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Date: July 6, 2019
Comparisons of Cultivated and Wild Silks

Comparison of the Characteristics of

Cultivated and Wild Silks

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submitted to Olds College

October 31, 2016
Abstract

The object of this study was to prepare, spin, test, and compare the characteristics of cultivated Bombyx and wild Muga, Red Eri, Tasar, Tussah, and White Eri silks in various forms. The specimens included silk yarn prepared and spun from slivers, cocoons, mawata, rolags, punis, and waste forms. Testing included abrasion testing of woven samples and shrinkage testing of spun yarns. Color, luster, smoothness, hand, durability, shrinkage and desired finished appearance were compared for each yarn.

The main conclusion was that each form and species of silk had its own distinct characteristics. Some may have been similar, but each was different in color, luster, smoothness, hand, durability, shrinkage, and desired finished appearance. The end use determined the choice of silk form and species.

Questions and curiosity surrounding how the various silks would dye and the differences between silk fibres taken from the inside of the cocoon versus the outside could be recommendations for further study. The silk fibres taken from the outside and the inside of the cocoons are not as strong as the middle fibres (Rayner, 1903).
Comparisons of Cultivated and Wild Silks

Table of Contents

Introduction ...................................................................................... 5

Figure 1. Bombyx Mori Moth .......................................................... 8
Figure 2. Antheraea Assamensis Moth ............................................ 9
Figure 3. Samai Ricini Moth ......................................................... 10
Figure 4. Antheraea Mylitta Moth ................................................. 11
Figure 5. Antheraea Pernyi Moth .................................................. 12
Figure 6. Samai Ricini Moth ......................................................... 13

Materials and Methods .................................................................... 14

Preparation Methods .................................................................... 15
Table 1. Degumming Temperatures and Times ................................ 19

Spinning Methods ......................................................................... 20
Table 2. Silk Fibre Preparation and Spinning Methods. ................. 20

Finishing Methods ........................................................................ 21

Shrinkage Test ............................................................................. 22
Abrasion Test ............................................................................... 22

Results ............................................................................................ 25

Yarn Samples ................................................................................ 25
Comparisons ............................................................................... 47
Table 3. Characteristic Comparisons ............................................ 47
Table 4. Finished Appearance Comparison .................................... 49

Abrasion Test Results ................................................................... 50
Table 5. Abrasion Revolutions. ..................................................... 50

Shrinkage Test Results .................................................................. 72
Table 6. Shrinkage Test Results. ................................................... 73

Conclusion ...................................................................................... 74
Comparisons of Cultivated and Wild Silks

References ...................................................................................... 76

Appendix A ...................................................................................... 79

Specimen Key .................................................................................... 79
  Table 7. Silk Form Specimen Key .......................................................... 79

Appendix B ...................................................................................... 80

Glossary of Terms ............................................................................... 80

Acknowledgments .............................................................................. 83
Comparisons of Cultivated and Wild Silks

The purpose of this in-depth study was to compare the characteristics of various forms of cultivated and wild silks. Comparisons included color, luster, smoothness, hand, durability, shrinkage, and desired finished appearance when determining their end use.

The scope of this in-depth study included the comparison of commonly available silk fibre forms. Each form was prepared and spun as appropriate to the specimen. One yarn was spun for each form of the following:

Bombyx: Four yarns (One reeled and thrown, one spun from a sliver, one spun from a handmade mawata, one spun from a commercially made mawata)

Muga: Two yarns (One spun from a sliver, one spun from manually degummed cocoons)

Red Eri: Two yarns (One spun from a sliver, one spun from manually degummed cocoons)

Tasar: Two yarns (One spun from a sliver, one spun from manually degummed cocoons)

Tussah: Two yarns (One spun from a sliver, one spun from manually degummed cocoons)
Comparisons of Cultivated and Wild Silks

White Eri: Two yarns (One spun from a sliver, one spun from manually degummed cocoons)

Waste Forms: Seven yarns (One spun from each of the seven waste forms including Bombyx carrier rods, castings, kibiso, noil, strippings, throwsters, and Tussah noil)

The limiting factors of the study included the availability of the raw fibres, textile testing facilities, and textile testing equipment. Although there are myriad types of silk moths in nature, the fibre forms used in the study were those that are commonly available to the retail consumer. The textile testing facilities considered were located at two universities in Michigan. One restricted the use of the textile lab to current students of that university. The second was accessed and used to perform abrasion tests of the woven samples. Tensile strength testing of the yarn was not available at that location. Tensile strength testing was then eliminated from the study and shrinkage testing was added. The shrinkage test was performed in a residential kitchen.
Many authors have written about the origin of the discovery of silk as a fibre and a luxury fabric. Legend describes the discovery of silk as a fibre around 2600 b.c. by Empress Si-Ling of China (Avizienis, 1996). According to the Central Silk Board located in India ("VanyaSilks", 2015), evidence of the origin of Eri silk was discovered in 1779. Jean Joseph Tavenier introduced Muga silk in 1662 and in 1950, an earthquake greatly impacted Muga silk sericulture ("VanyaSilks", 2015). It was not until in the 1960’s that Tasar silk was discovered in India ("VanyaSilks", 2015).
This background information serves as an introduction to each silk moth included in the study.

**Bombyx**

![Bombyx Mori Moth](http://www.wormspit.com/bombyxsilkworms.htm)

**Figure 1. Bombyx Mori Moth**


Species name: Bombyx Mori

Country of origin: China, Eastern Europe, India, South America (Cook, 2014)

Diet: White mulberry leaves (Rayner, 1903)

Cocoon color: White

Average filament length: 700 to 1,200 meters (Winegardner, 2014)
Muga

Figure 2. Antheraea Assamensis Moth
https://commons.wikimedia.org/wiki/File:Antheraea_assamensis.JPG

Species name: Antheraea Assamensis

Country of origin: Assam region of India (Cook, 2014)

Diet: Kaola and Shamal leaves ("Sericulture", 2002)

Cocoon color: Golden

Average filament length: 450 meters (Winegardner, 2014)
Red Eri

Figure 3. Samai Ricini Moth

Species name: Samai Ricini

Country of origin: India (Cook, 2014)

Diet: Castor and Tapioca leaves (Cook, 2014)

Cocoon color: Bright rusty amber

Average filament length: 450 meters (Winegardner, 2014)
Comparisons of Cultivated and Wild Silks

**Tasar**

*Figure 4. Antheraea Mylitta Moth*


Species name: *Antheraea Mylitta*

Country of origin: India (Selk, 2014)

Diet: Asan and Arjun leaves (Selk, 2014)

Cocoon color: Light brown

Average filament length: 450 meters (Winegardner, 2014)
Figure 5. Antheraea Pernyi Moth

Species name: Antheraea Pernyi

Country of origin: China and Korea (Cook, 2014)

Diet: Oak leaves (Cook, 2014)

Cocoon color: Light tan

Average filament length: 700 meters (Winegardner, 2014)
White Eri

Figure 6. Samai Ricini Moth

Species name: Samai Ricini

Country of origin: India (Cook, 2014)

Diet: Castor and Tapioca leaves (Cook, 2014)

Cocoon color: Cream

Average filament length: 450 meters (Winegardner, 2014)
Materials and Methods

Materials were procured by ordering on-line via e-commerce websites and purchasing at the merchant mall during Fibre Week at Olds College. Cultivated silk forms available to retail consumers and purchased for this study were Bombyx carrier rods, castings, cocoons, kibiso, mawata, noil, sliver, strippings, and throwsters. Wild silk forms for Muga, Red Eri, Tasar, Tussah, and White Eri included vacant cocoons and sliver. Two additional forms – Ceranchia and Cricula cocoons -- were originally considered for the study. Several degumming attempts were unsuccessful and, therefore, the two species were not included in the study.
Preparation Methods

Reeling

The Japanese, or two basin, technique for silk reeling cultivated cocoons was chosen for this study (Cook, 2010). Twenty-five Bombyx cocoons were soaked in a stainless steel pot on the stove. The water temperature was just below a simmer and maintained until the cocoons stopped making a sizzling sound. The cocoons were then groped with a coarse brush to catch the ends of the fibres. Several yards of silk were removed until it was smooth. Hot water (156°F) was added to a small crockpot set to high temperature. The cocoons were lifted with a slotted spoon and moved to the crockpot in preparation for reeling.

The ends were then held together and threaded through a croissure to help facilitate smooth movement of the filaments, adherence of the fibres to one another, and the removal of excess water. The ends of the filaments were attached to a clock reel that had been covered in plastic wrap. The reel was located near the slow cooker and croissure and turned in the clockwise direction. A back and forth movement of the reeling hand allowed the filaments to be placed on the reel in a crossing pattern. Regular monitoring of the cocoons in the crockpot ensured that all the cocoons were still connected. If one did become loose, the reeling was halted and the cocoon reconnected by finding the end of the thread and laying it atop the other threads. Reeling then resumed.
Care was taken to twice re-reel the silk filaments onto a bobbin until they were dry to the touch. Reeled silk that is allowed to dry on a bobbin will shrink and stick together (Cook, 2010). The reeling process was repeated one more time as two bobbins would be used to create a plied yarn. The filaments were thrown to create two trams, which were then plied together. This process was repeated until there were two plies that, together, contained a total of 200 baves.

**Mawata from Bombyx Cocoons**

The homemade mawata spun for this study were prepared using the following process. A mawata frame was constructed of wooden picture frame bars to which small finish nails were inserted in one inch increments. Ten Bombyx cocoons were added to a stainless steel pot containing \( \frac{1}{4} \) cup washing soda, \( \frac{1}{4} \) cup liquid detergent and one gallon of water. The mixture simmered at 196\(^\circ\)F to 204\(^\circ\)F for 30 minutes. Each softened cocoon was removed from the water, opened to remove the pupa, and stretched over the mawata frame. The frame containing the newly formed mawata was placed under running water for three minutes. Two quarts of water and \( \frac{1}{4} \) cup vinegar were mixed in a shallow glass baking dish. The framed mawata were then dipped into the acid solution to neutralize the pH level. They were rinsed again in clear water, carefully removed from the frame, patted dry with a towel and laid flat to dry.
Comparisons of Cultivated and Wild Silks

(Lang, 2015). The process was repeated twice more to equal a total of 30 mawata.

**Wild Silk Cocoons**

The original plan was to create mawata from the wild silk cocoons to include Ceranchia, Cricula, Muga, Red Eri, Tasar, Tussah, and White Eri. A weight-of-goods formula of 50 grams of cocoons, one teaspoon washing soda, and one teaspoon liquid detergent to one liter water was used to degum the wild cocoons. They simmered in separate pots per species for one to 3½ hours. None were successfully degummed.

An inquiry to Michael Cook (personal communication, March 23, 2016) revealed that a strength-of-solution formula might prove more effective. A new supply of wild cocoons was purchased and the process repeated with the new degumming formula. Mr. Cook’s recipe was ¼ cup washing soda, ¼ cup Orvus paste, and enough water to make one gallon of solution. Mostly, it worked. All of the cocoons were successfully degummed except for the Ceranchia and Cricula cocoons. After one more unsuccessful degumming attempt, the plan to use the cocoons in the study was finally abandoned.

The soft cloud-like appearance of the wild cocoons indicated that they were successfully degummed. The cocoons were rinsed in clear water until the soap was removed. They were then dipped in an
acidulated bath containing ¼ cup vinegar and two quarts water. Finally, they were rinsed in clear water. When stretching over the mawata frame was attempted, the degummed cocoons did not hold together well. The stretching process was abandoned and the cocoons were left to air dry, cut into three inch lengths, and carded in preparation for spinning.

**Waste Silk**

Preparation of the carrier rods, castings and kibiso included degumming, hand carding, and forming into rolags for spinning. The strength-of-solution formula was used to degum the waste forms using the same techniques described in the wild silk section above. The degumming process was very successful for the waste forms. As shown in Table 1, the degumming times and water temperatures varied by silk type and form. The commercially degummed waste forms were carded or combed, as appropriate.
<table>
<thead>
<tr>
<th>Silk</th>
<th>Form</th>
<th>Temperature</th>
<th>Degumming Process Time in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bombyx</td>
<td>Cocoons</td>
<td>204°F</td>
<td>30</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Carrier rods</td>
<td>196°F</td>
<td>60</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Castings</td>
<td>208°F</td>
<td>70</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Kibiso</td>
<td>196°F</td>
<td>60</td>
</tr>
<tr>
<td>Muga</td>
<td>Cocoons</td>
<td>198°F</td>
<td>60</td>
</tr>
<tr>
<td>Red Eri</td>
<td>Cocoons</td>
<td>197°F</td>
<td>60</td>
</tr>
<tr>
<td>Tasar</td>
<td>Cocoons</td>
<td>203°F</td>
<td>180</td>
</tr>
<tr>
<td>Tussah</td>
<td>Cocoons</td>
<td>204°F</td>
<td>180</td>
</tr>
<tr>
<td>White Eri</td>
<td>Cocoons</td>
<td>196°F</td>
<td>120</td>
</tr>
</tbody>
</table>
Comparisons of Cultivated and Wild Silks

**Spinning Methods**

Silk forms were prepared and spun as recorded in Table 2.

Samples of the yarns are located in the Results section of this study.

*Table 2. Silk Fibre Preparation and Spinning Methods.*

<table>
<thead>
<tr>
<th>Silk</th>
<th>Form</th>
<th>Preparation</th>
<th>Spinning Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bombyx</td>
<td>Cocoon</td>
<td>Reeled</td>
<td>Thrown</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Sliver</td>
<td>Commercial</td>
<td>Spun from fold</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Homemade</td>
<td>Attenuated</td>
<td>Worsted</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Commercial mawata</td>
<td>Attenuated</td>
<td>Worsted</td>
</tr>
<tr>
<td>Muga</td>
<td>Sliver</td>
<td>Commercial</td>
<td>Spun from fold</td>
</tr>
<tr>
<td>Muga</td>
<td>Cocoon</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Red Eri</td>
<td>Sliver</td>
<td>Commercial</td>
<td>Spun from fold</td>
</tr>
<tr>
<td>Red Eri</td>
<td>Cocoon</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Tasar</td>
<td>Sliver</td>
<td>Commercial</td>
<td>Spun from fold</td>
</tr>
<tr>
<td>Tasar</td>
<td>Cocoon</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Tussah</td>
<td>Sliver</td>
<td>Commercial</td>
<td>Spun from fold</td>
</tr>
<tr>
<td>Tussah</td>
<td>Cocoon</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>White Eri</td>
<td>Sliver</td>
<td>Commercial</td>
<td>Spun from fold</td>
</tr>
<tr>
<td>White Eri</td>
<td>Cocoon</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Carrier rods</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Castings</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Kibiso</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Noil</td>
<td>Hand carded puni</td>
<td>Long draw spun on charkha</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Strippings</td>
<td>Hand combed</td>
<td>Spun worsted from combs</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Throwsters</td>
<td>Hand carded rolag</td>
<td>Supported long draw</td>
</tr>
<tr>
<td>Tussah</td>
<td>Noil</td>
<td>Hand carded puni</td>
<td>Long draw spun on charkha</td>
</tr>
</tbody>
</table>
**Finishing Methods**

Once the yarns that were spun from manually degummed silk forms were completed, they underwent a final degumming process to remove the remaining sericin. The recipe follows.

Recipe for degumming silk yarn

\[
\begin{align*}
\frac{1}{4} \text{ cup washing soda} \\
\frac{1}{4} \text{ cup liquid detergent} \\
\text{Enough water to make one gallon}
\end{align*}
\]

The degumming solution was poured into a stainless steel pot, placed on the stove and heated to a boil. The heat was then reduced to a simmer and the skeined yarn added to the pot. Simmering continued for 45 minutes. Once the yarn was removed from the solution and slightly cooled, it was rinsed with clear tepid water. An additional rinse in a solution of \( \frac{1}{4} \) cup vinegar to one gallon water and a tight wring of the skein, completed the final degumming process. The yarn was then blotted on a towel and air dried (Cook, 2010).

Yarns that were spun from commercially prepared or degummed forms were finished in a warm water bath, rolled in a towel, and air dried. All yarns were gently steamed with the steam from a steam iron and snapped to restore scroop.
Comparisons of Cultivated and Wild Silks

Shrinkage Test

A shrinkage test was conducted to compare shrinkage rates between the various silk forms. Each yarn was cut into a six inch length and placed in separate vessels. Three hundred ml of water combined with one drop liquid detergent was heated to 122°F and poured into each vessel to cover the yarn. Once the water cooled to room temperature (73°F), the yarns were removed, rinsed in clear water (73°F), and drained on a towel until dry. The length of each yarn was measured to determine the amount of shrinkage that occurred and was recorded on Table 6.

Abrasion Test

An abrasion test was conducted in the textile lab at Central Michigan University in Mount Pleasant, Michigan. The lab was a stand-alone unit provided by Russells Technical Products. As indicated in Figure 7, climate control was maintained at 70°F and 65% humidity.

Each silk form was prepared, spun, and woven on a pin loom into swatches measuring six inches by six inches. A Taber Abraser machine, pictured in Figure 8 and located inside the Russells testing lab, was used to test each swatch.
The metal collar, nut, and hub were removed from the turntable of the abraser machine. A 150-grit closed coat silicon carbide sandpaper disc was placed on the turntable with the grit side facing upward. A small hole was cut into the center of each fabric square. The swatch was then laid atop the sandpaper disc. In order to secure the swatch to the machine, the collar, nut and hub were re-attached to the turntable over the fabric as shown in Figure 9.

The arm was lowered, counter reset to zero, and machine switched on. After every 20 revolutions, the machine was switched off, the arm raised, and the swatch checked for wear. If the yarn had not failed, the abrasion test process was repeated. This sequence continued until wear resulted in a broken yarn. The number of revolutions was recorded, the
swatch removed, and a new swatch was attached to the abraser machine. One sandpaper disc was used for every five swatches tested.
Results

Yarn Samples

Yarns were prepared as appropriate to each silk form. The following pages include the spun yarn samples, preparation and spinning methods, and measurements.
**Bombyx Reeled Cocoon**

Preparation: Japanese method of reeling

Number of cocoons per filament: 25

Number of filaments: 8

Spinning method: Reeled and thrown

TPI: 5.5

WPI: 26

Angle of twist: 20°

Plies: 2

Spun/Plied: ZZS

Weight: 9.144 meters = 2g

Denier: 492.1 denier
Comparisons of Cultivated and Wild Silks

**Bombyx Sliver**

Preparation: Commercially prepared sliver

Spinning method: Spun from the fold

TPI: 6

WPI: 29

Angle of twist: 30°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1.5g

Count: 7.2s
Bombyx Homemade Mawata

Preparation: Manually degummed and attenuated

Spinning method: Worsted

TPI: 4.5

WPI: 20

Angle of twist: 28°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 2g

Count: 5.4s
Comparisons of Cultivated and Wild Silks

Bombyx Commercial Mawata

Preparation: Commercially degummed and attenuated

Spinning method: Worsted

TPI: 4

WPI: 15

Angle of twist: $30^\circ$

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1g

Count: 10.8s
Muga Sliver

Preparation: Commercially prepared sliver

Spinning method: Spun from the fold

TPI: 4

WPI: 20

Angle of twist: 20°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1.4g

Count: 7.7s
Muga Cocoon

Preparation: Manually degummed, cut, and carded into rolags

Spinning method: Supported long draw

TPI: 3.5

WPI: 17

Angle of twist: 20°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1.8g

Count: 6s
Comparisons of Cultivated and Wild Silks

Red Eri Sliver

Preparation: Commercially prepared sliver

Spinning method: Spun from the fold

TPI: 6

WPI: 16

Angle of twist: 30°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1.3g

Count: 8.3s
Red Eri Cocoon

Preparation: Manually degummed, cut, and carded into rolags

Spinning method: Supported long draw

TPI: 5.5

WPI: 17

Angle of twist: 25°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 2g

Count: 5.4s
Comparisons of Cultivated and Wild Silks

Tasar Sliver

Preparation: Commercially prepared sliver

Spinning method: Spun from the fold

TPI: 6

WPI: 19

Angle of twist: 25°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 2.5g

Count: 4.3s
**Tasar Cocoon**

Preparation: Manually degummed, cut, and carded into rolags

Spinning method: Supported long draw

TPI: 4.5

WPI: 13

Angle of twist: 27°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 4.5g

Count: 2.4s
Comparisons of Cultivated and Wild Silks

Tussah Sliver

Preparation: Commercially prepared sliver

Spinning method: Spun from the fold

TPI: 7

WPI: 17

Angle of twist: 25°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 2g

Count: 5.4s
Tussah Cocoon

Preparation: Manually degummed, cut, and carded into rolags

Spinning method: Supported long draw

TPI: 4.5

WPI: 18

Angle of twist: 21°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 2g

Count: 5.4s
**White Eri Sliver**

Preparation: Commercially prepared sliver

Spinning method: Spun from the fold

TPI: 6.5

WPI: 22

Angle of twist: 28°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1.5g

Count: 7.2s
White Eri Cocoon

Preparation: Manually degummed, cut, and carded into rolags

Spinning method: Supported long draw

TPI: 4.5

WPI: 17

Angle of twist: 29°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1.1g

Count: 9.8s
Comparisons of Cultivated and Wild Silks

Bombyx Carrier Rods

Preparation: Manually degummed and carded into rolags

Spinning method: Supported long draw

TPI: 5

WPI: 12

Angle of twist: 28°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 2.5g

Count: 4.3s
Comparisons of Cultivated and Wild Silks

**Bombyx Castings**

Preparation: Manually degummed and carded into rolags

Spinning method: Supported long draw

TPI: 8

WPI: 17

Angle of twist: 32°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 1.5g

Count: 7.2s
**Comparisons of Cultivated and Wild Silks**

**Bombyx Kibiso**

Preparation: Manually degummed and carded into rolags

Spinning method: Supported long draw

TPI: 5.5

WPI: 11

Angle of twist: $30^\circ$

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 5g

Count: 2.1s
**Bombyx Noil**

Preparation: Commercially degummed and hand carded into a puni

Spinning method: Long draw spun on a charkha

TPI: 5

WPI: 13

Angle of twist: 32°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 3g

Count: 3.6s
Comparisons of Cultivated and Wild Silks

**Bombyx Strippings**

Preparation: Commercially degummed and hand combed

Spinning method: Spun worsted from combs

TPI: 8

WPI: 19

Angle of twist: $32^\circ$

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 2g

Count: 5.4s
Comparisons of Cultivated and Wild Silks

Bombyx Throwsters

Preparation: Commercially degummed and carded into rolags

Spinning method: Supported long draw

TPI: 5.5

WPI: 15

Angle of twist: 32°

Plies: 2

Spun/Plied: ZZS

Weight: 10 yards = 3g

Count: 3.6s
Comparisons of Cultivated and Wild Silks

**Tussah Noil**

Preparation: Commercially degummed and hand carded puni

Spinning method: Long draw spun on a charkha

TPI: 3

WPI: 17

Angle of twist: 25°

Plies: 2

Spun/Plied: SSZ

Weight: 10 yards = 2g

Count: 5.4s
## Comparisons

**Table 3. Characteristic Comparisons**

<table>
<thead>
<tr>
<th>Silk Yarn</th>
<th>Color</th>
<th>Luster</th>
<th>Smoothness</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bombyx reeled</td>
<td>White</td>
<td>Very shiny</td>
<td>Very smooth</td>
<td>Soft and very drapeable</td>
</tr>
<tr>
<td>Bombyx sliver</td>
<td>White</td>
<td>Very shiny</td>
<td>Nearly completely smooth</td>
<td>Soft and very drapeable</td>
</tr>
<tr>
<td>Bombyx homemade mawata</td>
<td>Off-White</td>
<td>Shiny with some matte</td>
<td>Slubs</td>
<td>Soft and drapeable</td>
</tr>
<tr>
<td>Bombyx commercial mawata</td>
<td>Cream</td>
<td>Shiny with some matte</td>
<td>Slubs</td>
<td>Soft and drapeable</td>
</tr>
<tr>
<td>Muga sliver</td>
<td>Light gold</td>
<td>Shiny</td>
<td>Nearly smooth yet fuzzy</td>
<td>Soft and drapeable</td>
</tr>
<tr>
<td>Muga cocoon</td>
<td>Deep gold</td>
<td>Shiny with some matte</td>
<td>Slubs</td>
<td>Soft and somewhat drapeable</td>
</tr>
<tr>
<td>Red Eri sliver</td>
<td>Bright rust</td>
<td>Shiny</td>
<td>Nearly smooth</td>
<td>Soft and drapeable</td>
</tr>
<tr>
<td>Red Eri cocoon</td>
<td>Beige</td>
<td>Mostly matte</td>
<td>Slubs</td>
<td>Coarse and somewhat crisp</td>
</tr>
<tr>
<td>Tasar sliver</td>
<td>Light brown</td>
<td>Slightly shiny with matte</td>
<td>Nearly smooth yet slightly fuzzy</td>
<td>Soft and slightly crisp with some drape</td>
</tr>
<tr>
<td>Tasar cocoon</td>
<td>Light brown with dark flecks</td>
<td>Slightly shiny with matt</td>
<td>Slubs</td>
<td>Very coarse and crisp</td>
</tr>
<tr>
<td>Tussah sliver</td>
<td>Light tan</td>
<td>Shiny</td>
<td>Nearly smooth</td>
<td>Soft and drapeable</td>
</tr>
<tr>
<td>Tussah cocoon</td>
<td>Tan with light brown flecks</td>
<td>Slightly shiny with matte</td>
<td>Slubs</td>
<td>Coarse and crisp</td>
</tr>
<tr>
<td>White Eri sliver</td>
<td>Cream</td>
<td>Slightly shiny with matte</td>
<td>Nearly smooth</td>
<td>Soft and slightly crisp with some drape</td>
</tr>
<tr>
<td>Silk Yarn</td>
<td>Color</td>
<td>Luster</td>
<td>Smoothness</td>
<td>Hand</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------</td>
<td>--------------</td>
<td>---------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>White Eri cocoon</td>
<td>Cream</td>
<td>Mostly matte</td>
<td>Slubs</td>
<td>Soft and drapeable</td>
</tr>
<tr>
<td>Bombyx carrier</td>
<td>Very light peachy pink</td>
<td>Slightly shiny with mostly matte</td>
<td>Slubs and slightly fuzzy</td>
<td>Soft and slightly crisp with some drape</td>
</tr>
<tr>
<td>rods</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx castings</td>
<td>Cream</td>
<td>Shiny with some matte</td>
<td>Nearly smooth with slubs</td>
<td>Soft and slightly crisp with some drape</td>
</tr>
<tr>
<td>Bombyx kibiso</td>
<td>Bright white</td>
<td>Shiny with some matte</td>
<td>Mostly slubs</td>
<td>Soft and crisp with slight drape</td>
</tr>
<tr>
<td>Bombyx noil</td>
<td>Light beige</td>
<td>Matte</td>
<td>Slubs</td>
<td>Soft and crisp</td>
</tr>
<tr>
<td>Bombyx strippings</td>
<td>Light beige</td>
<td>Matte</td>
<td>Mostly slubs</td>
<td>Soft and crisp with slight drape</td>
</tr>
<tr>
<td>Bombyx throwsters</td>
<td>Cream</td>
<td>Very shiny</td>
<td>Fuzzy</td>
<td>Soft and crisp with slight drape</td>
</tr>
<tr>
<td>Tussah noil</td>
<td>Cream with very light yellow cast</td>
<td>Matte</td>
<td>Slubs and slightly fuzzy</td>
<td>Soft and slightly crisp with some drape</td>
</tr>
<tr>
<td>Silk Yarn</td>
<td>Finished Appearance</td>
<td>End Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------</td>
<td>----------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx reeled</td>
<td>Very light weight</td>
<td>Woven blouse or knitted camisole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx sliver</td>
<td>Light weight</td>
<td>Woven kimono or next-to-skin knitwear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx homemade mawata</td>
<td>Very light weight</td>
<td>Knitted sweater or camisole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx commercial mawata</td>
<td>Very light weight</td>
<td>Knitted sweater or woven scarf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muga sliver</td>
<td>Light weight</td>
<td>Dressy knitwear, crochet skirt or woven wrap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muga cocoon</td>
<td>Heavy weight</td>
<td>Woven long jacket or open weave scarf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Eri sliver</td>
<td>Light weight</td>
<td>Dressy knitwear, crochet skirt or woven baby blanket</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Eri cocoon</td>
<td>Medium weight</td>
<td>Woven jacket or crochet cloche</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tasar sliver</td>
<td>Light weight</td>
<td>Knitwear or woven table runner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tasar cocoon</td>
<td>Heavy weight</td>
<td>Woven outerwear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tussah sliver</td>
<td>Medium weight</td>
<td>Knitwear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tussah cocoon</td>
<td>Heavy weight</td>
<td>Woven outerwear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Eri sliver</td>
<td>Medium weight</td>
<td>Crochet cloche</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Eri cocoon</td>
<td>Very light weight</td>
<td>Leno weave curtain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx carrier rods</td>
<td>Heavy weight</td>
<td>Woven jacket or open weave scarf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx castings</td>
<td>Heavy weight</td>
<td>Woven throw or knitted sweater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx kibiso</td>
<td>Heavy weight</td>
<td>Woven baby blanket</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx noil</td>
<td>Heavy weight</td>
<td>Woven outerwear or woven throw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx stripplings</td>
<td>Heavy weight</td>
<td>Woven yardage for throw pillows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombyx throwsters</td>
<td>Heavy weight</td>
<td>Woven outerwear or knitted sweater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tussah noil</td>
<td>Heavy weight</td>
<td>Knitted cardigan or woven jacket</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Abrasoin Test Results**

A table of results was prepared to record the number of revolutions needed to cause the yarn to fail for each sample. Two samples were tested for each form of silk to accommodate the requirement to submit two copies of the final in-depth study. As shown in Table 5, the results for the two samples are somewhat varied.

*Table 5. Abrasion Revolutions.*

<table>
<thead>
<tr>
<th>Silk</th>
<th>Form</th>
<th>Type</th>
<th>Abrasion Revolutions Sample 1</th>
<th>Abrasion Revolutions Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bombyx</td>
<td>Cocoons</td>
<td>Cultivated</td>
<td>210</td>
<td>200</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Sliver</td>
<td>Cultivated</td>
<td>255</td>
<td>235</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Mawata homemade</td>
<td>Cultivated</td>
<td>225</td>
<td>200</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Mawata commercial</td>
<td>Cultivated</td>
<td>175</td>
<td>173</td>
</tr>
<tr>
<td>Muga</td>
<td>Sliver</td>
<td>Wild</td>
<td>401</td>
<td>295</td>
</tr>
<tr>
<td>Muga</td>
<td>Cocoons</td>
<td>Wild</td>
<td>478</td>
<td>530</td>
</tr>
<tr>
<td>Red Eri</td>
<td>Sliver</td>
<td>Wild</td>
<td>300</td>
<td>290</td>
</tr>
<tr>
<td>Red Eri</td>
<td>Cocoons</td>
<td>Wild</td>
<td>295</td>
<td>300</td>
</tr>
<tr>
<td>Tasar</td>
<td>Sliver</td>
<td>Wild</td>
<td>500</td>
<td>510</td>
</tr>
<tr>
<td>Tasar</td>
<td>Cocoons</td>
<td>Wild</td>
<td>420</td>
<td>550</td>
</tr>
<tr>
<td>Tussah</td>
<td>Sliver</td>
<td>Wild</td>
<td>346</td>
<td>360</td>
</tr>
<tr>
<td>Tussah</td>
<td>Cocoons</td>
<td>Wild</td>
<td>320</td>
<td>317</td>
</tr>
<tr>
<td>White Eri</td>
<td>Sliver</td>
<td>Wild</td>
<td>275</td>
<td>210</td>
</tr>
<tr>
<td>White Eri</td>
<td>Cocoons</td>
<td>Wild</td>
<td>215</td>
<td>210</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Carrier Rods</td>
<td>Cultivated</td>
<td>551</td>
<td>556</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Castings</td>
<td>Cultivated</td>
<td>495</td>
<td>530</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Kibiso</td>
<td>Cultivated</td>
<td>275</td>
<td>226</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Noil</td>
<td>Cultivated</td>
<td>800</td>
<td>795</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Strippings</td>
<td>Cultivated</td>
<td>227</td>
<td>220</td>
</tr>
<tr>
<td>Bombyx</td>
<td>Throwsters</td>
<td>Cultivated</td>
<td>850</td>
<td>900</td>
</tr>
<tr>
<td>Tussah</td>
<td>Noil</td>
<td>Wild</td>
<td>400</td>
<td>420</td>
</tr>
</tbody>
</table>
Comparisons of Cultivated and Wild Silks

Bombyx Reeled Cocoon

Revolutions needed for yarn to fail (sample one – included here): 210

Revolutions needed for yarn to fail (sample two): 200
Comparisons of Cultivated and Wild Silks

**Bombyx Sliver**

Revolutions needed for yarn to fail (sample one – included here): 255

Revolutions needed for yarn to fail (sample two): 235
Comparisons of Cultivated and Wild Silks

**Bombyx Homemade Mawata**

Revolutions needed for yarn to fail (sample one – included here): 225

Revolutions needed for yarn to fail (sample two): 200
Bombyx Commercial Mawata

Revolutions needed for yarn to fail (sample one – included here): 175

Revolutions needed for yarn to fail (sample two): 173
Comparisons of Cultivated and Wild Silks

**Muga Sliver**

Revolutions needed for yarn to fail (sample one – included here): 401

Revolutions needed for yarn to fail (sample two): 295
Muga Cocoon

Revolutions needed for yarn to fail (sample one - included here): 478

Revolutions needed for yarn to fail (sample two): 530
Red Eri Sliver

Revolutions needed for yarn to fail (sample one – included here): 300

Revolutions needed for yarn to fail (sample two): 290
Red Eri Cocoon

Revolutions needed for yarn to fail (sample one – included here): 295

Revolutions needed for yarn to fail (sample two): 300
Tasar Sliver

Revolution needed for yarn to fail (sample one - included here): 500

Revolution needed for yarn to fail (sample two): 510
Comparisons of Cultivated and Wild Silks

Tasar Cocoon

Revolutions needed for yarn to fail (sample one – included here): 420

Revolutions needed for yarn to fail (sample two): 550
Tussah Sliver

Revolutions needed for yarn to fail (sample one – included here): 346

Revolutions needed for yarn to fail (sample two): 360
Comparisons of Cultivated and Wild Silks

**Tussah Cocoon**

Revolutions needed for yarn to fail (sample one – included here): 320

Revolutions needed for yarn to fail (sample two): 317
White Eri Sliver

Revolutions needed for yarn to fail (sample one – included here): 275

Revolutions needed for yarn to fail (sample two): 210
Comparisons of Cultivated and Wild Silks

White Eri Cocoon

Revolution needed for yarn to fail (sample one – included here): 215

Revolution needed for yarn to fail (sample two): 210
Comparisons of Cultivated and Wild Silks

Bombyx Carrier Rods

Revolution needed for yarn to fail (sample one – included here): 551

Revolution needed for yarn to fail (sample two): 556
Comparisons of Cultivated and Wild Silks

Bombyx Castings

Revolutions needed for yarn to fail (sample one – included here): 495

Revolutions needed for yarn to fail (sample two): 530
Comparisons of Cultivated and Wild Silks

Bombyx Kibiso

Revolutions needed for yarn to fail (sample one – included here): 275

Revolutions needed for yarn to fail (sample two): 226
Bombyx Noil

Revolutions needed for yarn to fail (sample one – included here): 800

Revolutions needed for yarn to fail (sample two): 795
Revolutions needed for yarn to fail (sample one – included here): 227

Revolutions needed for yarn to fail (sample two): 220
Comparisons of Cultivated and Wild Silks

**Bombyx Throwsters**

Revolutions needed for yarn to fail (sample one – included here): 850

Revolutions needed for yarn to fail (sample two): 900
Revolution needed for yarn to fail (sample one – included here): 400

Revolution needed for yarn to fail (sample two): 420
Shrinkage Test Results

Each yarn began as a six inch length. After exposure to water measuring 120°F and the return to room temperature, each dry yarn was measured to determine the amount of shrinkage that occurred. According to Hochberg (1980), the average percentage of shrinkage for silk is ten percent. The average shrinkage found in this study was 7.8 percent. Detailed results were recorded in Table 6.
## Table 6. Shrinkage Test Results.

<table>
<thead>
<tr>
<th>Silk Form</th>
<th>Resulting Difference in Length</th>
<th>Percentage of Shrinkage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bombyx Reeled Cocoon</td>
<td>-1/8 inch</td>
<td>2.0%</td>
</tr>
<tr>
<td>Bombyx Sliver</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>Bombyx Homemade Mawata</td>
<td>-3/8 inch</td>
<td>6.2%</td>
</tr>
<tr>
<td>Bombyx Commercial Mawata</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>Muga Sliver</td>
<td>-1/4 inch</td>
<td>4.1%</td>
</tr>
<tr>
<td>Muga Cocoon</td>
<td>-1 inch</td>
<td>16.6%</td>
</tr>
<tr>
<td>Red Eri Sliver</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>Red Eri Cocoon</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>Tasar Sliver</td>
<td>-1/4 inch</td>
<td>4.1%</td>
</tr>
<tr>
<td>Tasar Cocoon</td>
<td>-1 inch</td>
<td>16.6%</td>
</tr>
<tr>
<td>Tussah Sliver</td>
<td>-5/8 inch</td>
<td>10.3%</td>
</tr>
<tr>
<td>Tussah Cocoon</td>
<td>-1 inch</td>
<td>16.6%</td>
</tr>
<tr>
<td>White Eri Sliver</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>White Eri Cocoon</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>Bombyx Carrier Rods</td>
<td>-1/4 inch</td>
<td>4.1%</td>
</tr>
<tr>
<td>Bombyx Castings</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>Bombyx Kibiso</td>
<td>-1/4 inch</td>
<td>4.1%</td>
</tr>
<tr>
<td>Bombyx Noil</td>
<td>-1/2 inch</td>
<td>8.3%</td>
</tr>
<tr>
<td>Bombyx Strippings</td>
<td>-1/4 inch</td>
<td>4.1%</td>
</tr>
<tr>
<td>Bombyx Throwsters</td>
<td>-1/8 inch</td>
<td>2.0%</td>
</tr>
<tr>
<td>Tussah Noil</td>
<td>-3/8 inch</td>
<td>6.2%</td>
</tr>
</tbody>
</table>
**Conclusion**

As previously stated in the Abstract, the main conclusion was that each form and species of silk had its own distinct characteristics. Some may have been similar, but each was different in color, luster, smoothness, hand, durability, shrinkage, and desired finished appearance. The end use determined the choice of silk form and species.

Degumming and processing times varied considerably between the wild silk cocoons. The first degumming attempt used a solution that was too weak to degum the wild cocoons successfully. A strength-of-solution approach proved to be a better choice.

An original assumption that either all yarns created from cocoons or all yarns created from sliver would shrink at the same rate, resulted in an erroneous assumption. There was no correlation between the shrinkage rates of like forms. The same held true for different forms in the same species.

In most cases, the number of revolutions in the abrasion test were similar when testing two swatches of the same yarn. The heavier yarns required more revolutions to cause them to fail than did the finer yarns. This was to be expected as the heavier yarns created thicker woven fabric. The yarns spun from waste silk created thicker yarns due to the added texture in the unspun fibre and the drafting technique used. The
Comparisons of Cultivated and Wild Silks

unusually high number of revolutions needed to cause the short fibres of the Bombyx noil yarn to fail was unexpected.

Spinning, testing, and comparing each silk form and species offered a useful sampling of yarn for the consideration of end use. Each was unique with myriad possibilities. The desired finished appearance and end use determined the choice of silk to be used.

Further study could include testing and comparing the silk fibres taken from the outside and the inside of the cocoons. Comparing the dyeing results of those same yarns could also be considered.
References


Yakovlev, A. (2011, March 31). Retrieved from Wikimedia Commons on May 23, 2016:
https://commons.wikimedia.org/wiki/File:Antheraea_assamensis.JPG
### Appendix A

#### Specimen Key

The following table identifies the silk form specimens found in the attached shadow box.

*Table 7. Silk Form Specimen Key*

<table>
<thead>
<tr>
<th>Bombyx Cocoon</th>
<th>Muga Cocoon</th>
<th>Red Eri Cocoon</th>
<th>Tasar Cocoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tussah Cocoon</td>
<td>White Eri Cocoon</td>
<td>Bombyx Mawata (Homemade)</td>
<td>Bombyx Mawata (Commercial)</td>
</tr>
<tr>
<td>Bombyx Carrier Rod</td>
<td>Bombyx Castings</td>
<td>Bombyx Kibiso</td>
<td>Bombyx Noil</td>
</tr>
<tr>
<td>Tussah Noil</td>
<td>Bombyx Strippings</td>
<td>Bombyx Throwsters</td>
<td>Slivers for Bombyx, Muga, Red Eri, Tasar, Tussah, White Eri</td>
</tr>
</tbody>
</table>
Appendix B

Glossary of Terms

Bave – Two brins surrounded by sericin, extruded by the silk worm
(Cook, 2010)

Brin – One filament in a bave (Cook, 2010)

Carrier Rod – Waste silk that is the result of reeled silk that becomes wrapped around the carrier rod

Castings – Silk waste created during the reeling process

Cocoon – Silk encasement that protects the silk moth during the pupal stage of metamorphosis (Johnson, 1982)

Croissure – Apparatus used to facilitate smooth movement of the filaments, adherence of the fibres to one another, and the removal of excess water during silk reeling

Degum – Removal of sericin from the silk fibre (Cook, 2010)

Filament – Several silk baves that have adhered to one another during the reeling process. Filaments may then be thrown to create a tram

Grope – The use of a brush to catch the ends of the silk fibre on the cocoon when preparing to reel the silk

Hand - How a fabric or yarn feels (Kleeberg, 1975)
**Kibiso** – The first several yards of silk from the outside of the cocoon that has been removed prior to reeling

**Luster** – Reflection of light from the silk yarn or fabric

**Mawata** – Silk square from a partially degummed cocoon (Cook, 2010)

**Noil** – Short fibre waste silk left after combing or carding

**Puni** – Tightly rolled short fibres prepared for spinning

**Pupa** – The third stage of the silk moth’s metamorphosis. The pupa is found in reeled silk cocoons

**Reeling** – Removing silk fibres from wet unopened cocoons by unraveling and winding onto a reel

**Rolag** – Loosely rolled fibres prepared for spinning

**Scroop** – A desirable rustling sound that luxury yarns and fabric make when moved (Kleeberg, 1975)

**Sericin** – The silk gum that holds the silk fibres of the cocoon together (Cook, 2010)

**Sericulture** – Silk farming

**Silk Sliver** – A thin untwisted length of combed silk top

**Strippings** – The first fibres spun from the silk worm

**Throw** – To twist reeled silk filaments into a singles yarn
**Throwsters** – Waste silk from reeled silk that becomes tangled during the throwing process

**Tram** – Singles yarn made from loosely twisted (thrown) reeled silk filaments

**Waste forms** – Silk by-products remaining after reeling, throwing, or combing silk
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