The sensory setae morphology and behavior in the soldier caste of subterranean termite, *Coptotermes* spp. (Blattodea: Rhinotermitidae)

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Executive summary

Termites live in a colony as social insects. They are divided into three castes based on the labor differences in the nest, reproductive caste (queen and king), worker caste (pseudergate), and soldier caste. Each caste performs different labors and organize the role of each caste in the nest by certain communication system. Two types of communication systems generally exist, chemical and non-chemical communication. Chemical communication may include the works of pheromone between individuals. Whereas non-chemical communication is established when one individual vibrates the surroundings or structure to generate sound or vibration, which is accepted by another individual. In order to respond chemical and non-chemical signals, termites develop sensory receptors located on their organs or body parts. Some sensory receptors have different anatomical characteristics to support their function, such as sensory setae on termite's antennae. Setae can become an olfactory sensory receptor when it has porous cuticle allowing chemical substance's direct contact with the sensory cells, or mechanosensory receptor when it has long or broad flexible pegs or caps allowing the sensory cells beneath the pegs or caps to sense cuticle distortion.

In *Coptotermes*, setae distribution on the soldiers' body have been usually utilized as an alternative characteristic to diagnose species. However, the excessive use of size-correlated characteristics on the head parts covers the importance of the body setae distribution for species discrimination. There is also little information regarding the functional morphology of the setae, particularly setae that are not located on the antennae, such as mouthpart, head part, and thorax part. Since soldier caste has remarkable morphology modification to perform their defensive task, the biological structures of setae on their body to support their defensive labors or survival has been less studied.

The thesis aimed to investigate setae characteristics and their functional morphology on the body parts of *Coptotermes* spp. soldier. Firstly, the morphology analysis was illustrated by linear and geometric morphometric analysis to explain *Coptotermes* spp. soldier caste morphology. The importance of setae (sensilla) characteristics and the putative functions related to the soldier head

capsule shape was discussed. Secondly, the analysis of the morphology and ultrastructure characteristics of the sensory receptors on the non-olfactory body parts were illuminated to analyze hair-type sensory receptors potentials. The utilization of electron microscope supported the clarification of each sensory receptor's putative function related to their morphology and anatomy. Thirdly, the thesis explained the employment of video tracking software to analyze the orientation and behavior of soldier termites toward the airborne vibration source such as constant airflow.

The first chapter of the thesis gives an overview of the background of the studies and elaborates the thesis. In the second chapter, the morphology and body parts shape of the soldier of *Coptotermes* spp. were evaluated. The modified parts of *Coptotermes* spp. were analyzed by geometric morphometric analysis and the linear morphometric values were analyzed by principal component analysis. Head width, pronotum setae, and postmentum characteristics appeared to be important characteristics in *Coptotermes* species discrimination. Consistently, pronotum and head setae numbers in *Coptotermes* spp. increased as the posterior part of the *Coptotermes* head laterally expanded. However, the putative functions of those characteritistics were still unknown. The detailed morphology and anatomy of sensilla on the nonolfactory organs of *Coptotermes* spp. have yet to be characterized.

To further explored the putative function of the formerly mentioned characteristics, the third chapter of the thesis discussed the ultrastructure anatomy and morphology of the setae as sensilla (sensory receptors) on the pronotum, head, and labrum parts of the soldier of *Coptotermes* spp. Six total sensilla types were observed, with two mechanoreceptive sensilla types (hair and plate). The availability of long peg structure, the tubular dendrite as mechanosensitive outer dendrite segment, and flexible sockets are the characteristics of sensilla as the exteroceptive mechanoreceptor. The long flexible-peg mechanoreceptive sensilla may work as contact-chemoreceptive sensilla due to the addition of four elongated dendritic outer segments as chemosensor and uniporous characteristics. There was a significant depletion of mechano-chemoreceptive sensillum numbers in *C. gestroi*, which was compensated by a high density of short-peg mechanoreceptive sensilla on the pronotum. The existence of long peg, flexible sockets, and mechanosensitive outer dendritic segment may support the ability of the sensory receptors to sense airborne vibrations, such as wind or airflow. The difference of sensory receptors distribution between species may also indicate the various sensitivity or response of soldier termites against airborne vibration.

To test the morphology based hypothesis in the chapter third, the behavior of *Coptotermes formosanus* soldier termites was tested against airflow in certain velocity by morphological manipulation. The airflow test was supported with the fact that, apart from the alates, soldier caste is the only caste in *C. formosanus* that naturally have chances to go outside the nest to perform the defensive labors. Thus, soldiers of *Coptotermes* will face challenges outside the nest, such constant airflow. The sensitivity of soldier termite toward the airflow source was significantly dropped when the antennae was trimmed and pronotum setae were covered. Antennae was important organs for soldier termite airflow-related orientation and spatial ability. Without antennae, soldier termite demonstrated an alert response by bumping the wall and opening mandible as their spatial ability was limited. However, sensitivity of setae on the pronotum and other body parts to airflow significantly lowered the alert response and enhanced soldier termite spatial ability when the antennae was lost.

This thesis confirmed that the body setae are morphological characteristics that have biological structures to support their function as sensory receptors. The sensitivity to airflow is one function that could be demonstrated by morphological manipulation. The variation of the flexible long-peg sensilla distribution on the body of *Coptotermes* across species may also share the light to their subtle difference of their habitat preferences. As *Coptotermes* accustomed to the gallery system and shelter tube to protect their foraging activity, the chances for them to be exposed by the gallery or shelter tube breach are real. The soldier caste awareness to changes of the air dynamic by the breach on the nest could be helped by the flexible long-peg sensilla on their body, as airflow significantly altered their orientation and enhance the spatial ability when the organs with respective sensilla are intact. Apart the importance of setae as discriminative characteristics, the anatomical and structural information illuminate the distribution of setae as sensory organs may not happen as a random morphological variation. The thesis illuminated the importance of setae and their putative function to support the defensive role of soldier termite.