The potential of silkworm's thread

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1. Abstract

According to a previous research, when the researchers gave silkworms the carbon nanotube solution, their thread became stronger. We wondered why it became stronger, and whether other things would also make it strong. We did an experiment to test the hypothesis that it would be stronger and more flexible with the help of chemical bands. Moreover, we realized the artificial materials were incorporated into the thread by using a scanning electron microscope.

2. Motivation / Goal

We were interested in silkworms, which can make biological thread. According to a previous research, "Silkworms Spin Super-Silk After Eating Carbon Nanotubes" (2016, by Prachi Patel), The researchers could make twice stronger than usual thread after they ate mulberry sprayed using a carbon nanotube water solution. We thought we might be able to make silkworms produce stronger thread when they ate other substances.

3. Hypothesis

They can make stronger thread when

(1) they take in substances which have chemical bonds (such as Van Der Waal's force and Hydrogen Bonds)
(2) the elements in silkworm thread were changed
(3) the thickness of silkworm thread became larger
(4) silkworms became more energetic eating more feed than usual.

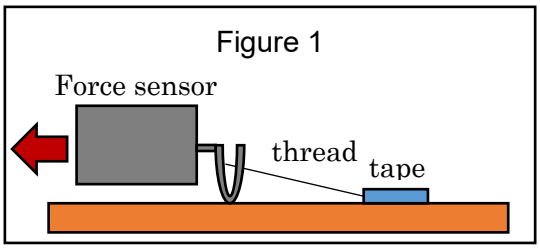
We regarded these hypotheses as the reasons why the strength of the thread increased, and conducted experiments based on these hypotheses.

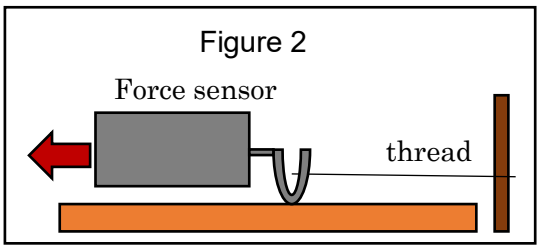
4. Method / Result

Method 1

We gave silkworms some substances in addition to artificial food. After that, we measured the strength and flexibility of the thread each group produced.

We made the thread rounded by using a cup. We wound the thread thirty times to make a one ring. We fixed one side of the thread using tape to table, and connected the other side to the power sensor to measure the strength and flexibility in the first and second experiments (figure1). In the third experiment, we used a stick instead of tape to fix one side of the thread (figure2). We defined strength as the tension when the thread breaks, and flexibility as the rate of the length of the thread before the experiment to that of the thread after the experiment.





〈Experiment 1〉

We made a 0.1% water solution of each substance. After that, we added 0.40 ml of this solution to 1.5g of artificial food. We divided 35 silkworms into seven groups and we gave the silkworms this food. In order to see the difference this would make, we made a control group. This group was only given artificial food. We gave the silkworms the following substances.

Graphite, sodium chloride, calcium hydroxide, hydrochloric acid, Tio2, potato starch (Graphite and Tio2 did not dissolve in water completely.)

〈Result 1〉

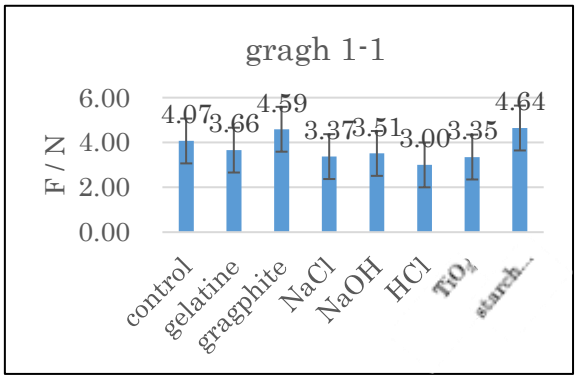
・About strength

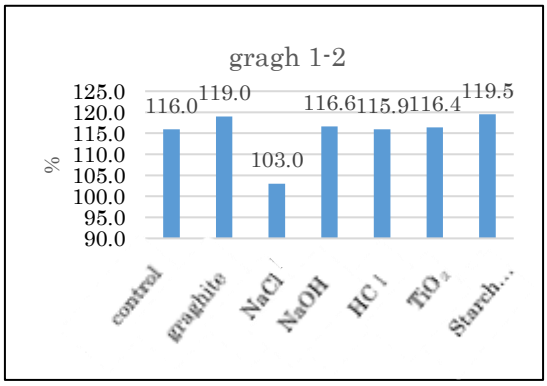
All of them made the thread of the same flexibility as the thread made before they eat artificial materials.

・About flexibility

The silkworm which ate salt made less flexible thread (-13.0%). The other silkworm made the same flexible thread.

We think the concentration of the solutions is too small to cause thread to change.





〈Experiment 2〉

We divided thirty silkworms into six groups. We gave different substances in addition to artificial food. In order to see the difference this would make, we made a control group. This group was only given artificial food. We gave 12.5g of artificial food to the silkworms and added 1.0g of other substances. We gave the silkworms the following substances.

carbon nanotube, water, rubber, gelatin, potato starch

(We gave the substances to the silkworms as solids, except water.)

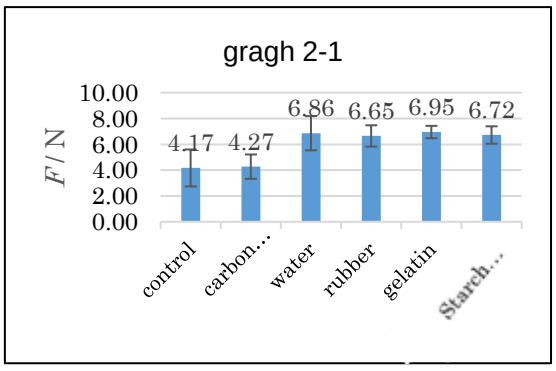
〈Result 2〉

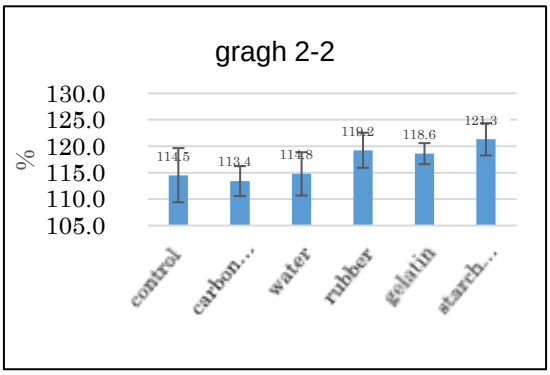
・About strength

The silkworm which were given rubber, gelatin, potato starch, water made three-seconds as strong as usual thread.

・About flexibility

The silkworm which ate rubber, gelatin, potato starch, made more flexible thread than usual thread (in turn +4.7%, +4.1%, +6.8%)





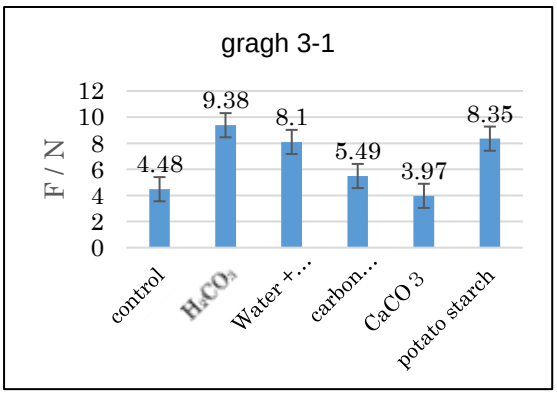
〈Result 3〉

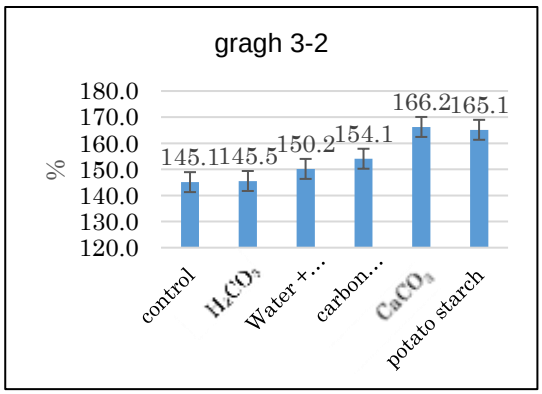
・About strength

The silkworm which ate silicic acid made thread twice as strong thread as the usual thread (+4.90N). The silkworm which ate potato starch made stronger thread (+3.67N) like Result 1. The silkworm which ate a mixture (water, gelatin and potato starch) made stronger thread (+3.62N). However, the silkworm which ate mixture made stronger thread than ones which ate potato starch. The silkworm which ate carbon-nanotube made weaker thread than usual thread (-0.51N). Since calcium-carbonate helps silkworm to eat more feed, the silkworm eat much feed. However, the strength became weaker.

・About flexibility

The silkworm which ate potato starch made more flexible thread than usual thread (+10.9%) The silkworm which ate mixture also made more flexible thread. The silkworm which ate other things made no less flexible thread.





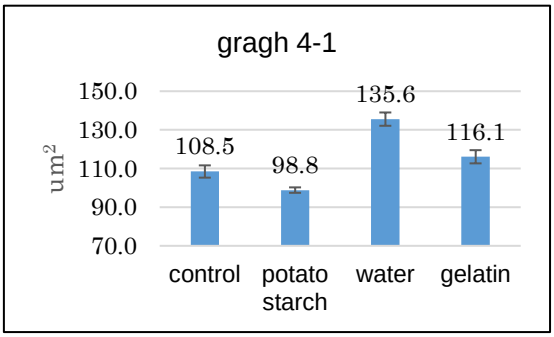
Method 2

We studied the thread made by the silkworm which ate Titan in Experiment 1, and the silkworm which took potato starch, gelatin, water, in Experiment 2 with scanning electron microscope. We compared them with the usual thread we got in Experiment 2.

We measured the thickness of each thread with the images of the scanning electron microscope. First, we drew a close circle of the vertical section of fibroins. Second, we measured the radius of the circle. Then we calculate the cross-sectional area using the radius.

〈Result 2〉

The silkworm which took in water made thicker thread (+27.1um^2).



5．Discussion

(The consideration about the hypothesis 1)

According to result 2 and 3, the thread made by silkworms which eat subjects gets stronger. They contain van der Waal's force or hydrogen bonds. However, the picture from the scanning electron microscope shows it is difficult to know if silkworms take substances into their bodies directly. Therefore, it is difficult for the thread to take subjects in directly. That's why it is impossible to say that substances which contain chemical bonds are incorporated into the thread and the characteristics of the thread change.

(The consideration about the hypothesis 2)

Result *1 is not enough as evidence. Therefore, we cannot affirm whether the hypothesis is right or not. We have to continue the experiment to confirm it.

(The consideration about the hypothesis 3)

According to the results from experiment 2, silkworms which take in water make stronger thread. Also, according to result *2, they make thicker thread. According to the previous research, the thread which silkworms make which takes the carbon nanotube solution in is about twice as strong as the original thread. However, in result 2, 3, the thread of the silkworms which had taken the carbon nanotube liquid in was as strong as the original thread. We think that this difference arises from whether silkworms take water in or not. Thus, the factor of the thread strength increasing isn't carbon nanotube but water.

(The consideration about the hypothesis 4)

According to result 3, silkworms which take calcium carbonate in eat more feed than others but don't make the thread which is different from the original thread concerning the strength and flexibility. Therefore, we think the amount of feed which silkworms eat doesn't have an influence on the thread characteristics.

6. Reference

『Silk reinforced with graphene or carbon nanotubes spun by spiders』（2015）
Nicol Pugno a professor in Trent University

『Silkworms Spin Super-Silk after
Eating Carbon Nanotubes and Graphene』(2016)　Prachi Patel

7. Appreciation

Japan Advanced in statute of Science and technology
Mr.,Hideto Shimahara

Japan Advanced in statute of Science and technology
Mr.Osamu Notoya

Kitanihon Spinning company

8. Key words

silkworm,　thread,　scanning microscope,　material