# Designing of storage units and spider web collectors for Pholcus phalangiodes for the mass production of spider silk

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**Abstract** –Spider silk has been a subject of interest among many researches due to its remarkable mechanical properties. However, existing methods for the extraction of spider silk can exhaust the silk production of spiders and it takes about a week for some spiders to recover lost silk. The purpose of this study is to design and construct storage units for P. phalangioides which allows the spiders to naturally spin their webs for collection. The storage units are composed of 25 units (five by five), painted black on the interior with proper ventilation and spider silk collectors for each of the units on the base. The spiders were properly fed and hydrated, and the collection of silk was done every five days. The percentages of produced spider silk and collected spider silk were obtained and were evaluated using arbitrary levels: from very low (0 percent) to very high (100 percent). A high production of spider silk with a mean average of 82.00 percent was obtained. The spider silk collectors with a very high efficiency value of 98.083 percent, collected a mean average of 80.25 percent of the total area covered by the silk. Additionally, there was no significant difference between experimental groups as determined by one-way ANOVA (p=0 .121); it proves that every storage unit has equal chance of enabling the spider to yield high production of spider silk. The storage units were conducive environments for the spiders to spin their silk. Mimicking the natural habitat of spiders in order for them to yield high production of spider silk was achieved.

**Introduction.** – Spiders belong to the class of arachnids and they are one of the few animals that can produce silk naturally. A spider can spin silk when it is landing, building its web, catching its prey, making protective nests and cocoons, and suspending itself [9]. Spider silk has been a subject of interest among many researches mostly because of its toughness, ductility, elasticity, antimicrobial properties, hypoallergenicity, biodegradability [10] and even its refractive index in optics [8]. It has been used by humans for thousands of years when hunting, fishing, and as well as for bandages [10]. Studies have also shown that it is tougher than Kevlar which is a synthetic fiber of high tensile strength. Spider silk also can possibly be used as a scaffolding material for growing organ tissues and as a fiber optic cable for embedded devices in tissues [8].However, the artificial production of spider silk as a long, strong fiber for human use has been difficult. There have been developments that procure artificial silk that is similar to that of a spiders by inserting the gene code for silk production of an *Araneus ventricosus* spider to the silkworm, *Bombyx mori.* However, the results show that the silk produced by the genetically modified silkworms are not as tough as that of the *A. ventricosus.* Another way to produce actual spider silk without harming the spider is the use of a hand-driven reeling machine which involves hooking up its spinneret on the machine. However, this can exhaust and completely use up the spiders silk material and it takes the spider approximately a week before it can fully recover its silk [7]. In a project headed by Godley Peers, it took them more than one million golden orb spiders, 82 people, and four years to produce a cloth made entirely of spider silk that measures four feet by eleven feet. The process was impractical in the sense that it required more time, manpower, and resources to produce an amount of cloth made entirely of spider silk. Considering the time it takes for the spider to recover its silk, and their safety in terms of mortality, spiders subject for milking must have storage units that can keep them away from environmental factors that can affect their behavior and risk their life, and/or must be allowed to spin their silk naturally. *P. phalangioides* (longbodied cellar spider or daddy long legs) are common house spiders which belong to the group of web-building spiders. They usually make webs that are tangled and loose to easily catch their prey in dark undisturbed places like basements, under stones and ledges, or in caves [5]. Due to its pervasiveness, *P. phalangioides* can easily be captured and used for spider silk farming.

**Materials and Methods.** – The methodology consists of three main parts: the designing process and construction, web production and collection, and assessment of the product. The cover has two layers of clear acrylic sheet; the first one is the top layer with squares of 13 cm by 13 cm cut out from it. The cut-outs which were used as the cover slips and were then bored with 9 holes that serve as ventilation holes. The second is the bottom layer with squares of 11 cm by 11 cm cut out from it, but the cut-outs were discarded. The second layer was glued together with the first layer so that it acts as the holder for the cover slips. In order to ensure accuracy, the design was rendered on CorelDRAW, and the cutting process was done using a laser cutter. One end of the cover slips was taped to form a tab which granted easier access into the storage units during assessment and feeding.

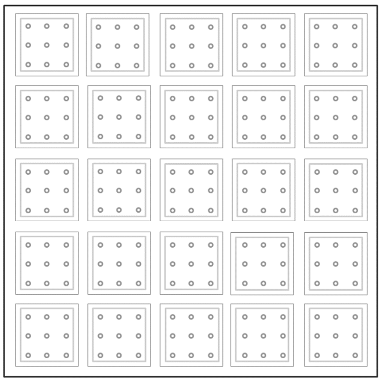

Fig. 1: Cover Lids Composed of the Bottom Layer and the Upper Layer With Ventilation Holes

The whole storage unit, which is a grid of five by five square units (a total of 25 storage units), is consisted of four outer walls, four inner long panels and 20 smaller panels which were glued together to form storage units, each having interior measurements of 15 cm by 15 cm by 15 cm. It provides just enough leg room for our *P. phalangioides* as recommended (three times its leg length).

For the base, the area was carefully calculated considering the average body length of the spiders, such that the spiders would not be crushed during spider web collection. We then bored 25 holes which were placed right at the center of each of the 25 storage units on the base. The wooden rods of 3mm-diameter, which served as the web collectors, were inserted into the holes. The walls around

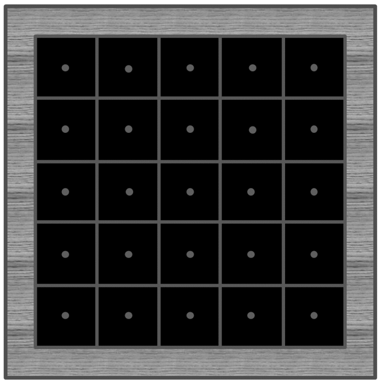

Fig. 2: Base with 25 holes for the collector and margin for the space allowance during collection

the base limits the movement of the storage units during web collection.

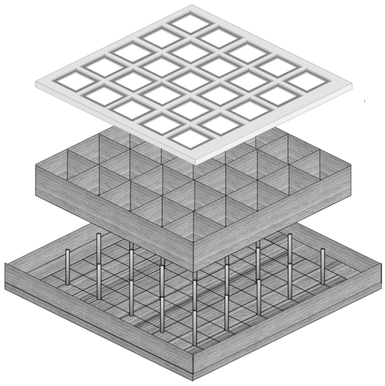

Fig. 3: Assembly of Cover Lids, Storage Units and Web Collectors

The product was assembled, without gluing them altogether, by placing the base with web collectors at the bottom most, the storage units in the middle, and the acrylic cover and slips at the topmost. The interior of the storage units including a part of the base below the storage units were then painted black which provided a darker environment that is suitable for the spiders. The spiders were left to produce their webs for five days. The web collection process was done by moving the storage units in a rotary motion. With the use of a mobile application called Seconds, the rhythm or pacing of movement was controlled. The spiders were fed and hydrated with live nymph lats and dampened cotton balls once every 3 days. For the assessment of the collection, the design was evaluated before and after the web collection process. With the use of quadrants marked on each of the cover of the storage units, the coverage of spider web in the storage units were estimated. If the web covered the entire quadrant, that is considered as 100 percent, if half, then 50 percent, if one fourth, then 25 percent, and so on. To get the percentage of the web collected in terms of surface area, we formulated this equation:

$$P = \frac{Precollection - Postcollection}{Precollection} x100$$

Pre-collection values determined the web coverage of the web produced by the spiders, and to obtain the collected spider web, the post-collection values were subtracted from the pre-collection values.

**Results and Discussion.** – The spiders were able to produce very high amounts of web with a mean average of 82.00 percent web coverage (Table 1). Most of the storage units have very high levels of web production. Having live lymph lats as food source might have stimulated the spiders to produce high levels of web since more web production helps them in catching their prey. Aside from that, other conditions such as adequate leg space, proper lighting, ideal temperature, and minimal human intervention were properly met.

Table 1. Average Percent of Web Production

| Group | A | B | C | D | E | Mean |
|---|---|---|---|---|---|---|
| Web Production | 95 | 92.50 | 77.50 | 66.25 | 78.75 | 82.00 |

In web collection, an average of 98.083 percent efficiency was obtained from the spider web collector marking its efficiency level as very high (Table 2). 80.25 percent of the area covered by web was collected by the web collector and only 1.75 percent remained uncollected. All the web collectors exhibited very high levels of collection as shown in this figure. Most of the uncollected web were clinging to the topmost part of the storage units (cover slips) or to edges where the collectors can no longer reach. Furthermore, some of the wooden rods were slightly bent or did not reach the proper dimensions to encompass the whole height of the storage units.

Table 2. Average Percent of Web Collection

| Group | A | B | C | D | E | Mean |
|---|---|---|---|---|---|---|
| Web Collection | 90 | 92.50 | 75 | 66.25 | 77.50 | 98.083 |

No spiders were killed in the data gathering. However, one spider escaped and another got injured. The escaped spider was replaced by a new spider on the last two data collections. Whenever there is a collection on-going, the spiders would attached themselves to the cover lids to protect themselves from being squashed by the collector. The spaces in the storage units allowed the spiders to move freely and to find areas where the collector could no longer reach (i.e. uppermost portion and corners). The injury of the spider was not caused by the movement of the base in the collection but due to the entanglement of its legs to a cotton ball. One possible explanation for the escape of the spider was that it was hard to notice its presence in the storage unit due to the dark interior. The spider might have camouflaged and disappeared during feeding or assessment. As determined by one-way ANOVA, there was no significant difference between the means of the sample groups. Having the p value of 0.121 (Table 3), the spider can produce the same amount of web regardless of the storage unit it is placed in. The experimental units were uniform and unvaried all throughout the data gathering and all of the spiders were under the same conditions and treatments.

Table 3. One-way Anova of the Means of the Sample Groups

| 0 | Sum of Sqr | Mean Sqr | df | F-ratio | p |
|---|---|---|---|---|---|
| Between groups | 2790.625 | 697.656 | 4 | 2.086 | 1 1.21 |
| Within groups | 6687.500 | 334.375 | 20 | | |
| Total | 9478.125 | | 24 | | |

**Conclusion and Recommendations.** – The storage units were conducive environments for the spiders to produce their web. Mimicking the natural habitat of spiders in order for them to yield high production of spider web was achieved. Conditions such as adequate leg space, proper lighting, adequate food supply, and minimal human intervention were met. The spider web collector was able to collect very high levels of spider web without killing any spiders. For future developments, it is recommended to use an electro-mechanically operated spider web collectors or storage units. Additionally, using a metallic rods as web collectors would be more efficient since it has a smooth surface and spider web would be easier to harvest, and finally, strictly following the measurements of the conceptual design is essential in order to avoid discrepancies.
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