Anatomical and physical properties of tendril perversion of *Coccinia grandis* (L.) Voigt

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Abstract

The structure of biomaterial is interest in biomimetic and biomechanics research. The physical properties, mechanical, characteristic of twisting and bending of plant tendrils are also thought-provoking to study. In this study, we proposed an innovative biomaterial spring device for holding an object and providing support. The device uses *Coccinia grandis* (L.) Voigt tendril as inspired by the relations of left-hand (LH) and right-hand (RH) climbing tendrils with a single branch. To study the morphology and anatomy, testing stress, length, number of the helix of the tendril which relation of mimic string material *Coccinia grandis* (L.) Voigt tendril and helical metal which have two helixes, three helixes and four helixes were tested by using food texture analysis. The anatomical showed many cell types and slight differences between straight and coiled tendrils. The result showed the tendril of two helixes has the highest stress and four helixes the least. Also, tensile testing showed that the number of helixes does not affect the stress of the tendril models.

Keywords: Tendril, anatomy, biomimetic, *Coccinia grandis* (L.) Voigt

1. Introduction

Biomimetic is an important interdisciplinary field which has many research areas for instance engineering, chemistry and biology, including being applied in the synthesis of the material innovation process. The biological structures are composited of many cell types and substance supporting cell structure such as the fibre cell and lignin, having amazing properties the characteristic of biomaterial encourage study [1]. In the 15th century, Leonardo da Vinci designed the wings of a glider [2] which was inspired by the bat’s wings although his design was not successful. But, it inspired the next generation of inventors to develop the idea continuously until the first airplane was successfully flown in the 19th century by the Wright brothers, both of whom were inspired by the flight of birds. Biomimetic science and technology have been developed in widely different devices in various fields to work together as a system. Subsequently, this science needs a multi-disciplined team, such as computer science, electronics engineering, mechanical engineering, physics, chemistry and biology all come together to solve problems. Nature has many hidden secrets materials, phenomena and complex
materials. Scientists use two methods to mimic nature [1, 3], the first method begins with the problem to be solved and analysis it by searching for living entities that have similar problems and try to imitate the creature’s methodology. The second method is based on the discovery of natural data until the knowledge and understanding of intelligent adaptation of the mechanism of life which then becomes the inspiration to develop new technology. Biomimetics can be divided into three types [4]: (i) mechanism-driven biomimetics is to solve engineering problems by seeking examples in nature to study and solve the problems, such as for instance the lotus effect that tries to find materials that clean themselves [5]. (ii) Organism-driven biomimetics is the study of living organisms to search for distinctive properties and using those features to create new products such as velcro. (iii) Integrative biomimetics is the guideline that combines both the approaches mentioned above, such as studying the movement of cockroaches. One classic example the lotus effect was successfully studied by a researcher and applied in the field of self-cleaning surface [6] attracting interest for various applications such as solar cells, textiles, anti-freezing and anti-snow surfaces, filters, microfluidics, medical devices, blood vessel replacements by fabricating flexible hybrid inorganic nanowires decorated microfibers [7].

Tendril is interested in natural products which are the part of the trunk, flower, leaf or branch of a plant that changes into a spiral style for support [8]. The tendril has a long, twisting, spiral-like springs to make it flexible. When the wind blows back and forth wherein ivy plants, which are of interest to researchers in various fields, the tendril of each plant provide highly effective support using biology material. The spiral shape of the climbing tendril supports very effectively and can be explained by studying similar homoclinic and heteroclinic orbits in the three-dimensional configuration problem of a cylinder constrained rod [9]. The gourd’s tendril is positioned opposite the petiole, and it does not grow directly from the axillary but the axillary bud. An anatomical structure compared to natural plants is gourd flowering, whether male or female, occurs at the position of the axillary near the tendril, including where the gourd divides. The new branches are separate from the axillary positions and close to the tendril. Therefore, there is a hypothesis that the tendril of the gourd may emerge from flowers, inflorescences, branches and leaves [10].

This research aimed to study anatomy and physical properties of *Coccinia grandis* (L.) Voigt tendril at Chumphon Province, southern Thailand. The relationship between magnitude stress and extraction length, size, number of perversion of the tendril as biomaterial springs, for holding an object with flexibility at a certain distance depending on the size of the tendril, to support trees or branches in the desired direction. The results obtained are compared with the tendril model made from metal wire, then designed to use a tendril simulation to create innovation by using adhesion with support for flexible strength.

2. Methodology

In this study, we use the tendril of *Coccinia grandis* (L.) Voigt at Chumphon province, southern Thailand. *Coccinia grandis* (L.) Voigt tendrils are natural products which are the part of the trunk but acting as branches that separate from the trunk. The harvested samples are as shown in Figure 1(a), where the tendril has two helixes and Figure 1(b) where it has three helixes. The growth of the tendril can be divided into four steps, as showed in Figure 1(c). The first step in the tendril growth is growth in a straight line to find near support to twist before becoming a helix (Step 1). After the tendril achieves the support, the tendril gradually becomes helical at both the tendril launching and end point due to growth, the distance between the source of the tendril and the support is constant (Step 2-3). The tendril helical has the characteristic of a helical spring, competitive and flexible, enabling it to withstand the wind (Step 4). The primary deformation of the tendril structure is formed by bending and twisting when it becomes a helical structure like a helical spring.

The characteristics of *Coccinia grandis* (L.) Voigt tendril is shown in Figure 1 (a)-(b) after already making contact and spiraling around the support, which has two helixes and three helixes, respectively. In this study, we found the tendril had two helixes showed the most stress and four helixes the least stress. Figure 1 (a)-(b) shows the geometrical relations of left-hand (LH) and right-hand (RH) climbing towel gourd tendrils on the same plant branch. Through understanding the twist deformation features of innovative three-dimensional elastic chiral mechanical metamaterials, an innovative multi-functional
tetrachical cylindrical tube is proposed, which can generate cylindrical tube twist deformation upon compression loading conditions [11].

Figure 1. The tendril of characteristics of Coccinia Grandis (L.) Voigt in Chumphon Province, southern Thailand, (a) tendril has two helixes and (b) tendril has three helixes and (c) steps of tendril growth.

Figure 2. Under tensile testing of the tendril and helical metal (a) tendril with 2 helixes (b) tendril with three helixes, (c) tendril with four helixes and (d) tendril models using an aluminium coil that have one to five helixes.

The Coccinia grandis (L.) Voigt tendril was tested by using a texture analyzer in the tension mode. Figure 2(a)-(c) shows the tendrils have one bend (two helixes), two bend (three helixes) and three bend (four helixes), respectively. The tendril that has one bend and has two helical tendrils that are right-handed (RH) the helix rotates clockwise (CW) and left-handed (LH) the helix rotates counterclockwise (CCW). Figure 2(d) is a model to mimic the tendril by winding an aluminium coil into spring and turning it to find the mechanical properties of the model as tendrils, including comparing the mechanical properties with the natural the Coccinia grandis (L.) Voigt tendril properties. To observe
the *Coccinia grandis* (L.) Voigt anatomy, the trunk, straight and coil tendril were cross-sectioned by using the free hand technique [12]. The small pieces were put into a plate containing distilled water. The thinnest part was selected and then stained with 0.01% v/v. Safranin-O and dissolved in distilled water for 1 min. The stained section was gently transferred to a slide, two drops of water were added and then the section was covered with a coverslip. The slide was observed and the image captured under a light microscopic.

3. Results and discussion
The experimental testing results of the *Coccinia grandis* (L.) Voigt tendril shown in Figure 3-5. The results are divided into two parts: the first part, showed the morphological structure of the internal structure of the cross-section of the tendril is shown in Figure 3, secondly mechanical testing of tendrils and tendril models are shown in Figure 4.

![Figure 3](image)

**Figure 3.** The morphological and anatomical of the trunk straight and coiled *Coccinia grandis* (L.) Voigt, (a) photograph representing the morphological of the straight trunk and coiled tendril, (b)-(d) the trunk under light microscopic, magnifying power 4x 10x and 40x, respectively, (e)-(g) the coiled tendril under magnifying power 4x, 10x and 40x, respectively and (h)-(i) the straight tendril under magnifying power 4x and 10x, respectively.

The *Coccinia grandis* (L.) Voigt belongs to the Curcubitaceae family. Similar to plants in the same family, it has tendrils that support the trunk to find sunlight or take the plant to the numerous environmental niches [11]. The photograph in Figure 3 shows the morphological of the trunk, straight and coiled tendril was used to study anatomical. The result representing many cell types are shown in Figure 3(b)-(i) identified with the blue arrows 1-6 which are the epidermis, collenchyma, fibre, parenchyma, xylem and phloem, respectively. The epidermis collenchyma and parenchyma are primary cell wall structure whereas the xylem phloem is a set of 4 cell types; some dead (haveing a secondary cell wall) and some alive (not accumulating a secondary cell wall). The specify cell type xylem and phloem have lignin achromatize by safranin-O. The fibre cell (red colour) with the blue arrow number 3 was not founded in the straight or immature tendril is shown in Figure 3(e)-(i). The cross-section revealed that the fibre cells found in the trunk were symmetrical whereas the mature tendril was asymmetric, as shown in Figure 3(b) and (e). The fibre cell of the tendril representing three layers was slightly similar to the wild cucumber tendril representing two layers which were ribbon [13]. The twist of the tendril involved with the lignified gelatinous fibre cells (g-cells) provided a supporting structure via the cell wall lignification water flux and stiffness of the cellulose micro-fibrils [14]. The differential lignification of 2 layers result in cell contraction and coil via the hydrophobic of lignin [13].
The mechanical properties were determined by using a tensile analyzer to measure force, mechanical extension and stress stretching at 1-3 times, affecting the strength by preventing impact and sedimentation. The create a climber model was created by using aluminium coil with a diameter of 0.56 ± 0.01 to study, its properties, including the comparison of straight wire as shown in Figure 4. The experiment compared the mechanical properties of the tendril model made from metal wire with four samples that are two helixes, three helixes, four helixes and linear metal wire. The results showed that in the tendril models, the helix numbers is not have different effects, as shown in Figure 4(b), but were different from the linear wire.

![Figure 4](image_url)

**Figure 4.** The stress of (a) the *Coccinia grandis* (L.) Voigt tendril having two helixes, three helixes and four helixes and (b) the stress of the tendril metal model having two to five helixes.

Figure 4 (b) shows the relationship between stress and mechanical extensions from the root. The results show that the number of helixes is much less stressed compared to the tendril. The smaller helixes mean that the number of helixes may be due to support a defined distance. With too many tendrils, the tendril is longer so it can be attach to the support. The handgrip is less secure when it has a smaller number of helixes because they can hold support a short distance. In this study, the tendril spring model can be applied like biomimetics to develop a spring tension to hold maintain a support for setup camping as shown in Figures 5(a) and (b).

![Figure 5](image_url)

**Figure 5.** (a) a designing of a tendril spring model can be applied for the elastic holding of the support and (b) a useful application of the tendril spring model.
4. Conclusions
A natural product is a miracle product having interesting biomaterials by changing the physical characteristics according to the living environment. In this study, the experimental results of the tendril inversion affected the tensile force and physiological of the trunk, straight and coiled tendril of *Coccinia grandis* (L.) Voigt. The experimental results showed the strength of the tendril is not as hypothesized but that the amount of bending affects the strength of the spring tendril. On the other hand, the amount of bending varies the tendril's weakness also increases, the same as reported by the metal models that the amount of the bending does not affect the strength. The tendril is very flexible as a natural spring, which is the adaptation of plants that they can hold and be wind resistant or other forces that can cause the trunk to fall off, this is one of the biomimetic to create a new innovative device production.

Acknowledgements
The authors would like to thank King Mongkut’s Institute of Technology Ladkrabang Prince of Chumphon Campus for providing the financial support and thank the Department of General Science for supporting the research laboratory.

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