

## First Report on the Leaf Ultrastructures of *Ficus ulmifolia* Lam. (Is-is)

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**Abstract:** *Ficus ulmifolia* Lam., endemic to the Philippines, is popularly known as "Is-is" or the "scouring leaf". The leaves are traditionally used for polishing cooking pots and for sanding wood floors. Previous research studies have focused not on its abrasive property but on the leaf's medicinal potential. If the scouring properties are fully studied, *F. ulmifolia* could be a sustainable, eco-friendly alternative to synthetic products, such as sandpaper and scouring pads. Likewise, understanding its natural scouring property from a structural standpoint can provide biomimetic models that can help design a bio-based scouring alternative. This study discusses how the observed polishing property can be explained by analyzing the morphological differences between the abaxial and the adaxial leaf surfaces of the plant. The methodology included: (1) evaluation of the scouring property, (2) imaging of leaf surfaces, (3) analysis using an imaging software, and (4) statistical analysis of morphological parameters. The scouring test revealed that the sanding property is unique only to the adaxial side. Microscopic images revealed the presence of unicellular, filiform, and non-glandular trichomes, mostly hooked (curled) tip for the abaxial surface, and pointed tip for the adaxial side. The abaxial surface exhibited a significantly higher trichome coverage ( $25.44 \pm 2.49\%$ ) consisting of smaller trichomes (base diameter,  $33.8326 - 54.7656 \mu\text{m}$ ), while the adaxial surface gave a lower coverage ( $16.77 \pm 3.46\%$ ) with larger trichomes (base diameter,  $66.4794 - 103.322 \mu\text{m}$ ). These findings suggest that the polishing property, found only on the adaxial surface of *F. ulmifolia*, may be partly due to the pointed shape of the trichome tips, but since trichome density is less in the adaxial surface, the influence of the epicuticular waxes on leaf surface morphology should be studied in the future. To the best of our knowledge, this is the first report on the ultrastructures and scouring property of *F. ulmifolia* leaf.

**Key Words:** *Ficus ulmifolia*; Is-is; scouring property; abaxial, adaxial; trichomes

### 1. INTRODUCTION

*Ficus ulmifolia* Lam. (family Moraceae), is endemic in the Philippines, where it is popularly known in Tagalog as Is-is (Stuart, Jr., 2023). The

mature plant reaches up to 6 m in height, grows in thickets and open areas up to 1500 m altitude, and prefers a wet, tropical environment. Its flowers are in full bloom all year round, while the fruit, a subglobose fig, is edible but has little flavor and is usually eaten

with sugar. The plant is listed as a Least Concern (LC) species by the IUCN (2024).

In a previous study, it was reported that the dichloromethane extract of the air-dried leaves afforded squalene, polyprenol,  $\beta$ -amyrin fatty acid ester,  $\alpha$ -amyrin acetate and  $\beta$ -amyrin acetate, lutein, lupeol acetate,  $\beta$ -carotene, phytol,  $\alpha$ -amyrin fatty acid ester, sitosterol, and stigmasterol (Ragasa et al., 2009). Most of these compounds were generally reported to exhibit bioactivities such as antioxidant and anti-cancer properties (e.g.,  $\alpha$ -amyrin acetate,  $\beta$ -amyrin acetate sitosterol, squalene, and stigmasterol).

One of the most remarkable properties of *F. ulmifolia* is its ability to be used as a natural cleaning agent; hence, it is popularly known as the sandpaper or the scouring leaf (RP-National Parks Development Committee, n.d.). The rough leaves are traditionally used in rural areas as a substitute for sandpaper, for scrubbing pots and utensils, or for polishing wood. However, this particular characteristic has not been fully explained yet, perhaps due to the increasing popularity of synthetic products with the same function, the scarcity of trees in populated, urban areas, or, perhaps, the lack of interest in uncovering how nature serves as a perfect model for future biomimetic materials. It is expected that the characteristics of the leaf surface of *F. ulmifolia* influence its properties. Below is a general discussion on why plant surfaces matter.

The functions of plant surfaces are classified according to: (1) mechanical properties, (2) influence on reflection and absorption of radiation, (3) transpiration, (4) adhesion or non-adhesion, (5) gas exchange, and (6) protection against predators (Barthlott et al., 2017). Trichomes are hair-like outgrowths that are parts of the epidermal layers of plants. Recently, emphasis has been given to the ability of different epidermal structures on plant leaves to affect properties such as wettability (hydrophobicity or hydrophilicity), oleophilicity, and dust retention. Many studies have focused on leaf trichomes as these structures are found to influence the properties and functions demonstrated by the plant (Bhushan, 2009; Bool et al., 2018; Ensikat et al., 2011; Resurreccion et al., 2019). The pioneering research in this area focused on the *Nelumbo nucifera* (lotus) leaf, found to have trichomes with nanostructures. These were attributed to what is known as the “lotus effect”, which became the

inspiration for modern superhydrophobic and self-cleaning materials (Yang et al., 2024). The Burdock plant, *Galium aparine*, whose burrs attach to certain materials, became the inspiration for Velcro, a hook-and-loop fastener. The unique egg-beater-shaped trichomes of the aquatic fern, *Salvinia molesta*, are responsible for the so-called “Salvinia effect” that pertains to hydrophilic layers on hydrophobic surfaces (Konrad et al., 2021).

Nature inspires us to innovate modern products. Hence, biomimicry will continue to dictate how materials science advances. From airplanes, Velcro, and swimwear to large myco-remediation systems and sustainable city plans, biomimetic applications can enhance functionality since they are anchored on principles already tested by nature. There is a growing interest in learning more about the unique structures, functions, and applications of plants around us and how these can provide templates for more efficient materials and products.

There are no reports yet describing how the scouring properties of *F. ulmifolia* leaves can be attributed to their epidermal ultrastructures. This paper compares the abaxial and the adaxial leaf surfaces of the plant and discusses how the observed scouring property can be explained. To date, this is the first report on this aspect of the plant.

## 2. METHODOLOGY

### 2.1 Collection of Leaves

The mature leaves of *Ficus ulmifolia* were collected at the De La Salle University – Laguna Campus during the dry season, March to May. It was previously identified at the Botany Division of the National Museum of the Philippines. The voucher specimen is kept at the DLSU Laguna for deposit at the DLSU Manila Herbarium. Figure 1 shows the abaxial and adaxial sides of the leaves.

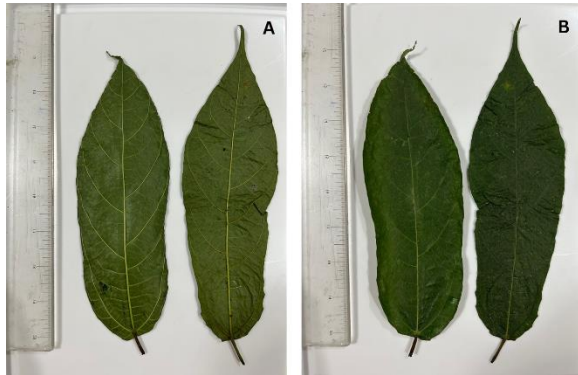


Figure 1. Fresh leaves of *F. ulmifolia* showing the (A) abaxial and (B) adaxial sides.

## 2.2. Experimental Design

### 2.2.1 Evaluation of the Scouring Property

A simple test was conducted to determine which side(s) of the *F. ulmifolia* leaf exhibited the scouring property. Each surface (abaxial and adaxial) was used to polish a piece of construction lumber. No other test was done to qualify or quantify the polished area.

### 2.2.2 Imaging of Leaf Surfaces

Scanning electron microscopy (SEM) was used to study the epidermal structures on the leaf surfaces of *F. ulmifolia*. This analysis was done by Katrin Field, Inc. in Biñan, Laguna, using the Phenom ProX desktop SEM (Parker Systems, Netherlands). No additional sample preparation was done. Representative parts of the leaf were cut up (5mm x 5mm) and attached to metal stubs. Magnifications of 200x, 300x, 310x, 500x, and 1000x were used to examine the leaf surface structures.

### 2.2.3 Image Analysis

ImageJ software (NIH, USA) was utilized to process and analyze five abaxial and five adaxial surface images according to trichome base diameter and trichome coverage (area covered by trichomes relative to the total image area). Images were calibrated using their embedded scale bars. Pre-

processing involved conversion to grayscale, brightness/contrast adjustment, and thresholding to create binary images for clear object differentiation. Region of Interest selection and particle analysis tools were used to quantify specific areas and features. Three independent trials were performed for every photomicrograph, and the mean of each set of three trials was computed to obtain the average trichome base diameter and coverage.

### 2.2.4 Statistical Analysis

Trichome coverage data from the abaxial and adaxial leaf surfaces of *F. ulmifolia* were first tested for normality using the Shapiro–Wilk test. An independent t-test was subsequently conducted to compare the mean trichome coverages. All statistical analyses were performed using Jamovi (Version 2.6), with significance determined at  $p < 0.05$ .

## 3. RESULTS AND DISCUSSION

### 3.1 Evaluation of the Scouring Property of Leaf Surfaces

The abaxial and the adaxial leaf surfaces of *F. ulmifolia* were tested individually to determine if they could polish a piece of ordinary construction lumber. The test revealed that the sanding property is unique to the adaxial side only (data not shown). This leaf surface continued to polish until such a time that it became brittle and eventually disintegrated. The next sections of this paper will attempt to explain this property based on imaging techniques.

### 3.2 Imaging of Leaf Structures

Comparison of the abaxial and the adaxial leaf surfaces of *Ficus ulmifolia* proved that the scouring property is unique to the adaxial surface only. To better understand the possible reason for the abrasiveness of the *F. ulmifolia* leaf, scanning electron microscopy (SEM) was used to examine the images of the ultrastructures present on the abaxial and adaxial surfaces of the plant.

Figure 2 shows representative SEM micrographs of the abaxial and the adaxial surfaces of *F. ulmifolia*, showing the leaf's trichomes, epicuticular wax, and the stomata (for abaxial). For both sides, the type of trichome seen is unicellular filiform and non-glandular (A-D). The trichomes are not dense and are sparsely distributed on the surface (C, D). Each trichome has a round base (A, B) and appears conical or tapered. However, there is an obvious difference between the abaxial and adaxial ultrastructures. For the abaxial side, the trichome base appears smaller, and the arm does not taper to a pointed apex but is hooked or is curled down (A, C). In contrast, for the adaxial surface, the trichome tip appears sharp and pointed (B, D). In addition, since trichome coverage is low, the stomata are also visible on the abaxial surface. Comparing the trichome shape, it is possible that the pointed tip seen on the adaxial side contributes to the scouring property of the leaf. This corroborates the scouring test, which revealed that the polishing property is unique to the adaxial surface only. Data on trichome base size and trichome coverage will be presented in the next section.

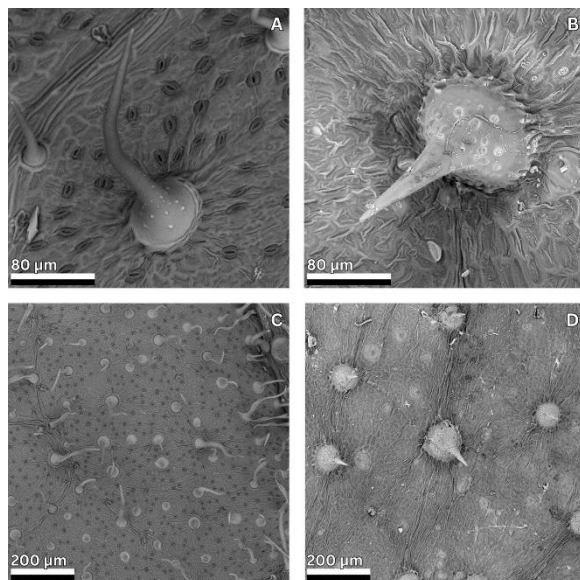


Figure 2. Scanning electron micrographs of *F. ulmifolia* leaf surface. Abaxial (A, C); adaxial (B, D); A-B: 1000x; C-D: 300x.

Figure 3, on the other hand, provides a closer look at the abaxial (A) and the adaxial (B) leaf surfaces, clearly revealing the ridge-like structures throughout the leaf. These structures resemble the folding of the waxy epidermal layer (i.e., epicuticular wax) as reported in a classic paper by Hardin (1979), and may be relevant to the properties of the plant leaf. Since trichome coverage in the adaxial surface is lower, it remains to be studied whether these ridge-like structures also contribute to the scouring property. For example, comparing the two surfaces, it can be seen that the adaxial side exhibits a more rugged texture. Hence, while the density of the pointed trichomes is less in the adaxial surface, it is possible that the ridges themselves also contribute to the overall roughness of the leaf.

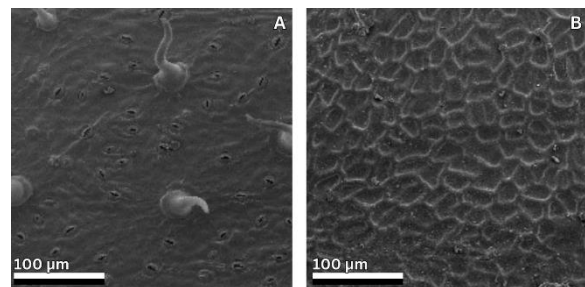


Figure 3. Rugged structures on the leaf surfaces of *F. ulmifolia* (A, abaxial; B, adaxial) at 200x magnification.

Another plant whose leaves also exhibit a similar scouring property is *Streblus asper* Lour., popularly known as kalios or sandpaper tree (Stuart, Jr., 2021). Similar to *F. ulmifolia*, there is also limited study on this aspect of the plant.

### 3.3 Image and Statistical Analysis

Trichome base diameter and coverage were quantified on a sample of five abaxial and five adaxial leaf surface images using ImageJ software. On the abaxial leaf surface, trichome base ranged from 33.8326 to 54.7656  $\mu\text{m}$ , while on the adaxial surface, the diameter ranged from 66.4794 to 103.322  $\mu\text{m}$ .

Quantitative analysis revealed mean trichome coverages of  $25.44 \pm 2.49\%$  on the abaxial leaf surface and  $16.77 \pm 3.46\%$  on the adaxial leaf surface. This trichome coverage asymmetry is

represented in Figures 2C and 2D. The non-overlapping confidence intervals seen in Figure 4 indicate a notable difference in the trichome coverage on the abaxial and adaxial leaf surfaces.

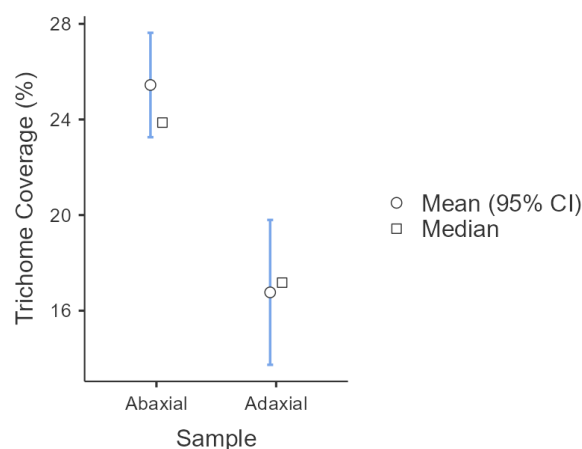


Figure 4. Trichome coverage in the abaxial and adaxial leaf surfaces of *F. ulmifolia*.

Verifying statistical significance is important to differentiate a definite pattern from a random effect. The Shapiro-Wilk normality test was first applied to determine the appropriate test for the mean comparison, yielding a value of 0.941, indicating that the data closely follows a normal distribution. Consequently, an Independent Samples t-test was conducted to compare the mean trichome coverage of the abaxial and adaxial surfaces. The test yielded a statistically significant difference ( $p = 0.002$ ). The distribution of trichomes on the abaxial surface likely reflects adaptive responses to environmental stressors. In *Metrosideros polymorpha*, it has been shown that trichomes on the lower leaf surface (abaxial) contribute to increased leaf temperature in cold, dry environments, enhancing photosynthesis in these conditions while reducing water-use efficiency (Amada, et al., 2021).

Despite its higher trichome coverage, the abaxial leaf surface was ineffective at scouring. The shape of the abaxial trichomes may have constrained their abrasiveness. As discussed in the previous section, the abaxial trichome is hooked (curled down) compared to the abaxial trichome that is sharp and

pointed at the apex. Even while exhibiting lower trichome density, the adaxial leaf surface has trichomes with a larger base and pointed tip, and these could have contributed to the scouring property since the wider base may be related to rigidity and strength, while the sharp tip may be important for abrasion. Hence, the data suggests that trichome density may not be a good basis for determining scouring effectiveness. Other factors like specific trichome shape, epicuticular folds or ridges, epidermal cell shape and arrangement, and mineral deposits may also be relevant (Neinhuis, et al., 1997). The epicuticular wax layer covers leaf surfaces, as amorphous films or wax crystals, with micro- and nano-structures that can enhance surface roughness (Wang et al., 2014). Studies using *Solanum* species have shown how waxes influence herbivore feeding behavior and development (Watts, 2023). The same rough microstructures that deter herbivores are also likely contributors to mechanical abrasiveness.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

This study investigated if the leaf surface characteristics of *F. ulmifolia* could explain its scouring property, specifically observed on the adaxial surface. It was found that the trichome distribution displays a distinct asymmetry, with the abaxial surface exhibiting a significantly higher trichome coverage ( $25.44 \pm 2.49\%$ ), with smaller trichome base size (diameter range of  $33.8326 - 54.7656 \mu\text{m}$ ). In contrast, the adaxial surface has a lower trichome coverage ( $16.77 \pm 3.46\%$ ), with larger trichome base size (diameter range of  $66.4794 - 103.322 \mu\text{m}$ ). The trichomes are unicellular, filiform, and non-glandular for both, but hooked for the abaxial, while pointed for the adaxial. These results suggest that the scouring property observed in the adaxial side could be attributed to the trichome shape, larger base, and pointed apex. These characteristics, when combined, could contribute to the ability of the adaxial side to polish. Regarding trichome coverage, since this factor is lower in the adaxial side, it is possible that other parameters are relevant, such as the ridge-like morphology of the surface that is due to the presence of epicuticular waxes. Further studies can examine

the composition of the epicuticular waxes and the presence of surface crystals, as the latter can add sharpness to the surface. Future studies can also involve physical tests to completely understand the surface roughness of the plant and its associated scouring properties. In the production of sandpapers, surface roughness is typically measured using 3D profilometry, which is a technique used to determine the three-dimensional shape and surface features of a solid material. Additional tests for *F. ulmifolia* can be inspired by industrial parameters.

*F. ulmifolia* leaf has untapped potential as a natural abrasive. The plant's ability to be cultivated sustainably and ecologically supports its future use. Processing techniques for incorporating Is-is into bio-based scouring composites warrant further investigation.

## 5. ACKNOWLEDGMENTS

The De La Salle University Research Coordination Office (now the Research and Grants Management Office) provided some support for this work. Dr. Danilo Tandang, from the National Museum of the Philippines, identified *F. ulmifolia*. Some *F. ulmifolia* SEM images were from R.R.S. Bool, E.D.P. Labios Jr., and B.F.R. Perona. The assistance of DLSU Laguna grounds personnel, G. Gabiazon and E. Igal, during the plant collection is also acknowledged.

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