Fumigation toxicity of three plant essential oils against *Dermestes* spp. larvae, (Coleoptera Dermestidae), a major pest of dried fish in the Tropics

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Abstract

Cured dried fish represents a cheap source of human dietary protein in developing countries such as Senegal (West Africa), but it is rapidly attacked by Dermestid beetles (Coleoptera Dermestidae), mainly *Dermestes maculatus*, DeGeer, and *D. frischii* Kugelann, and losses are serious when dried fish is stored for more than 2 or 3 months. In this work, the fumigation toxicity of essential oils extracted from *Callistemon viminalis* (Gaertn.) G. Don, (Myrtaceae), *Mentha spicata* Huds (Lamiaceae) and *Xylopia aethiopica*, Dunal (Annonaceae) were evaluated against *D. maculatus*, and *D. frischii* first instar larvae. The mortality was assessed at the following concentrations: 0.064 µl/ml ; 0.128 µl/ml ; 0.256 µl/ml ; and 0.512 µl/ml, after 24 hours of exposure time. Larvae of both species were more susceptible to essential oil of *Mentha spicata* than to the two other plants, with a higher percent mortality recorded at each concentration. Moreover, *Mentha spicata* gave 70% mortality at the lowest concentration (0.064), and 90 % at the highest one (0.512). The LC_{50} of *M. spicata* is 5 µl/ml, while 15 and 20 µl/ml, respectively for *Calistemon viminalis* and *Xylopia aethiopica.*

Keywords: cured fish protection, *Dermestes maculatus, D. frischii,* essential oils, *Calistemon viminalis*, *Xylopia aethiopica*, *Mentha spicata*, fumigation

1. Introduction

In many developing countries, fish represent the main animal protein supply, and also a source of income for local populations. Fish catch is traditionally processed by fermentation, drying, salting, smoking, braising, or combined methods, giving different types of cured fish, and permitting fish distribution to reach remote inland areas, without cold storage, and decrease of post-harvest fish losses.

In Senegal, more than thirty thousand tons of cured fish are produced each year, representing 1/3 of total fish landings, which is estimated to average of 350 to 400 thousand of tons; the main type, (60%) is processed with fresh Clupeidae fishes as *Sardinella maderensis*, *S. aurita* and *Ethmalosa fimbriata* which are braised entire, after cooling, skins and heads are removed, then fishes are salted and dried on the racks : this kind of cured fish, can replace fresh fish or meat and is used for consumption in national and regional levels.

Insect infestation by blowflies and Dermestid beetles is a very serious problem, as great losses can be recorded, and fish mongers use chemicals for cured fish protection. There is a need of safer alternatives to combat beetle infestations during storage.

Research has been done on cured fish protection (reviewed by Johnson and Esser, and Gueye-Ndiaye and Golob, 2004), but few reports concern evaluation of the effectiveness of plant essential oils (Don Pedro, 1989; Fasakin, 2003; Akinwumi, 2011); these methods considered as safe and environmentally friendly. We review the effectiveness of the essential oils of

Callistemon viminalis (Gaertn.) G. Don (Myrtaceae), *Mentha spicata* Huds (Lamiaceae), *Xylopia aethiopica* Dunal (Annonaceae) against the larvae of *Dermestes maculatus* Degeer and *D. frischii* Kugelann (Coleoptera-Dermestidae), major insect pests of stored processed fish.

2. Materials and Methods

2.1. Test insects

Dermestes maculates and *Dermestes frischii*, both feed on cured fish on drying racks and fish stores. Adult specimens are harvested in "penccum Senegal", a big curing site located ten kilometers from Dakar, and brought back to the Laboratory of Biology Unit of CERES/Locusstoxput in the Biology Laboratory of the Regional Center for Research in Eco toxicology and Environmental Security (CERES/LOCUSTOX) where they are reared in plastic boxes with a mesh at the bottom lid for aeration.

Unsalted braised-dried sardinella and moistened cotton for water supply are put inside each plastic box where 40 unsexed dermestid adults were added. The boxes are then left to the ambient temperature and are monitored as the stock culture for providing larvae for the experiments.

2.2. Plant material

C. viminalis is not a native plant in Senegal, but grows easily in The Botanical Garden of Cheikh Anta Diop University of Dakar where we obtained leaves used in this work. *Mentha spicata* is a very common aromatic herb in Senegal where it is used with hot tea drinks, and fresh drinks of *Hibiscus sabdarifa.* For our study, it's grown in plastic jars in the Laboratory courtyard for one month and a half before use. Leaves of these two plants when harvested, are previously dried separately a week long, out of direct sunlight before extraction of essential oil (E.O.). *Xylopia aethiopica* dry fruits are very common in the markets where they are purchased for the experiments; they are used with hot drinks, and also as an antihelminthic drug. Previous to E.O. extraction they are ground, using a small mortar and pestle.

2.3. Essential oil extraction

Essential oils are extracted from these different plant material by a water distillation method of hydro distillation; 100 grams of plant material are added to about 1 liter of tap water and brought to a boiling point for 3 hours. The water vapor is condensed in a distillate, collected in a flask, and then decanted to retrieve the essential oil supernatant. Water traces are eliminated with an anhydrous sodium sulfate, and oils collected in small tubes and kept in ae refrigerator at 4°C (Belyagoubi, 2005).

2.4. Experimental procedure

Four (4) concentrations of essential oils for each plant (v/v): 0.064 µl/ml; 0.128 µl/ml 0.256 µl/ml and 0.512 µl/ml were tested on the insects in the following way: the liquid is deposited on Whatman filter paper introduced in a glass container of 250 ml prior to introducing the glass then closed hermetically and then left ambient temperature for 24 h. There were four replicates for each concentration and an untreated control.

After 24 h exposure time, total number of dead larvae is recorded in each replicate, and mortality percent calculated with correction by Abbotts Formula:

$$Mc = \frac{Mt - Mt0}{100 - Mt0} \times 100$$

Mc: mortality corrected; Mt: Number of dead larvae in each treatment; Mt0: number of dead larvae in the control.

2.5. Statistical analysis

Corrected mortality (percent) are presented as histogram figures using Excel software, and ANOVA with Statview is used to compare the effect of E.O. concentrations on larval mortality. The bars with the same letter are not significantly different. The EPA software version 1.5 is used to calculate the LC_{50} of each plant material.

3. Results and Discussion

3.1. Extraction efficiency

The extraction rate is given by the ratio of the mass of essential oil obtained on the mass of the plant material used.

$$tx\% = \frac{m1 \times 100}{m0}$$

m0 = mass in grams of the plant fresh material
m1 = mass in grams of essential oil and
***tx* %** = extraction rate of the essential oil

Table 1 Rates in essential oil of different plants.

Plants	Extraction rate in essential oil
Callistemon viminalis	2.88 %
Mentha spicata var. mint	1.66 %
Xylopia aethiopica	1.60 %

The E.O. extraction rate is higher with *Callistemon viminalis.*

3.2. Biocidal tests

Figures 1, 2, and 3 give corrected percent mortality for: E.O. from *Callistemon viminalis*, *Xylopia aethiopica*, and *Mentha spicata*. All of them induced larval mortality, even with the lowest concentration (0.064 µl/ml), which induced 70%. Percent mortality obtained with the three plant extracts are shown for each concentration (Fig. 4), and *Mentha spicata* seems more effective than the two others, particularly at the three lowest concentrations: 0.064 µl/ml; 0.128 µl/ml, and 0.256 µl/ml. At the highest dose, (0.512 µl/ml), all the three plants induced at least 85% mortality. The E.O. extraction rate was also high, particularly with *Callistemon viminalis*, and compares to Ndomo et al. (2009) who obtained 0.85% using the same extraction technique.

Previous studies record biocidal activity of *Callistemon viminalis*, with *Sitophilus oryzae*, *Tribolium castaneum* and *Rhyzopertha dominica* (Lee et al., 2004), the bruchid beetle *Acanthocelides obtectus* (Say), (Ndomo et al., 2009), while, Djossou (2006) obtained 100% mortality with the adults of *Callosobruchus maculatus* after 3 days exposure. Sokovic et al. (2009) reports a fungicidal activity of *Mentha spicata* E.O., due to carvone molecules.

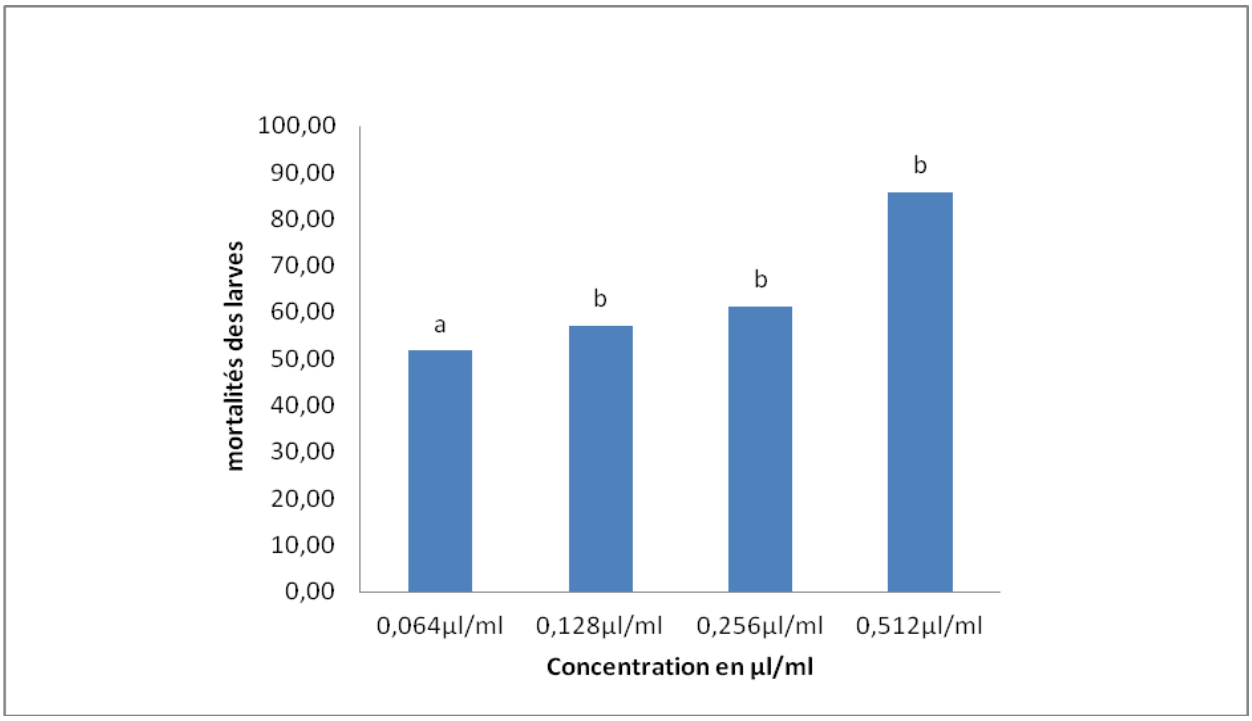

Figure 1 Percent mortalities of larvae of *Dermestes* spp. as a function of the concentrations of essential oil of *C. viminalis*.

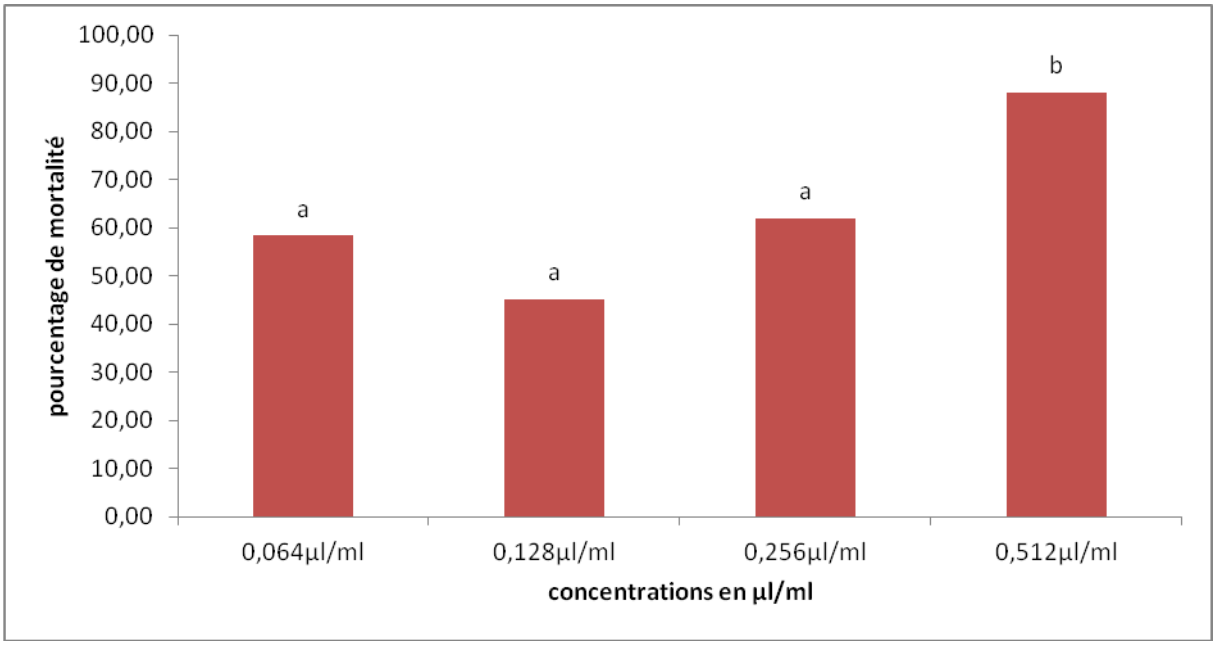

Figure 2 Percent mortalities of first instar larvae of *Dermestes* spp. as a function of the concentrations of essential oils of *X. aethiopica*.

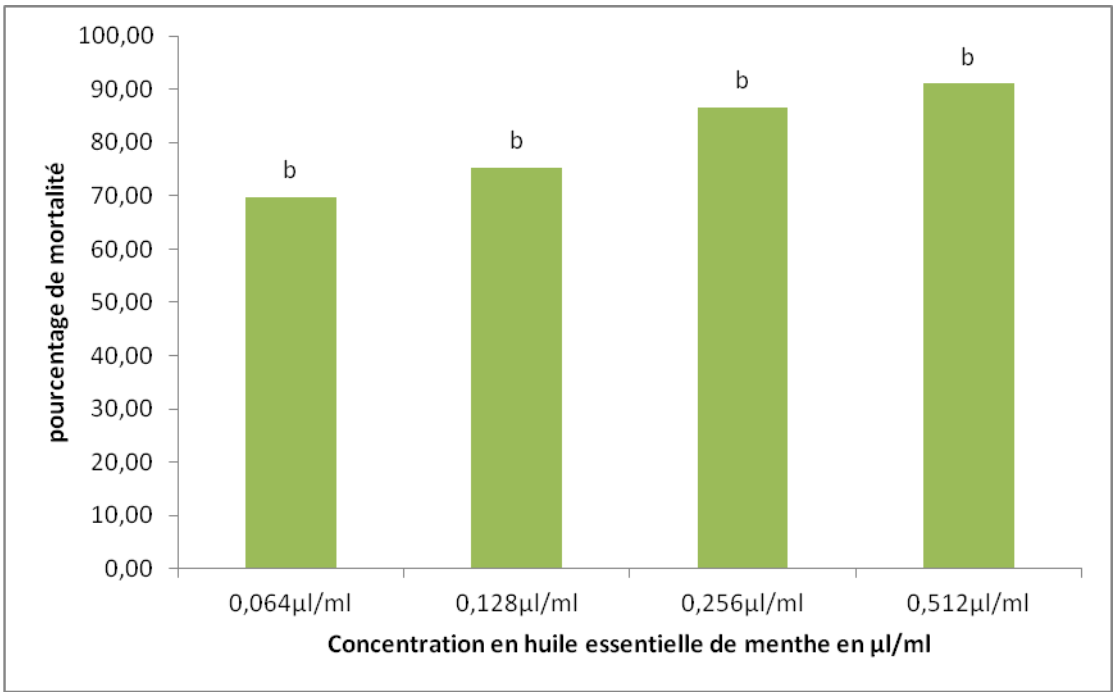

Figure 3 Percent mortalities of first instar larvae of *Dermestes* spp. as a function of the concentrations of essential oils of *M. spicata var. "Mint"*.

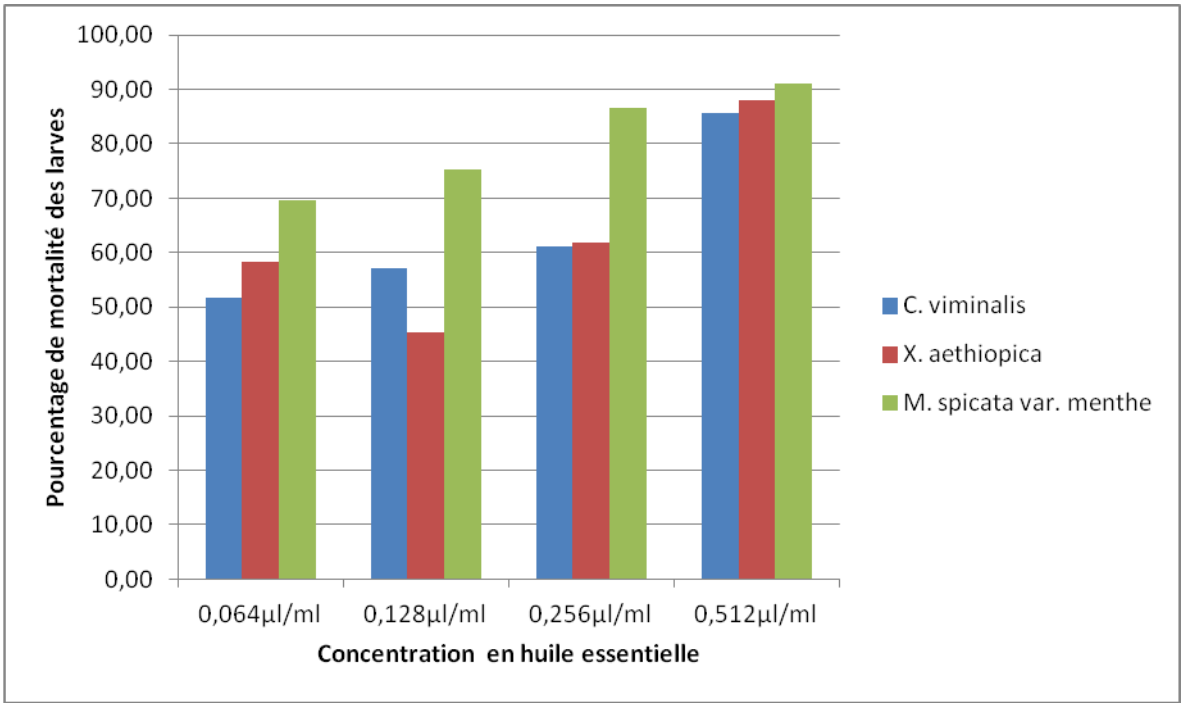

Figure 4 Comparison of the fumigant effect of *C. viminalis* , *X. aethiopica* and *M. spicata* on first instar *Dermestes* spp. larvae.

4. Conclusions

Dermestid larvae are voracious and very noxious for cured fish end products due to their short life cycle, and the fact they could rapidly render the product unfit to human consumption and unmarketable, causing income losses. This paper shows that they are susceptible to Essential oils extracted from some edible plants at an exposure times of 24 hours. They are s a potential alternatives to insecticides used by fishmongers to protect stored dried fish. In our opinion, insect infestation in fisheries, particularly beetle infestations, are not easy to tackle by only one method, and we suggest the use of efficient plant extracts in a "package integrated approach" including: use of good practices, while processing and storing cured fish, hygiene and sanitation with regular removal of fish offals, which are a permanent source of re-infestation, increased training, and modern structures for fish handling and processing.

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