Floor-Type Characterization, Temperature And Humidity Tolerance For Tunga Penetrans Infestation In Igbokoda, Ondo State, Nigeria.

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Abstract: Tunga penetrans, the jigger flea is causal agent of the skin inflammatory disease so-called tungiasis which is considered common with unhygienic, poor and indigent residents of communities in the world. This study illustrates the various floor type characteristics and designated key environmental factors that buoy up infestations in endemic foci. Sand fleas were sampled using a clean white cloth laid on floors of house and verandas and environmental variables determined using EOSUN electronic device for temperature cum relative humidity measures. Result divulge that majority of the fleas were obtained from inside house of Zion (36 fleas) and verandas of Kofawe (29 fleas). Inside the house of the various locations, unpaved floor types accounted for 52.8% and 70% of the sampled fleas in Zion and Kofawe respectively and 50% of the sampled in both paved and paved floors with cracks in Laranda while in verandas, 36.7% and 62.1% of the sampled fleas were from unpaved floor types in Zion and Kofawe and 54.2% of the fleas recorded in paved floors with cracks in Laranda. Temperature ranges of 28.0°C-35.6°C and relative humidity ranges of 50.0%-88% were reported for this study. Since the various floor-type characteristics and selected environmental conditions are optimum for flea population growth, targeting the temperature and relative humidity tolerance level through manipulation for species and paving the unpaved and amending the paved with cracks floor types is recommended to discourage infestations.

Keywords: Floor-type characterization, temperature, humidity tolerance, Tunga penetrans and Igbokoda

1. Introduction
Tungiasis is an ectodermal skin membrane parasitosis common within the scope of exposed bodily parts in contact with infected soil. Infected soil could be in unpaved houses, paved houses with cracks, and even untaurred streets where residents move with unprotected feet. The penetration of female sand flea into the exposed skin cause the disease tungiasis. The attack of Tunga penetrans has long been known to cause many pathognomic problems among residents of poor and indigent territories rendering them disable and even visiting tourists to endemic areas are infested though with a mild-moderate case. In Italy alone, an approximate of about 50 cases have been reported from tourist attacks of T. penetrans in recent decades not to lay emphasis on the other 20 cases reported in past decades (Veraldi & Valsecchi, 2007). The disease history was dated back to Fernandez de Oviedo Gonzalez who in 1525 reported that Spanish armies in the native indigenous populations from Haiti frequently suffered from the sand flea disease (Heukelbach et al., 2001). Early references were reported in Africa during the first half of the 18th century, probably with the first case appearing in Senegal and subsequently in Gabon, Angola and many African countries were they are considered endemic presently (Hoeppli, 1963). The sand flea is cogitated the smallest organism in the world with a length range of below 1mm -10mm and lacking defined compound eyes (Bitam et al., 2010). This sight deficiency cause them to attack only body parts at proximities to their habitation. The lacinia and epipharynx of the female are developed due to the characteristics of neosomy, tachygenesis, and burrowing into host to complete their life cycle (Nagy et al., 2007; Bitam et al., 2010). During dry periods of peak reproduction, fertilized eggs are expelled into the environment only after female sand flea penetrates host and copulation with male in situ. Host identification strategies and penetration mechanisms are unknown. On a general basis, blood meal is a requirement for female flea completion of ovarian cycle and once completed, eggs are released prolifically through uncovered keratin by evacuated stools on the host epidermal surface which slides down the surrounding when contacted with soil (Bitam et al., 2010; Pampiglione et al., 2009; Veraldi et al., 2013). Animals that bath and bask during warm periods especially chickens pigs, dogs, goats and cats are at high risk of infestation serving as animal reservoir of T. penetrans infestations but pigs were reported and confirmed the major animal reservoir hosts of the infection (Mutebi et al., 2015; Ugboroiko et al., 2008). The world prevalence of the disease have been reported to be between 15.7 and 54.8% (Ade-Serrano and Ejezie. 1981, Chadee 1994, Heukelbach et al., 2001, Wilcke et al., 2002; Carvalho et al., 2003, Ehrenberg and Ault. 2005). This disease is considered neglected due to the attitude of medical practitioners towards the infestation and cannot be neglected as blood loss observed in severely infected individuals could lead to death if precautions are neglected. Life-threatening sequels commonly associated with this debilitating and severe re-occurring morbidity in endemic areas includes acute and chronic inflammation of toes and heels, deformation and loss of nail on toes, ulceration and abscesses, painful fissures and lymphoedema (Matias, 1989, Heukelbach et al., 2001; Wilcke et al., 2002; Feldmeier et al., 2003; Joseph et al., 2006; Ugbomoiko et al., 2007; Kehr et al., 2007; Feldmeier and Keyser, 2013). Although, super-infection by bacteria is ever present in non-vaccinated individuals causing inflammation to increase, tetanus and gangrene, leading to intense pain, difficulty in walking and death in rare cases (Obengui. 1989; Tonge. 1989; Lit voc et al., 1991; Mashek et al., 1997; Heukelbach et al., 2001; Feldmeier et al., 2002; Feldmeier et al., 2004; Feldmeier et al., 2006; Ugboroiko et al., 2007; Feldmeier et al., 2009). A variety of aerobic and anaerobic bacteria have also been
isolated from embedded sand fleas (Fischer et al., 2002, Heukelbach et al., 2004). Environment factors such as temperature and humidity are reported to encourage egg hatches into cracks in floors of house dwellings or in nests and beddings at about two to twelve days (Bitam et al., 2010). The temperature and humidity tolerance ranges were not reported and are considered lacking for flea infestations in endemic areas. Apart from the confirmed DNA sequence data available for the discrimination of non-nosomics T. penetrans and T. trimamillata (Luchetti et al., 2005) and genetic variability of T. penetrans (Siphonaptera, Tungidae) sand fleas across South America and Africa (Luchetti et al., 2005), detailed DNA information on genetic diversity and composition are lacking. Hence more scientific interventions are needed for the infestation. But first the habitat structure, temperature and humidity tolerance is needed to justify the biology of the vector agent.

2. Methodology

2.0. Experimental area and population

The study was performed in three communities, Zion, Laranda and Kofawe Igbokoda, Ondo State, Nigeria. The villages are traditional fishing communities and were relatively sequestered until recently with Laranda being 50meter apart from Zion and 50km apart from Kofawe. The communities are inhabited by an approximately 125 families each with an estimated total population of 820 each with a little fluctuations. Houses are located in large sandy compounds with thatched fences in some and lacking in others. Only a single dilapidated health care center is available in Zion and lacking in the other two sites.

2.1. Study design

The randomized field sampling of sand fleas and environmental factor measurement from the three sites were carried out between 8th of March and 8th June, 2017 which coincides with the dry season when infestations of sand fleas were ranked at peak. A total of 30 houses were randomly selected to determine floor type characteristics of resident and sampled for the presence of flea in the three mapped locations. At least 6 – 10 houses were sampled weekly either those classified as paved, paved with cracks or unpaved houses. Fleas were sampled by laying a clean white cloth half-way the floor of rooms in each paved or paved houses with cracks and using a broom to sweep towards the white cloth. The white cloth was observed carefully for the presence of flea, present fleas were recorded for both sampled rooms and verandas. The unpaved houses were sampled by first over wetting the sandy floors and a shovel scoop of sand emptied into a bucket of water half-filled with water and the floating fleas were collected, viewed and counted. Prior to house sampling, head of household consented to the study. Houses were also swept weekly in the mornings and evenings to obtain sands in house and veranda. Sands were placed in a dark cellophane bag containing 10ml of 10% formaldehyde flea. During sweeping, sands on floor of houses were crushed repeatedly to inactivate the flea before sands were gathered to avoid penetration of researcher. Gathered sand were transported to the Department of Biological Sciences laboratory, Osustech, to be viewed under a microscope, counted and recorded for both inside rooms and verandas. Temperature and relative humidity were measured using E-OSUN temperature-relative humidity digital device. Temperature and relative humidity was taken at early hours of the day bi-weekly for the 12 weeks.

2.2. Data analysis

Data was entered in an Ms Excel package 2013, checked for errors and a single factor ANOVA was used to determine significant difference for fleas inside house and verandas of the classified floor types. Similar for temperature and humidity tolerance.

3.0. Results

Flea sampling in relations to floor type, with temperature and relative humidity tolerance level for flea infestations was determined within all the sampled site for 12 weeks. Floor types were characterized as paved for cemented floors, unpaved for sandy, muddy or dusty floors, and paved with cracks for cemented floors with mild, moderate or severe cracks to harbour fleas.

3.1. Floor type and fleas

3.1.1. Floor type and fleas inside the house

In total, 36 fleas in Zion, 8 fleas in Laranda and 10 fleas in Kofawe was recorded inside the houses comprising of 19, 0 and 7 fleas sampled from within the unpaved floor type, 4, 4 and 3 fleas recorded in paved floors with cracks and a total of 13, 4 and 0 fleas sampled from paved floor types in Zion, Laranda and Kofawe respectively (Table 3.1.1). Within Zion, 52.8% of the sampled fleas were from unpaved floor types while 11.1% of fleas were obtained from paved floor type with crack. The range of fleas encountered for Zion was 7 with a maximum of 7 fleas encountered in a floor type and in a null flea in others. There was a high significant difference ($F_{(2,29)}=12.23$, $P<0.05$) between sand fleas sampled inside house in Zion. Equal flea percentage were recorded in both paved and paved floors with cracks in Laranda. The sampled fleas is at the range of 2 and the maximum fleas sampled is 2 for the floor types. There was no significant difference ($F_{(2,29)}=1.89$, $P>0.05$) between sand fleas sampled inside houses. A greater percent (70%) of sampled fleas were encountered in unpaved floor type and none in paved floors. A very high significant difference ($F_{(2,29)}=16.68$, $P<0.05$) exist for fleas sampled in rooms of Kofawe. Majority of the houses in Zion were not paved compared to those in Laranda and Kofawe as shown in figure 3.1.1 below. In contrast, greater percent of the inside house of Laranda and Kofawe were paved compared to those recorded in Zion. However, paved floors with cracks were common in Laranda than in Zion and Kofawe.
Table 3.1. Show the summary of total flea number sampled inside the house in the sampled site (n= 30 houses each)

<table>
<thead>
<tr>
<th>Floor type</th>
<th>Zion</th>
<th>Laranda</th>
<th>Kofawe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (%)</td>
<td>M±SD</td>
<td>R (m-M)</td>
</tr>
<tr>
<td>Paved</td>
<td>13 (36.1%)</td>
<td>0.57±0.99</td>
<td>4 (0-4)</td>
</tr>
<tr>
<td>Paved with cracks</td>
<td>4 (11.1%)</td>
<td>4.00±0.00</td>
<td>0 (0-4)</td>
</tr>
<tr>
<td>Unpaved</td>
<td>19 (52.8%)</td>
<td>3.17±2.14</td>
<td>6 (1-7)</td>
</tr>
<tr>
<td>Total</td>
<td>36 (100%)</td>
<td>1.20±1.71</td>
<td>7 (0-7)</td>
</tr>
</tbody>
</table>

N.B: M±SD implies Mean± Standard deviation and R (m-M) implies range of values (minimum-maximum values)

Fig. 3.1.1. Show percentage occurrence of floor types inside the house in the sampled site

3.1.2. Floor type and fleas in veranda of sampled houses

In the veranda of houses sample, a total of 24 sand fleas in Zion, 24 fleas in Laranda and 29 fleas in Kofawe was recorded in veranda outside the houses comprising of 11, 9 and 18 fleas sampled from unpaved floor type, 7, 13 and 10 fleas recorded in paved floors with cracks and a total of 6, 2 and 1 flea sampled from paved floor types in Zion, Laranda and Kofawe respectively (Table 3.1.2). Within Zion, a greater percent (36.7%) of the sampled fleas were from unpaved floor types while the least (25.0%) of fleas was obtained from paved floor types. There was a high significant difference (F2,28=10.46, P<0.05) between sand fleas sampled in the veranda of houses. A greater percent (62.1%) of sampled fleas were encountered in unpaved floor type and a least (3.5%) in paved floors. A very high significant difference (F2,25=16.29, P<0.05) exist for fleas sampled in veranda outside houses in Kofawe. More than 50% of verandas in Zion were paved compared to other locations sampled for sand fleas. Verandas in Kofawe sampled were often not paved compared to other two locations as shown in figure 3.1.2 below while cracked verandas were common in also to Laranda than in Zion and Kofawe.

Table 3.1.2. Show the summary of total flea number sampled in verandas of house in the sampled site (n= 30 houses each)

<table>
<thead>
<tr>
<th>Floor type</th>
<th>Zion</th>
<th>Laranda</th>
<th>Kofawe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (%)</td>
<td>M±SD</td>
<td>R (m-M)</td>
</tr>
<tr>
<td>Paved</td>
<td>6 (25.0%)</td>
<td>0.46±0.97</td>
<td>3 (0-3)</td>
</tr>
<tr>
<td>Paved with cracks</td>
<td>7 (29.2%)</td>
<td>3.50±3.54</td>
<td>5 (1-6)</td>
</tr>
<tr>
<td>Unpaved</td>
<td>11 (36.7%)</td>
<td>1.22±1.09</td>
<td>3 (0-3)</td>
</tr>
<tr>
<td>Total</td>
<td>24 (100%)</td>
<td>0.80±1.38</td>
<td>6 (0-6)</td>
</tr>
</tbody>
</table>

N.B: M±SD implies Mean± Standard deviation and R (m-M) implies range of values (minimum-maximum values)
3.2. Temperature determination for fleas
Floor temperature ranges in total were highest in Laranda (32.9°C) with a little low fluctuations in Zion and Kofawe (32.6 and 32.3°C) respectively. Within Zion community, paved floor type has the lowest temperature (32.4°C) in comparison to paved floors with cracks (34.5°C) (Table 3.2). There was no significant difference (F(2,29)=0.63, P>0.05) in the temperature recorded in the various floor types in Zion. The highest mean temperatures was recorded in floors with cracks (33.1°C) compared to those recorded in paved and unpaved floor types (32.9°C respectively). There was no significant difference (F(2,29)=0.36, P>0.05) in the temperature recorded in the various floor types in Laranda. The highest mean temperature was reported in unpaved floors (33.5°C) compared to the little fluctuations in paved and paved floor types with cracks. There was no significant difference (F(2,29)=1.71, P>0.05) in the temperature recorded in the various floor types in Kofawe.

Table 3.2. Temperature values in houses sampled in the various sites (n= 30 houses each)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Zion</th>
<th>Laranda</th>
<th>Kofawe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paved</td>
<td>M±SD: 32.4±1.81 R (m-M): 6.6±(29.0-35.6)</td>
<td>M±SD: 32.9±1.29 R (m-M): 6.2 (29-35.6)</td>
<td>M±SD: 32.0±1.76 R (m-M): 5.5 (29-34.5)</td>
</tr>
<tr>
<td>Paved with cracks</td>
<td>34.5±0.00 R (m-M): 0.34±(34.5-34.5)</td>
<td>33.1±0.74 R (m-M): 2 (31.9-33.9)</td>
<td>33.2±0.70 R (m-M): 0.1 (33.1-33.2)</td>
</tr>
<tr>
<td>Unpaved</td>
<td>32.8±2.40 R (m-M): 6.3±(28-34.3)</td>
<td>32.9±4.38 R (m-M): 6.2 (29-35.2)</td>
<td>33.5±1.60 R (m-M): 4.3 (30.8-35.1)</td>
</tr>
<tr>
<td>Total</td>
<td>32.6±1.91 R (m-M): 7.6±(28-35.6)</td>
<td>32.9±1.43 R (m-M): 6.2 (29-35.2)</td>
<td>33.2±1.75 R (m-M): 6.1 (29-35.1)</td>
</tr>
</tbody>
</table>

N.B: M±SD implies Mean± Standard deviation and R (m-M) implies range of values (minimum-maximum values)

3.3. Humidity determination for fleas
The mean relative humidity ranges was generally high in Kofawe (70.0%) with a little low fluctuations in Zion and Laranda (68.6% and 68.9%) respectively. In Zion community, houses with cracking paved floor type has the highest humidity (73.0%) in comparison to paved and unpaved floors (68.9 % and 69.2%) (Table 3.3). There was no significant difference (F(2,29)=0.063, P>0.05) in the humidity recorded in the house sampled with various floor types in Zion. The highest mean humidity was recorded in houses with unpaved floors (74.5%) compared to those recorded in paved and paved floor types with cracks (68.6 and 68.0%) respectively. There was no significant difference (F(2,29)=0.53, P>0.05) in the humidity recorded in the various houses with floor types in Laranda. The highest mean humidity was reported in houses with paved floors (70.9%) compared to the little fluctuations in houses with unpaved and paved floor types with cracks. There was no significant difference (F(2,29)=1.93, P>0.05) in the humidity recorded in the various houses with floor types in Kofawe.

Table 3.3. Show the different humidity values recorded in the sampled site (n= 30 houses each)

<table>
<thead>
<tr>
<th>Humidity</th>
<th>Zion</th>
<th>Laranda</th>
<th>Kofawe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paved</td>
<td>M±SD: 68.9±1.85 R (m-M): 38 (50.0-88.0)</td>
<td>M±SD: 68.6±7.52 R (m-M): 30 (54.0-84.0)</td>
<td>M±SD: 70.9±10.69 R (m-M): 34 (54.0-88.0)</td>
</tr>
<tr>
<td>Paved with cracks</td>
<td>73.0±0.00 R (m-M): 0 (73.0-73.0)</td>
<td>68.9±4.3 R (m-M): 24 (59.0-83.0)</td>
<td>57.0±6.24 R (m-M): 6 (54.0-60.0)</td>
</tr>
<tr>
<td>Unpaved</td>
<td>69.2±9.43 R (m-M): 25 (59.0-84.0)</td>
<td>74.5±13.44 R (m-M): 19 (65.0-84.0)</td>
<td>64.8±13.22 R (m-M): 33 (55.0-88.0)</td>
</tr>
<tr>
<td>Total</td>
<td>68.6±10.89 R (m-M): 36 (50.0-88.0)</td>
<td>68.9±27.61 R (m-M): 152 (54.0-84.0)</td>
<td>70.0±11.28 R (m-M): 34 (54.0-88.0)</td>
</tr>
</tbody>
</table>

N.B: M±SD implies Mean± Standard deviation and R (m-M) implies range of values (minimum-maximum values)
4. Discussion

This study recorded high flea population in Zion Igbokoda with 52.8\% of the sampled fleas from unpaved floor types while 11.1\% of fleas obtained from paved floor type with crack. This flea population sampled from Zion is linked to the fact that 76\% of the houses sampled were unpaved and remain sandy for the sampled location compared to the other two sampled locations. Although, the different paved floor types with cracks may serve mainly as suitable hideouts for adult sand fleas, development nest of immature stages that slide and glides off host infested sites and even a reservoir area for re-infestation during dry periods when the infestation is reported to peak in individuals inhabiting houses with suitable loose, dry, sandy soil. Even in Laranda and Kofawe, greater flea percentage were recorded in paved floors with cracks and unpaved floor type than in paved floors. Flea occurrence in paved floors may be a probability occurrence from those species that cling to hairs, furs and every other separable materials for flea transport into houses with paved floors. There was high significant differences in the flea populations sampled from Zion and Kofawe may be due to the greater percentage of the unpaved floor type were must have encouraged the habitation of fleas and developmental stages. The development of female sand flea from eggs which hatch into legless and eyeless larvae, pupating into matured brown adult with biting and sucking mouth parts is within 1–2 weeks (Linardi et al., 2014; Pampiglione et al., 2009). The considerable flea population recorded in verandas of the house sampled from the different locations is linked to floor types as greater percentage of verandas in Kofawe were not paved as well as a 20-35\% of the verandas in kofawe and Zion. Even with floors of verandas, a greater percent (36.7\% and 62.1\%) of sampled fleas were encountered in unpaved floor type in Zion and Kofawe while a greater percent (54.2\%) of the fleas were recorded in paved floors with cracks in Laranda. The life cycle assessment of sand fleas is hinged on varying environmental factors such as temperature and relative humidity along with floor type characteristics to act as bed for development when all environmental conditions are tolerable. In this study, paved floor type has the lowest temperature (32.4°C) in comparison to paved floors with cracks (34.5°C) in Zion, highest mean temperatures was recorded in floors with cracks (33.1°C) compared to those recorded in paved and unpaved floor types (32.9°C) respectively in Laranda and in Kofawe, highest mean temperature was reported in unpaved floors (33.5°C) compared to the little fluctuations in paved and paved floor types with cracks. There was no significant differences (P > 0.05) in temperature ranges for floor types in the different locations sampled. In contrast, mean relative humidity ranges was generally high in Kofawe (70.0\%) with a little low fluctuations in Zion and Laranda respectively. Zion sampled houses with cracking paved floor type has the highest humidity (73.0\%), highest mean humidity was recorded in Laranda houses with unpaved floors (74.5\%), and highest mean humidity was reported in houses with paved floors (70.9) in Kofawe. Also there was no significant difference (P > 0.05) in the relative humidity reported in the various sampled locations. The temperature and relative humidity reported in this study is equal to those reported to be optimum for insect survival, fecundity and growth. This may be the case in some other regions where temperature is suitable for the growth in flea population. 25°C-35°C and 65-75% of moisture level are reported optimum for insect survival. Researches on jigger infestations has not addressed the biological cause of flea spread. The presence of vulnerable host who do not take precautions amongst those listed for environmental conditions are among factors aiding the reproduction and spread of the causal agents. When these temperatures are increased through high-temperature-fume sprays or when floor of houses are cleaned for paved or constantly watered by thorough sprinkling, the flea population off host may be targeted. While as authors have addressed, the use of personal protective equipment and insecticide sprays on the other hand would and use of repellent-based extracts would target on-host species that may act as reservoir to spread of fleas in an area. Organic matter availability in litters and waste dumps close to house have been linked to sand flea abundance (Bitam et al., 2010). Since the larvae of sand fleas have been tagged free living organic feeders as feeding on human fecal waste is reportedly common in some species (Krasnov, 2008). Even rearing birds close to residential area can lead to a great abundance in flea population due to high accumulates of organic matter. On a general note, flea development from eggs to larvae is dependent on environmental factors (Dobler and Pfeffer 2011) and the manipulation of temperature and relative humidity from those optimal for development will create a tool for population control. It is reported that seasonal fluctuations influences the sand flea infestation rate and frequent occurrence as high jigger prevalence is during the dry season (Heukelbach, 2005). The significant decrease infestation rate during rainy periods may be linked to lower temperature and rise in moisture level tolerance for jigger development. It was noticed in the semi-arid Northeast Brazil that flea infestation decrease as soon as the rainy season begins and increased again in drier conditions (Winter et al., 2009). Seasonal variation of infestation rates is determined by sandy or muddy nature of the soil which is the environmental determinant of off-host propagation patterns and development of sand flea (Linardi et al., 2010). The nature of floor of abode of these endemic populations provide a suitable habitat condition for T. penetrans development. The floor types in endemic foci could take the predictably form of being unpaved, muddy, dirty or possessing a fractured solid floor or even ground covered with broken tiles. In an urban slum, residual areas, roads and streets not paved with waste dumps around area were reported to encourage flea habitation (Feldmeier and Heukelbach 2009). Haven identified that floor type and environmental conditions can raise the risk and chances of flea growth, the proper pavement of sandy or clayey floors in a severely affected communities would reduce in-house infestation and re-infestation. However, cementing floors of severely affected community in western Nigeria was reported to reduce transmission rates and prevalence of tungiasis by almost 75\% (Ugbomoiko et al., 2006). Conclusively, it is known that floor type and environmental tolerance levels can encourage flea populations in endemic foci. Controlling sand flea population apart from the use of insecticide sprays and surgical manipulation of infested feet is possible by targeting the temperature and relative humidity tolerance level for species or mending floor
types reported to encourage infestations. More studies are therefore needed on aerial sprays of high temperature moist fumes on infected soils to target fleas than the conventional use of insecticide that would in time develop resistance and present a difficult state in controlling the species.

Acknowledgements
I am grateful to residents of the community who allowed me sample their houses of fleas and Pastor Eniomodun, Proprietor of Achievers’ Academy, Igbokoda for assistance rendered.

References


