



## Termiticidal efficacy of extracts of two indigenous plants against *Macrotermes subhyalinus* Rambur (Blattodea: Termitidae)

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### Abstract

The termiticidal potentials of methanol, n-hexane, acetone and water extracts of heart wood of *Milicia excelsa* (Welw.) C. Berg and leaves of *Khaya senegalensis* (Desr) and their botanical mixture against *Macrotermes subhyalinus* (Rambur) attacking *Triplochiton scleroxylon* (Obeche) wood blocks were evaluated in this study. The trial lasted for 12 weeks in open field and under shade conditions. Visual rating and weight loss determination were used to assess the level of termite damage on treated wood blocks. Treated wood blocks in the open field were comparatively less infested than those under shade. Botanical mixture extracted with n-hexane protected the wood blocks better than all of methanol, acetone and aqueous extracts. Also, treated wood blocks in open fields had lower percentage weight loss to termite compared to those under shade. The GC-MS analysis revealed the presence of thirty-four and forty-four compounds in *M. excelsa* and *K. senegalensis*, respectively. *Milicia excelsa*, however, contains more toxic compounds [Butylated Hydroxyl toluene (BHT), Docosane, Tridecane, Cyclohexane and Citra] than *K. senegalensis* (Cyclohexane and Cucubene). *Milicia excelsa* could, therefore, be touted as a better wood protectant than *K. senegalensis*, especially in the open field. The mixture of n-hexane extract of both plants was more potent at protecting the wood blocks for three months duration. Various insecticidal compounds identified in each plant could also be adopted as eco-friendly termiticidal agents for managing subterranean termites.

**Keywords:** *Milicia excelsa*, *Khaya senegalensis*, *Triplochiton scleroxylon*, weight loss.

### INTRODUCTION

Termites are an important component of tropical and sub-tropical ecosystems. They are group of social insects that belong to the order Blattodea and family Termitidae (Bignell and Eggleton, 2000; Mitchell, 2002). They play an integral role in the fertilization and formation of soil as well as decomposition of organic matter and growth

of vegetation (Freyman *et al.*, 2008; Jouquet *et al.*, 2011; Garba *et al.*, 2011). Generally, termites survive by feeding on detritus materials and they have been reported in high abundance in most agro-ecosystem (Bruno *et al.*, 2001; Robert, 2007). There are currently close to 3,000 named termite species in 282 genera worldwide (Kambhampati and Eggleton, 2000). The genera commonly found in Western Africa include *Ancistrotermes*, *Macrotermes*, *Amitermes*, *Odontotermes*, *Microtermes*, and *Cubitermes* (Termitidae) (Mitchell, 2002).

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However, termites are best known as the most serious pest of trees and wooden structures, causing severe damages to agricultural crops and urban structures throughout the world (Loko *et al.*, 2017). Losses associated with termite infestation on wooden structures and agricultural crops ranges from about 20 to 45% (Logan *et al.*, 1990). *Macrotermes subhyalinus* (Rambur) has been identified as one of the commonest and the most damaging termite species of agroforestry in Nigeria (Malaka, 1996; Pearce, 1997). *Macrotermes subhyalinus* can completely destroy wooden structures under favourable climatic condition within few months if left unchecked as they are voracious feeders and highly destructive (Malaka, 1996; Nyeko and Olubayo, 2005). Wood is one of the most frequently used material for construction purposes worldwide and had been directly linked to civilization of man (Tolunay *et al.*, 2008). However, the destructive activity of termite on woods has led to various socio-economic problems in Nigeria.

The most common method used for prevention and control of termite infestation is application of synthetic termiticides to structural peripherals (Kasseney *et al.*, 2016). The most common chemicals used for this purpose are broad-spectrum synthetic termiticides such as organophosphates and pyrethroids. Even though these synthetic pesticides play a significant role in controlling termites, there are serious ecological and economic problems associated with the large-scale use. These include: toxicity to non-target pests, pollution, injury to wood workers, bioaccumulation, pest resistance and in addition to these, they have prohibitive cost to resource poor farmers. This has underpinned the need to search for more suitable insecticides that would be more environmentally benign and less dangerous to human, especially in the management of termite.

The use of crude extracts or naturally occurring chemicals derived from botanicals for the

management of termite population in open field has been established to be relatively safer, effective, cheaper and less toxic to humans than most synthetic preservatives (Arango *et al.*, 2005; Verma *et al.*, 2009). In fact, some plants with repellent characteristics are often left on the farm as protectant against termite species belonging to genus *Macrotermes* and *Trinervitermes* (Sileshi *et al.*, 2008; Mugerwa *et al.*, 2014). Similarly, several botanicals such as *Azadirachta indica*, *Allium sativum* and *Tagetes erecta* have been touted as suitable preservatives to enhance the service life of wood (Schmutterer, 1990; Ascher, 1993; Verma *et al.*, 2009). However, there is need for continuous research into identification and testing of extracts from plants that have not been fully investigated for their pesticidal properties against termite.

*Milicia excelsa* (Welw.) C. Berg and *Khaya senegalensis* (Desr) A. Juss. are examples of botanicals that are yet to be fully investigated for their termiticidal potentials against *M. subhyalinus* infesting wooden structures in Nigeria. *Milicia excelsa* and *K. senegalensis* are deciduous trees belonging to family Moraceae and Meliaceae, respectively (Burkill, 1997; Orwa *et al.*, 2009). *Milicia excelsa* can however grow to a height of 50 m (Burkill, 1997) while *K. senegalensis* can only grow to a height of 15-30 m (Orwa *et al.*, 2009). The insecticidal, repellent and durability properties of both botanicals have earlier been established in several studies (Harris, 1971; Fengel and Wegner, 1984; Kityo and Plumtre, 1997; Syofuna *et al.*, 2006). There is however a paucity of information on the termiticidal activity of each botanical and their mixture against *M. subhyalinus*. Consequently, the heartwood of *M. excelsa* and leaves of *K. Senegalensis* were investigated for their termiticidal potentials against *M. subhyalinus* infesting wooden structures in Nigeria.

## MATERIALS AND METHODS

### Source and Preparation of Wood Samples

The wood, *Triplochiton scleroxylon* (Obeche) (Schum) used as substrate in this study was obtained from a Sawmill in Akure, Ondo State, Nigeria. Akure, the capital city of Ondo State in South-Western Nigeria was located at latitude 7.2571° N and longitude 5.2058° E of the equator. The choice of wood was based on previous records of highly susceptibility to insect pests (Ocloo, 1973; Louppe *et al.*, 2008; Owoyemi *et al.*, 2017). The wood was cut into dimension of 5×5×10 cm at Department of Forestry and Wood Technology, Federal University of Technology, Akure (FUTA). It was oven-dried to constant weight at 100-105°C (ASTM, 2003).

### Preparation of Plant Materials and Extracts

Leaves of *Khaya senegalensis* and heartwood of *Milicia excelsa* were sourced locally from a farm in Ijare, Ondo State, Nigeria. Each plant part was collected separately inside a sack in the month of May, 2018. The leaves were properly cleaned from dust using tissue paper and air-dried at room temperature ( $27 \pm 2^\circ\text{C}$ ) in the Laboratory of Biology Department, FUTA. The plants parts were ground to powder using Hammer mill (ATHM 150E) grinder. Ground samples were sealed in air-tight plastic containers and kept inside refrigerator ( $4^\circ\text{C}$ ).

Aqueous extract of *M. excelsa* and *K. Senegalensis* were prepared by soaking 200 g of each pulverized plant into 5 L of warm water ( $60^\circ\text{C}$ ) for 24 h. Each botanical mixture was then sieved using a quadri-folded muslin cloth to obtain their aqueous extract. Acetone, methanol and *n*-hexane extracts of each plant material and their mixture were also prepared by soaking method. For example, acetone, methanol and *n*-hexane extracts of *M. excelsa* were prepared by adding 200 g of *M. excelsa* powder to 5 litres of each solvent and properly stirred using a stirring rod for 2 h. After 24 h, each solvent mixture

was sieved through a quadri-folded muslin cloth to obtain acetone, methanol and *n*-hexane extracts of *M. excelsa*. The method was later repeated for *K. senegalensis* and the botanical mixture.

### Field Assay

Visual rating and weight loss were used to determine the level of termite infestation on wood treated with individual extracts of *M. excelsa*, *K. senegalensis*, and extracts of their mixture. Solvents (only) and Solignum® (Standard termiticides) were used as negative and positive controls, respectively. The wood blocks were treated based on the method described by Syofuna *et al.* (2006) with little modifications. Twenty wood block samples were soaked into 4 litres of each treatment as well as negative (Solvents) and positive controls (Solignum®). The wood blocks were allowed to stay for a period of five days in each treatment. After day 5, they were removed from each treatment and controls before being air dried in the laboratory at room temperature ( $27 \pm 2^\circ\text{C}$ ) for two days. The Initial weight of each wood block was recorded.

The experiment was carried out under two conditions (shade and open field) in areas infested with *Macrotermes subhyalinus* at Federal University of Technology, Akure. The experimental sites were properly cleared manually by hand weeding and laid out into a dimension of 5x4 m<sup>2</sup>. The temperature and relative humidity under shade were  $28.5 \pm 2^\circ\text{C}$  and  $72\% \pm 5$  respectively while open field were  $37.6^\circ\text{C} \pm 2$  and  $57\% \pm 5$  respectively. Treated wood-blocks (10 replicates per treatment) were placed under shade, and in open field at 15 cm apart within treatment and 30 cm apart between treatments according to ASTM (2003). The control wood-blocks (10 replicates for each control) were also set-up under shade and in open field. The wood-blocks were observed and assessed weekly for 3 months. Level of

infestation was visually rated according to the methods of Pearce (1997) and Syofuna *et al.* (2006). At three months of field trial, the remains of the exposed wood blocks were cleaned and oven dried (100-105°C) to constant weight and weighed (final weight). The degree of attack and damage to the test wood blocks were scored 0 through 5 and each score was assigned percentages from 0 to 100% according to the method proposed by Pearce (1997) with little modification. Average weight loss in wood blocks was calculated using the equation below as adapted from ASTM (2003):

$$\% \text{ Weight Loss} = \frac{IW - FW}{1} \times \frac{100}{IW}$$

where IW is the average initial weight and FW is the average final weight.

#### **Head Space – Solid Phase Micro Extraction, Gas Chromatography – Mass Spectrophotometry (HS-SPME, GC-MS) analysis of *M. excelsa* and *K. senegalensis***

The analysis was carried out in Laboratory of Organic Chemistry, Faculty of Pharmaceutical Science of USP Black Ribeirao, University of Sao Paulo, Brazil. The phytochemical constituents of *M. excelsa* and *K. senegalensis* used were profiled using HS-SPME, GC-MS analysis. Dried plants samples of *M. excelsa* and *K. senegalensis* were ground to powder using Hammer mill (ATHM 150E) grinder, and further sieved using a sieve with a mesh size of 50 µm before being utilized for the HS-SPME step. A sample of plant material (60 mg) was sealed in 2 mL vials and stored at -18°C for 2 h before HS-SPME sampling. The SPME device was inserted into the sealed vial containing the plant sample and the fiber was exposed to the headspace (equilibration time 15 min and temperature 50°C; sampling time 120 min and temperature 50°C). After sampling, the SPME device was immediately inserted into the GC injector and the fiber was thermally desorbed

for 15 min at 230°C. Analyses were carried out on an Agilent GC-6890 Plus system coupled to a 5973 MSD (Little Falls, DE, and USA). For HS-SPME-GC-MS analysis, the injector was operated in the splitless mode at 230°C for 5 min and thereafter split in ratio 1:10. The chromatographic conditions were: column, HP - 5MS (25 m × 0.25 mm i.d., 0.3 mm film thickness; Agilent); oven temperature programme from 40°C (held for 3 min) to 125°C (0 min) at 4°C min<sup>-1</sup>, then at 1.5°C min<sup>-1</sup> to 140°C (4 min) and finally at 5°C min<sup>-1</sup> to 250°C (5 min); carrier gas was Helium at a flow rate of 1.0 mL min<sup>-1</sup> in constant flow mode. Interface temperature was 280°C and the MS were obtained in the electron impact mode at 70 eV, scan mode, range *m/z* 35-350 at a rate of 2.36 scans s<sup>-1</sup>. Data were acquired in a PC system using software ChemStation G1701CA (Agilent).

#### **Statistical Analysis**

The data collected were converted to percentages, arcsine transformed and subjected to Analysis of Variance (ANOVA) at  $\alpha = 0.05$ . Tukey's test was used to separate means. Student t-test was used to compare the weight loss in wood exposed to extracts in open field and under shade. All analyses were done using Statistical Package for Social Sciences (SPSS) Version 21.0 Software Package.

## **RESULTS**

### **Effectiveness of plant extracts on treated wood against *Macrotermes subhyalinus* infestation**

#### **Visual rating of treated wood blocks**

At six weeks of trial in open field, there were no signs of termite attack on woods treated with water extracts of *M. excelsa*, *K. senegalensis* and *n*-hexane extract of the mixture of both botanicals and the standard Solignum® control (Fig. 1). Untreated wood samples had the greatest damage (71%). Among the extract-

treated woods, samples treated with acetone extract of *K. senegalensis* and *M. excelsa* had the highest level (18%) of termite infestation. Termite infestation increased in treated wood blocks by the 12th week after exposure (Fig. 2). Among the extract-treated wood, samples treated with *n*-hexane extract of the mixture of *K. senegalensis* and *M. excelsa* was found to have the lowest infestation (21%) and the highest recorded in wood treated with methanol extract of *K. senegalensis* (50%). Highest (95%) and lowest (6%) wood damages were observed in untreated and Solignum-treated wood blocks, respectively.

All the extracts of *K. senegalensis* had highest infestation (60-65%) compare to other extracts tested at six weeks of trial under shade (Fig. 3). Woods treated with *n*-hexane extract of *M. excelsa* were the lowest damaged (40%). Untreated wood blocks were totally consumed (100%). No damage was however recorded in wood treated with Solignum®. Also, the highest levels of attack were observed in all the extracts of

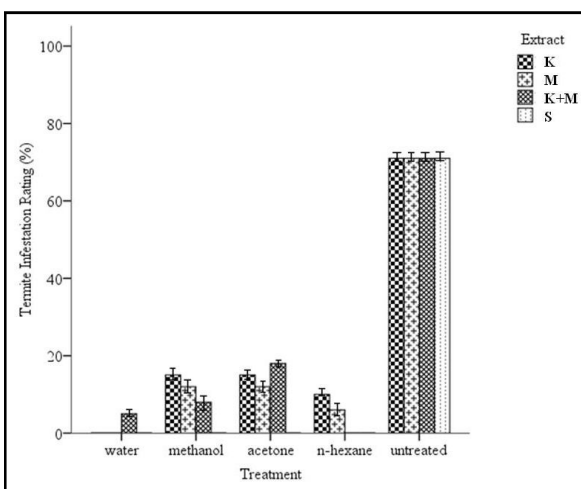


Figure 1: Rating of level of termite infestation on woods treated with plant extracts at six (6) weeks of exposure in open field  
 K = *Khaya senegalensis*  
 M = *Milicia excelsa*  
 K+M = *Khaya senegalensis* + *Milicia excelsa*  
 S = Solignum (standard control)

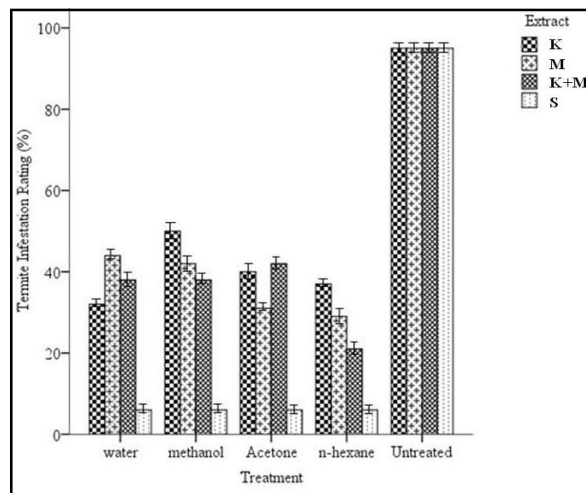


Figure 2: Rating of level of termite infestation on woods treated with plant extracts at twelve (12) weeks of exposure in open field.  
 K = *Khaya senegalensis*  
 M = *Milicia excelsa*  
 K+M = *Khaya senegalensis* + *Milicia excelsa*  
 S = Solignum (standard control)

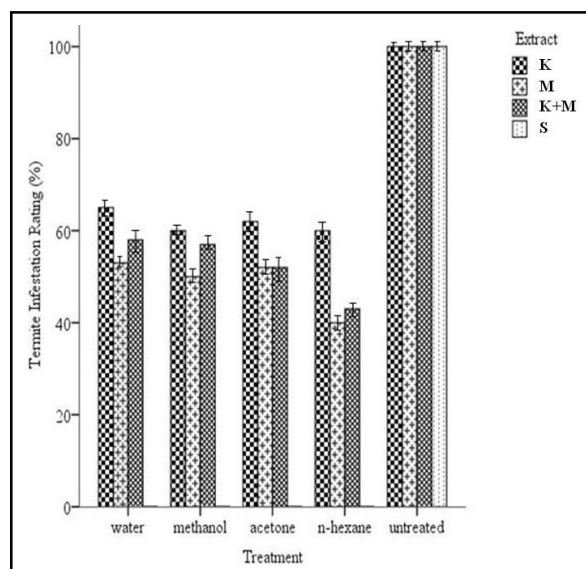


Figure 3: Rating of level of termite infestation on woods treated with plant extracts at six (6) weeks of exposure under shade.  
 K = *Khaya senegalensis*  
 M = *Milicia excelsa*  
 K+M = *Khaya senegalensis* + *Milicia excelsa*  
 S = Solignum (standard control)

*K. senegalensis* at twelve (12) weeks of exposure under shade (Fig. 4). Among the extracts tested, wood treated with water extract of *M. excelsa* (70%) had the lowest damaged. Untreated wood blocks were totally consumed (100%) and the lowest damaged (19%) was recorded in wood treated with the standard control (Solignum®).

### Weight Loss of Wood Blocks

Weight of treated wood blocks of *K. senegalensis*, *M. excelsa* and mixture of their extracts ranged from 31.32-49.07%, 28.32-43.91% and 21.14-41.19% respectively (Table 1). Weight loss significantly varied with type of solvents

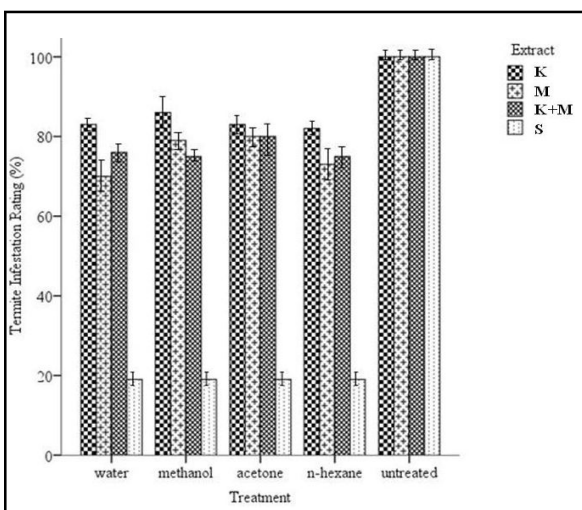


Figure 4: Rating of level of termite infestation on woods treated with plant extracts at twelve (12) weeks of exposure under shade.

K = *Khaya senegalensis*

M = *Milicia excelsa*

K+M = *Khaya senegalensis* + *Milicia excelsa*

S = Solignum (standard control)

in the three treatments: *K. senegalensis*, *M. excelsa* and mixture of the extracts (ANOVA,  $P < 0.001$ ). The weight loss of wood treated with water extracts ranged from 31.32-43.91%. The effectiveness of methanol extracts of the plants was significantly different ( $p < 0.01$ ) and the weight loss ranged from 37.67-49.07%. The weight loss in wood treated with acetone extracts of the plants

ranged from 30.10-41.19% while the weight loss in woods treated with *n*-hexane extracts ranged from 21.14-36.72% ( $p < 0.01$ ). The highest (96.03%) and lowest (5.68%) weight loss was recorded in untreated and Solignum® treated wood blocks respectively (Table 1). Similarly, wood blocks treated with all the extracts of *K. Senegalensis* and botanical mixture (K+M) had significantly lower ( $p < 0.05$ ) weight loss compared to untreated and solvent treated wood blocks (Table 1).

Weight of wood blocks treated with *K. senegalensis*, *M. excelsa* and mixture of their extracts ranged from 82.77-86.18%, 70.73-80.50% and 75.74-80.20% respectively (Table 2). Weight loss varied significantly with type of solvents in the three treatments: *K. senegalensis*, *M. excelsa* and mixture of the extracts. The weight loss of wood treated with water extracts ranged from 70.73%-83.64% and there were significant differences ( $p < 0.01$ ) among the treatment. Wood treated with water extract of *K. senegalensis* (83.64%) had the highest weight loss and wood treated with water extract of *M. excelsa* (70.73%) had the lowest. Wood treated with methanol extracts was significantly different ( $p < 0.01$ ) and the weight loss ranged from 75.80-86.18%. The wood treated with *K. senegalensis* had the highest weight of 86.18% while the botanical mixture had the lowest of 75.80%. Weight loss of woods treated with acetone and *n*-hexane extract ranged from 80.24%-83.93% and 73.60-82.77% respectively. There was no significant difference ( $p > 0.05$ ) between wood treated with acetone extract of *M. excelsa* (80.50%) and the mixture (80.24%). Meanwhile there was significant difference ( $p < 0.01$ ) in the weight loss of wood treated with *n*-hexane extract. Extract of *M. excelsa* also had the least weight loss of 73.60% of all the three treatments. Of the four solvent extracts, aqueous extract exhibited the highest protection on treated wood blocks, evidenced by the lowest weight

loss recorded in wood blocks treated with water extract of *M. excelsa*. All the wood blocks treated with aqueous, n-hexane and methanol extracts had significantly lower ( $p < 0.05$ ) weight loss compared to untreated and solvent treated wood blocks (Table 2). Regardless of the nature of extract, wood blocks in the open field were better protected due to significantly lower ( $p < 0.05$ ) values compared to those blocks under shade (Table 3).

### Profile of Compounds identified in *M. excelsa*

Thirty-four (34) compounds were identified in heartwood of *M. excelsa* (Table 4). Major compounds identified were Tridecane<n->

(11.61%), 1, 2-Benzenedicarboxylic acid (8.30%) among others. The compound with the least quantity (0.55%) was 2, 5-di-tert-Butyl-1, 4-benzoquinone. In *K. senegalensis*, forty-four (44) chemical compounds were identified in leaves (Table 5). Major compounds identified were Ylangene (14.93%), Cadinene<gamma-> (10.14%) among others. The compound with the least quantity (0.04%) was Decanedioic acid.

### DISCUSSION

The use of plant parts and its derivatives to control insect pests has been an age long practice in African agriculture (Maistrello *et al.*, 2003). In this study, all extracts of the two plants were effective only in open field trial by protecting the treated wood

**Table 1:** Weight loss (%) in extract-treated woods exposed to *Macrotermes subhyalinus* in open field (Mean  $\pm$  SE)

Plant	Untreated	Solignum	Water	Methanol	Acetone	n-Hexane	Solvent controls			
							Water	Methanol	Acetone	n-Hexane
<i>K. senegalensis</i>	96.03 $\pm 0.00^{aj}$	5.68 $\pm 0.15^{aA}$	31.32 $\pm 0.98^{aB}$	49.07 $\pm 0.49^{cE}$	39.31 $\pm 0.26^{bD}$	36.72 $\pm 0.35^{cC}$	84.79 $\pm 0.35^{aI}$	65.30 $\pm 0.33^{aH}$	53.50 $\pm 0.22^{aF}$	61.22 $\pm 0.31^{aG}$
<i>M. excelsa</i>	96.03 $\pm 0.00^{ai}$	5.68 $\pm 0.15^{aA}$	43.91 $\pm 0.83^{cD}$	41.36 $\pm 0.35^{bC}$	30.10 $\pm 0.28^{aB}$	28.32 $\pm 0.54^{bB}$	84.79 $\pm 0.35^{aH}$	65.30 $\pm 0.33^{aG}$	53.50 $\pm 0.22^{aE}$	61.22 $\pm 0.31^{aF}$
<i>K. senegalensis</i> + <i>M. excelsa</i>	96.03 $\pm 0.00^{ai}$	5.68 $\pm 0.15^{aA}$	37.41 $\pm 0.56^{bC}$	37.67 $\pm 0.31^{aC}$	41.19 $\pm 0.40^{cD}$	21.14 $\pm 0.23^{aB}$	84.79 $\pm 0.35^{aH}$	65.30 $\pm 0.33^{aG}$	53.50 $\pm 0.22^{aE}$	61.22 $\pm 0.31^{aF}$

Mean values followed by the same lower-case letter(s) down the column are not significantly different at  $\alpha = 0.05$  using ANOVA and Tukey's test while mean values followed by the same upper-case letter(s) across the rows are not significantly different at  $\alpha = 0.05$  using ANOVA and Tukey's tests.

**Table 2:** Weight loss (%) in extract-treated wood exposed to *Macrotermes subhyalinus* under shade (Mean  $\pm$  SE).

Plant	Untreated	Solignum	Water	Methanol	Acetone	n-Hexane	Solvent controls			
							Water	Methanol	Acetone	n-Hexane
<i>K. senegalensis</i>	97.02 $\pm 0.00^{aE}$	19.90 $\pm 0.33^{aA}$	83.64 $\pm 0.60^{bB}$	86.18 $\pm 0.33^{cC}$	83.93 $\pm 0.36^{bB}$	82.77 $\pm 0.41^{cB}$	96.73 $\pm 0.24^{aE}$	90.58 $\pm 0.47^{aD}$	88.83 $\pm 0.56^{dD}$	88.91 $\pm 0.55^{aD}$
<i>M. excelsa</i>	97.02 $\pm 0.00^{aF}$	19.90 $\pm 0.33^{aA}$	70.73 $\pm 0.76^{aB}$	79.72 $\pm 0.59^{bD}$	80.50 $\pm 0.44^{aD}$	73.60 $\pm 0.69^{aC}$	96.73 $\pm 0.24^{aF}$	90.58 $\pm 0.47^{aFE}$	88.83 $\pm 0.56^{aE}$	88.91 $\pm 0.55^{aE}$
<i>K. senegalensis</i> + <i>M. excelsa</i>	97.02 $\pm 0.00^{aE}$	19.90 $\pm 0.33^{aA}$	76.60 $\pm 0.73^B$	75.80 $\pm 0.51^{aB}$	80.24 $\pm 0.30^{aC}$	75.74 $\pm 0.45^{bB}$	96.73 $\pm 0.24^{aE}$	90.58 $\pm 0.47^{aED}$	88.83 $\pm 0.56^{dD}$	88.91 $\pm 0.55^{aD}$

Mean values followed by the same lower-case letter(s) down the column are not significantly different at  $\alpha = 0.05$  using ANOVA and Tukey's test while mean values followed by the same upper-case letter(s) across the rows are not significantly different at  $\alpha = 0.05$  using ANOVA and Tukey's tests.

**Table 3:** Comparison of effectiveness of extracts in open field and under shade experiment using Student t-test. Each value is a mean of ten (10) replicates.

Extract	Condition	Weight loss (%)							
		<i>K. senegalensis</i>	t (p-value)	<i>M. excelsa</i>	t (p-value)	Mixture	t (p-value)	control	t (p-value)
Methanol	Shade	86.18	8.13 (0.001)	79.72	3.67 (0.005)	75.79	4.35 (0.002)	19.91	1.76
	Open	49.07		41.36		37.67		5.68	(0.112)
<i>n</i> -Hexane	Shade	82.77	7.19 (0.001)	73.60	5.60 (0.001)	75.73	7.76 (0.001)	19.91	1.76
	Open	36.72		28.79		21.14		5.68	(0.112)
Acetone	Shade	83.92	4.91 (0.001)	80.50	9.18 (0.001)	80.24	5.69 (0.001)	19.91	1.76
	Open	39.31		30.09		41.19		5.68	(0.112)
Water	Shade	83.64	10.89 (0.001)	70.73	3.42 (0.008)	76.60	3.97 (0.003)	19.91	1.76
	Open	31.33		43.89		37.49		5.68	(0.112)

**Table 4:** Chemical compounds identified in *Milicia excelsa* leaves

S/N	RT (mins)	Name of compounds	CAS No.	% of Total
1	9.646	6-Methyl-5-hepten-2-one	110-93-0	1.60
2	11.341	Eucalyptol	470-82-6	0.75
3	11.480	Benzene, iodo-	591-50-4	3.58
4	14.483	Nonanal	124-19-6	0.80
5	17.930	Naphthalene	91-20-3	1.33
6	19.002	Decanal	112-31-2	1.87
7	19.370	Decane, 2,5,9-trimethyl- (CAS)	62108-22-9	0.75
8	20.602	Citral	5392-40-5	1.22
9	21.986	Octane, 2,3,6-trimethyl- (CAS)	62016-33-5	3.32
10	23.182	Tridecane<n->	629-50-5	11.61
11	24.959	Cyclohexane	1795-15-9	0.78
12	26.486	Dodecane	61141-72-8	2.07
13	27.476	Tetradecane	629-59-4	7.92
14	29.675	5,9-Undecadien-2-one, 6,10-dimethyl	689-67-8	2.65
15	30.336	2,5-di-tert-Butyl-1,4-benzoquinone	2460-77-7	0.55
16	31.420	Dodecane, 4,6-dimethyl-	61141-72-8	1.89
17	31.573	Hexadecane <n->	544-76-3	3.15
18	32.095	BHT	128-37-0	7.90
19	3.204	Dodecane, 4,6-dimethyl-	61141-72-8	2.48
20	35.180	1-Hexadecene (CAS) Cetene	629-73-2	2.24
21	35.469	Octadecane<n->	593-45-3	2.99
22	39.174	Nonadecane<n->	629-92-5	3.24
23	39.399	Hexadecane, 2,6,10,14-tetramethyl	638-36-8	2.19
24	39.555	Tricontane<n->	638-68-6	2.11
25	41.097	Hexadecane (CAS) n-Hexadecane	544-76-3	1.14
26	42.697	Eicosane<n->	112-95-8	2.39
27	42.907	2-Ethylhexyl salicylate	118-60-5	1.91
28	43.654	Benzene, (1-pentyloctyl)- (CAS)Tridecane,	4534-49-0	1.07
29	45.002	1,2-Benzenedicarboxylic acid	84-69-5	8.30
30	45.570	Homosalate	118-56-9	1.36
31	46.056	Docosane<n->	629-97-0	1.39
32	48.061	Dibutyl phthalate	84-74-2	6.39
33	49.259	Pentacosane<n->	629-99-2	1.69
34	52.333	Tetracosane	646-31-1	1.09

\*S/N is serial number \*RT is Retention Time \*CAS no. is Chemical Abstracts Service Number



**Table 5:** Chemical compounds identified in leaves of *Khaya senegalensis*.

S/N	RT (mins)	Name of compounds	CAS No.	% of Total
1	7.729	alpha.-Thujene	2867-05-2	0.08
2	17.894	Azulene	275-51-4	0.19
3	18.956	Decanedioic acid, didecyl ester	2432-89-5	0.04
4	20.694	Decane, 2,3,5-trimethyl- (CAS)	62238-11-3	0.08
5	22.299	Dodecane, 4,6-dimethyl	61141-72-8	0.56
6	24.809	Elemene<delta->	370572-92-2	2.75
7	25.335	Cubebene<alpha->	31141-66-9	0.55
8	25.874	5-Isopropenyl-2-methyl-7-oxabicyclo [4.1.0]	0-00-0	0.21
9	26.088	Cyclosativene	30541-92-5	1.48
10	26.290	Ylangene	14912-44-8	14.93
11	26.461	Copaene<alpha->	138874-68-7	1.16
12	26.842	Beta bourbonene	5208-59-3	5.59
13	26.935	Bourbonene	5208-59-3	0.56
14	27.060	Cadina-3,5-diene	267665-20-3	0.68
15	27.152	Cyclohexane	515-13-9	4.52
16	28.270	beta.-ylangene	0-00-0	2.45
17	28.688	Cubebene<beta->	13744-15-5	2.67
18	28.965	Germacrene-D	23986-74-5	1.62
19	29.275	Guaia-6,9-diene	37839-64-8	3.24
20	29.499	Guaiene<alpha->	53863-54-0	4.13
21	29.646	5,9-Undecadien-2-one	689-67-8	1.39
22	30.072	Muurolo-4(14),5-diene <cis->	157477-72-0	2.42
23	30.638	Muuroloene<gamma->	30021-74-0	2.89
24	30.798	alpha.-Amorphene	23515-88-0	1.10
25	31.023	Selinene<beta->	17066-67-0	1.55
26	2.49	1-Naphthalenol	19435-97-3	2.49
27	31.592	alpha.-Muuroloene(-)	10208-80-7	1.52
28	32.170	Cadinene<gamma->	38357-83-4	10.14
29	32.513	Cadinene<delta->	16729-01-4	2.39
30	32.625	Andrographolide	5508-58-7	0.39
31	32.723	2(4H)-Benzofuranone	15356-74-8	2.05
32	32.800	Cubebol	23445-02-5	0.61
33	32.905	Naphthalene	483-77-2	0.89
34	33.071	Cadinene<alpha->	82468-90-4	1.97
35	33.200	Dodecane	61141-72-8	0.58
36	33.275	Calacorene<alpha->	77129-50-1	0.47
37	33.584	Cubebol	23445-02-5	1.75
38	4.635	Spathulenol	6750-60-3	0.74
39	34.839	Caryophyllene oxide	17627-43-9	2.41
40	35.263	salvial-4(14)-en-1-one	00-0	6.49
41	36.067	Epicubenol	19912-67-5	0.48
42	5.17	2-Pentadecanone, 6,10,14-trimethyl- (CAS)	502-69-2	5.17
43	44.981	1,2-Benzenedicarboxylic acid	84-69-5	0.31
44	48.047	Dibutyl phthalate	84-74-2	0.52

S/N = Serial number

RT = Retention Time

CAS No. = Chemical Abstracts Service Number

blocks for six weeks without signs of infestation. Aqueous extracts of individual plant were more effective than *n*-hexane, acetone and methanol extracts. Similarly, the *n*-hexane extract of mixture of plants was most effective among extracts of mixture of plants. Acetone extract of mixture of plants was least effective at protecting wood against termite in this study. This finding agrees with the report of Syofuna *et al.* (2006) who reported while evaluating the efficiency of natural wood extractives as wood preservatives against termite's attack that aqueous extracts of *M. excelsa* were more effective against termites than *n*-hexane and acetone extracts. The authors hinged the effectiveness on solubility of the extractives in water which may also account for the similar trend observed in this study.

It has been reported that the heart wood of *M. excelsa* is durable and resistant to termite, and as such are used for construction purposes (Wayne, 1984; Hines and Eckman, 1983). Also, Syofuna *et al.* (2006) used *M. excelsa* as positive control in their experiment due to the confirmation of its resistance to termites. Vogt (1995) had reported that, *K. senegalensis* was also resistant to fungi and termites. In this study, the lack of signs of termite attack after six months signifies possibility of inherent protectant properties in the extracts. Also in this study, weight loss was much lower in *M. excelsa*-treated wood than in *K. senegalesis*-treated wood. The greater protection conferred on *M. excelsa*-treated wood could be attributed to the number of reported bioactive compounds in the extracts. Although, *K. senegalensis* contained more compounds than *M. excelsa*, higher number of insecticidal compounds was however identified in the latter. Butylated Hydroxyl toluene (BHT) had been used as ingredient pesticide formulation (Yehye *et al.*, 2015). Fumigant, stomach and contact toxicity of tridecane was reported by Hawthorne and Sievers (2016). Also, cyclohexane

had been used as nerve poison agent in pesticides formulation (Shields and Weschler, 2012). Citral has also been found toxic to aquatic life and man (McDonald, 1992). These compounds, found in *M. excelsa*, may have acted in concert to elicit repellent and antifeedant activity thus resulting in the greater level of wood preservation observed in this study.

Although *K. senegalensis* appeared to be less effective compared to *M. excelsa*, nevertheless, the substrate exposed to *n*-hexane extracts of mixture of *K. senegalensis* and *M. excelsa* was least attacked and had the lowest weight loss at twelfth week exposure. This signals some level of synergism and persistence in wood protection potential of *n*-hexane extracts. The wood treated with aqueous extracts that were well preserved at the onset of the trial up to six weeks eventually had higher termite attack and weight loss than the *n*-hexane extract-treated wood. This suggests that the persistent bioactive components in the plants may likely be non-polar compounds (Adnan *et al.*, 2007). Therefore, it could be inferred that the polar components may be photo-sensitive thus readily degraded faster than non-polar compound.

In contrast, the extracts were not effective under shade. Signs of infestation were noticed on all extract-treated wood under shade as early as week 2 of the experiment indicating that environmental conditions have significant effects on the effectiveness of the extracts. Contrary to the observed potency of aqueous extract in open field, *n*-hexane extracts of *M. excelsa* and mixture of *n*-hexane extracts of both botanicals were more effective than other extracts but not as effective as aqueous extract of the individual plants in open field. Variation in environmental conditions, temperature and humidity, between the two experimental sites may have accounted for the observed variance. High humidity and warm temperature are known to enhance growth of microorganism which will result in degradation

of the extracts and the wood (Dannemiller *et al.*, 2016). Incidence, survival and multiplication of subterranean termite depend mainly on availability of moisture, and warm temperature (Cornelius and Osbrink, 2010). They rely on moisture from soil, wood and mud tubes for protection from desiccation (McManamy *et al.*, 2008). The temperature (28.5°C) and relative humidity (72%) observed in this study under shade which corresponds to the reported optimum condition (28°C and 67-92%) by other researchers (Syofuna *et al.*, 2006; Kulis *et al.*, 2008) for survival of subterranean termites.

### CONCLUSION

Extracts of *K. senegalensis* and *M. excelsa* had varied levels of wood protection potentials. The extracts were effective only in open field. Aqueous extracts of individual plants and *n*-hexane extracts of mixture of the two plants preserved treated wood for six weeks in open field test against termite infestation. The *n*-hexane extracts of mixture of *K. senegalensis* and *M. excelsa* persisted in preserving the treated wood for twelve weeks. *M. excelsa* was more effective at preserving wood against the subterranean termite. Butylated Hydroxyl toluene (BHT), Docosane, Tridecane, Cyclohexane and Citra were the components of *M. excelsa*, and Cyclohexane and Cucubene in *K. senegalensis* had been found to have insecticidal properties which could be of importance in developing ecologically tolerable agents for managing subterranean termites.

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### REFERENCES

- Adnan, Y., Muhammad, S. K., Asif, A. K., Atif, R. and Aslam, P. M. (2007).** Effect of different Extraction methods on Yield and Quality of Essential Oil from four *Rosa species*. *Floriculture and Ornamental Biotechnology* 1(1): 73-76.
- Arango, R. A., Green, F., Hintz, K., Lebow, P. K. and Miller, R.B. (2006).** Natural durability of tropical and native woods against termite damage by *Reticulitermes flavipes* (Kollar). *International Biodeterioration and Biodegradation* 57(3): 146-150.
- Ascher, K.R.S. (1993).** Non-conventional insecticidal effects of pesticides available from the neem tree, *Azadirachta indica*. *Archives of Insect Biochemistry and Physiology* 22: 433-449.
- ASTM (2003).** D1413-99 Standard Test Method for Wood Preservatives by Laboratory Soil-Block Cultures. ASTM International, West Conshohocken.
- Bignell, D.E. and Eggleton, P. (2000).** Termites in ecosystems. In: Abe T, Bignell DE, Higashi M, editors. Termites: evolution, sociality, symbiosis, ecology. Dordrecht: Kluwer Academic Publishers, pp. 63-387.
- Bruno, G., Johannes, L. and Maike, F. (2001).** Carbon and nitrogen mineralization in cultivated and natural savanna soils of Northern Tanzania. *Biology and Fertility of Soils*, 33: 301-309
- Burkill, H. M. (1997).** The Useful plants of West Tropical Africa. 2nd edition vol. 4, Families M-R. Royal Botanic Gardens, Kew, Richmond, United Kingdom, 969pp.
- Cornelius, M.L. and Osbrink, W.L. (2010).** Effect of soil type and moisture availability on the foraging behavior of the Formosan subterranean termite (Isoptera: Rhinotermitidae). *Journal of Economic Entomology* 103(3): 799-807. DOI: 10.1603/ec09250
- Dannemiller, K. C., Weschler, C. J. and Peccia,**

- J. (2016).** Fungal and bacterial growth in floor dust at elevated relative humidity levels. *International Journal of Indoor Environment and Health*, 27: 354-363. DOI: 10.1111/ina.12313.
- Fengel, D. and Wagener, G. (1984).** *Wood chemistry, Ultrastructure and Reaction*. Waster and Grugter, New York, 613pp.
- Freyman, B.P., Buitenwerf, R., Desouza, O. and Olf, H. (2008).** The importance of termites (Isoptera) for the recycling of herbivore dung in tropical ecosystem: a review. *European Journal of Entomology*, 105:165-73
- Garba, M., Cornelis, W.M. and Steppe, K. (2011).** Effet of termite mound material on the physical proprieties of sandy soil and on the growth characteristics of tomato (*Solanum lycopersicum* L.) in semiarid Niger. *Plant and Soil*, 338: 451-66.
- Harris, W.V. (1971).** Termites, their recognition and control (2nd ed.). London, Longmans, Green, p. 187.
- Hawthorne, S.B. and Sievers, R.E. (1984).** Emission of organic air pollutants from shade oil wastewaters. *Environmental Science Technology*, 18: 483-490. Doi: <https://doi.org/10.1021/es00124a016>.
- Hines, D.A. and Eckman, K. (1983).** Indigenous multipurpose trees of Tanzania: uses and economic benefits for people. Publications Division, Food and Agricultural Organization of the United Nations, VialedelleTerme di Caracalla, 00100 Rome, Italy, pp. 1-95.
- Jouquet, P., Traoré, S., Choosai, C., Hartmann, C. and Bignell, D. (2011).** Influence of termites on ecosystem functioning. Ecosystem services provided by termites. *European Journal of Soil Biology*, 47: 215-22.
- Kambhampati, S. and Eggleton, P. (2000).** Taxonomy and phylogeny of termites. In Abe, T., Bignell, D.E., Higashi M. (Eds.), *Termites: Evolution Sociality, Symbiosis and Ecology*. Dordrecht: Kluwer Academic Publisher, pp. 1-23.
- Kassene, B.D., Nyamador, W.S., Mondedji, A.D., Ketoh, G.K. and Glitho, I.A. (2016).** Termiticidal activities of few plant extracts against *Macrotermes subhyalinus* smeathman and *Trinervitermes geminatus* wasmann (Isoptera: Termitidae) survival. *African Journal of Agricultural Research* 11(28): 2475-2480.
- Kityo, P.W. and Plumptre, R.A. (1997).** The Uganda Timbers User Handbook: A guide to better timber use. Commonwealth Secretariat, Marlborough House, Pall Mall, London, SW1Y 5HX (United Kingdom). ISBN: 0-85092-493-6, 135pp.
- Kulis, J.A., Sajap, S. and Loong, C.Y. (2008).** Effect of moisture and relative humidity on survival and feeding activity of the Asian Subterranean Termite, *Coptotermes gestroi* (Isoptera: Rhinotermitidae). *Sociobiology*, 52(3): 579-587
- Logan, M.W., Cowie, R.H. and Wood, T.G. (1990).** Termite (Isoptera) control in agriculture and forest by nonchemical methods a review. *Bulletin of Entomological Research*, 80: 309-30.
- Loko, L.E.Y., Orobiyi, A., Agre, P., Dansi, A., Tamò, M. and Roisin, Y. (2017).** Farmers' perception of termites in agriculture production and their indigenous utilization in Northwest Benin. *Journal of Ethnobiology and Ethnomedicine* 13:64. DOI 10.1186/s13002-017-0187-2
- Loupe, D. (2008).** In: Loupe Dominique (ed.), Otend-Amoako A.A. (ed.). *Resources vPgPtales de l'Afrique tropicale*. ProtA 7(1): bois d'oeuvre. Wageningen: PROTA, pp. 107-111.
- Maistrello, L., Henderson, G. and Laine, R.A. (2003).** Comparative effects of vetiver oil, nootkatone and disodium octaboratetetrahydrate on *Coptotermes formosanus* and its symbiotic fauna. *Pest Management Science* 59: 58-68.
- Malaka, S.L.O. (1996).** *Termites in West Africa*. 1st Edn., University of Lagos Press, USA, ISBN: 978-017-144-4, pp. 165.
- McDonald, L.L. (1992).** Preliminary evaluation of new materials as toxicants, repellents and attractants against stored product

- insects. Washington Agricultural Research Service, US Department of Agriculture, p. 8.
- McManamy, K., Philip, G., Deanna, D. and Roberto, M. (2008).** Wood Moisture Content Affects the Survival of Eastern Subterranean Termites (Isoptera: Rhinotermitidae), Under Saturated Relative Humidity Conditions. *Sociobiology* 52 (1): 145-156.
- Mitchell, J. D. (2002).** Termites as pests of crops, forestry, rangeland and structures in Southern Africa and their control. *Sociobiology*, 40: 47-69.
- Nakayama, T., Yoshimura, T. and Imamura, Y. (2004).** The optimum temperature-humidity combination for the feeding activities of Japanese subterranean termites. *Journal of Wood Science*, 50: 530-534.
- Nyeko, P. and Olubayo, F.M. (2005).** Participatory assessment at farmers' experience of termite problems is Agro forestry in sources District Uganda. Network Paper No. 143, pp. 1-15.
- Ocloo, J. K. (1973).** The estimation of damage by the larger *Macrotermatinae* (Isoptera, Insecta) using volume measurement. *Ghana Journal of Science*, 13: 92-96.
- Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009).** Agroforestry Database: a tree reference and selection guide version 4.0 (<http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp>).
- Owoyemi, J.M., Adiji, A.O. and Aladejana, J.T. (2017).** Resistance of some indigenous tree species to termite attack in Nigeria. *Journal of Agricultural and Urban Entomology* 33: 10-18. <http://dx.doi.org/10.3954/1523.5475-33.1.10>.
- Pearce, M.J. (1997).** Termite: biology and pest management. Wallingford, CAB International, United Kingdom, p. 204.
- Pearce, M.J. (1997).** Termites, Biology and Pest Management. CAB International, Willing Ford UK, p. 172.
- Robert, O.E., Frank, U.O. and Agbonsalo, O.U. (2007).** Influence of Activities of Termites on Some Physical and Chemical Properties of Soils under Different Land Use Patterns: A Review. *International Journal of Soil Science*, 2: 1-14.
- Rust, M. K. and Su, N. (2012).** Managing Social Insects of Urban Importance. *Annual Review of Entomology* 57(1): 355–375. doi:10.1146/annurev-ento-120710-100634
- Schmutterer, H. (1990).** Properties and potential of natural pesticides from the neem tree *Azadirachta indica*. *Annual Review of Entomology*, 35: 271-297.
- Shields, H.C. and Weschler, J.C. (2012).** Volatile organic compounds measured at a telephone switching center from 30 May, 1885-6 December 1988: A detailed case study. *Journal of Air Waste Management Association* 42(6): 792-804. Doi: <https://doi.org/10.1080/10473289.1992.10467031>.
- Smith, J.L. and Rust, M. K. (1993).** Effect of relative humidity and temperature on the survival of *Reticulitermes* (Isoptera: Rhinotermitidae). *Sociobiology*, 21: 217-224.
- Syofuna, A., Banana, A. and Nakabonge, G. (2006).** Efficiency of Natural Wood Extractives as Wood Preservatives against Termite attack. *MADERAS: Ciencia y Tecnología*, 14(2): 155-163.
- Tolunay, A., Akyol, A. and Ozcan, M. (2008).** Usage of trees and forest resource at house hold level: A case study of Asagi Yumrut as village from the West Mediterranean region of Turkey. *Research Journal of Forestry*, 2:1-14.
- Verma, M., Sharma, S. and Prasad, R. (2009).** Biological alternatives for termite control: A review. *International Biodeterioration and Biodegradation*, 63(8): 959-972.
- Vogt, K. (1995).** A field workers's guide to the identification, propagation and uses of common trees and shrubs of dryland Sudan. SOS Sahel International (UK), p. 167.
- Wayne, T. (1984).** A pocket directory of trees and seeds in Kenya. Nairobi: KENGO.
- Yehye, W.A., Rahman, N.S., Ariffin, A., Hamid, S.B. Alhadi, A.A., Kadir, F.A. and Yaeghoobi, M. (2015).** Understanding the chemistry behind antioxidant activities of butylated hydroxyl toluene (BHT). *European Journal of Medicinal Chemistry*, 101: 295-

315.

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