Daet al. (2022) reported its presence in the country, more specifically in the town of Ferkessédougou. However, these authors described it as a rare species. The present study reveals for the first time the establishment of *P. truncatus* in northern Côte d'Ivoire, given its abundance and ubiquity in the granaries of the Bagoué region. Its presence could be explained by cross-border trade in cereals with neighboring countries such as Mali and Burkina Faso, where the insect is rife. Indeed, the work of Sankara et al. (2017) indicates its presence in several localities in Burkina Faso. The establishment of this pest in Côte d'Ivoire could also

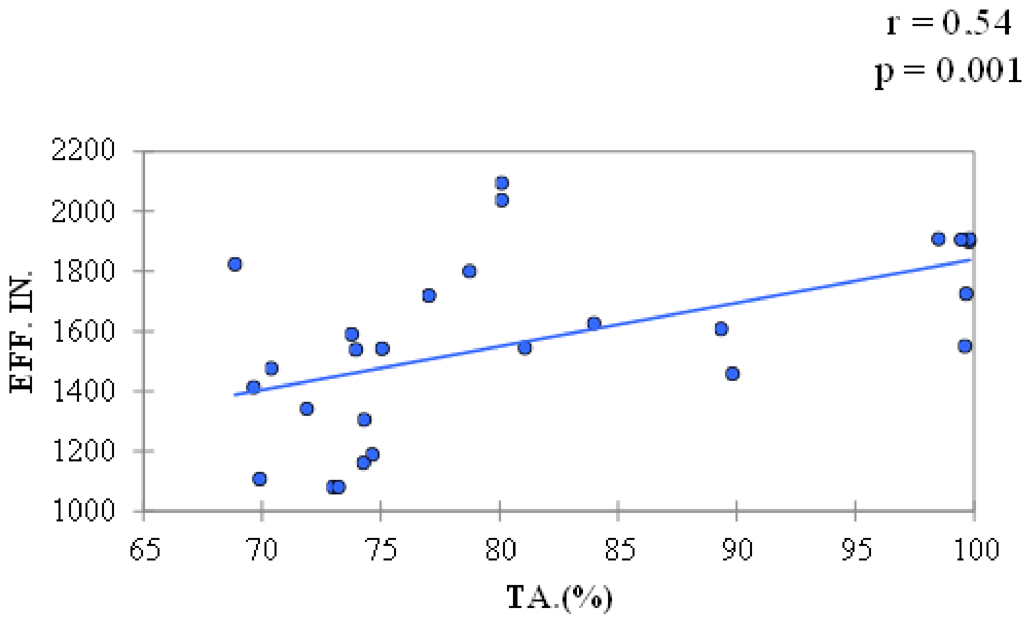


**Figure 3.** Correlation between insect numbers collected and grain attack recorded in Tengrela maize stocks. Pearson correlation test at 5% threshold.

be explained, on the one hand, by the changing climatic conditions, and on the other, by its high dispersal capacity. Hell et al. (2006) demonstrated the mobility and voracity of *P. truncatus.* According to Guèye et al. (2011), since its accidental introduction into Africa in the late 1970, *P. truncatus* has been steadily expanding its range. Moreover, the strong presence of *P. truncates justifies* the presence of *T. nigrescens, a* specific predator of this pest. Indeed, Hell et al. (2006) and Omondi et al. (2011) observed that this predator is specific to the great grain beetle *P. truncatus*, consuming its eggs and larvae.

The relative abundances obtained in this study suggest that for each ecological group, one species is in the majority at the expense of the others. Thus, *T. castaneum* and *O. surinamensis,* respectively secondary and tertiary pests, are more important in terms of numbers of individuals than other species with the same status. These results corroborate those of Oura et al. (2022), who identified a majority species in each ecological group. However, in their work, *T. castaneum*, a secondary pest, was in the majority. This difference could be explained by the state of the maize stocks sampled in their studies. In fact, secondary pests prefer broken kernels.

The very high damage and weight losses recorded in this study could be explained by the strong presence of primary pests, which in addition to causing significant damage, pave the way for secondary and tertiary pests. Damage estimates, based on attack rates, revealed an average of 82.53%. This result shows a high level of depreciation of maize by insects during storage. This high level of depreciation could be explained by the 12-month storage period and the large number of insect pests collected. Indeed, the work of Johnson (2009) revealed that damage and weight loss are a function of these two parameters.

## Conclusion

This study, carried out on corn stocks in Tengrela in northern Côte d'Ivoire, provided information on the insects present on corn stocks in all the storage structures sampled. These insects are grouped into 4 orders, 10 families, 11 genus and 12 species. The most abundant species is *P. truncatus* (Coleoptera: Bostrichidae). It accounts for 60% of the insects collected in the course of this work. This study thus reveals, for the first time, the establishment of *P. truncatus* in Côte d'Ivoire. Based on the significant results recorded, it is necessary to carry out further studies on its biology, ecology, and ethology to develop an efficient control method for this important pest.

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## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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