A Reservoir of Colors

Natural Techeiles Dyeing From the Murex Trunculus

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This article serves as a summary of experiments conducted on natural dyeing using the *Murex trunculus*. The goal is to demonstrate that it is possible to obtain a **techeiles** shade through natural dyeing from the *Murex*, rather than to take a stance on the identification of the **Chilazon** or to resolve the various claims raised in the many articles written on this topic.

Abstract

In 1983, Professor Elsner discovered that sunlight affects the hue of the dye extracted from the *Murex trunculus* (referred to in ancient texts as *Purpura*). He found that when a reduced vat of dye is exposed to sunlight, it produces a **techeiles** shade.[1]

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[1] Prof. Elsner (in Sefer HaTecheiles, p. 301)

This discovery enabled the identification of the long-lost **Chilazon Techeiles** with the *Murex trunculus*. According to Jewish tradition, **techeiles** is meant to resemble the color of the **sky**[2] or the **sea**[3]. However, the **natural purple hue** initially obtained from the *Murex trunculus* did not align with this tradition.[4] As a result, Jewish scholars who investigated **Purpura** did not endorse it.

Now, however, it has been demonstrated that the very **Chilazon** known in **Temple times** as the mollusk used to dye **royal garments**[5] can also **easily produce a techeiles shade**. Thus, the **Chilazon Techeiles** has been found.

However, Professor Elsner's method relied on **reduction dyeing**, which involves breaking down the dye using a reducing agent. The process employed modern chemicals such as sodium dithionite—substances that were not available during the Temple era. Without identifying natural alternatives that could function as reducing agents, his findings could not be definitively established as a viable **techeiles** dyeing method in antiquity.

Two ancient descriptions of dyeing with a marine mollusk exist today, but neither provides a complete picture.

1. A **partial description** appears in the **Talmud Bavli**,[6] which mentions the addition of certain ingredients to the dye vat and boiling, but does not specify which substances were used or the duration of the process.
2. Another **account** is found in the writings of **Pliny the Elder**, who lived during the Second Temple period.[7] His description only mentions the addition of salt and a dyeing process lasting approximately ten days.

Professor Zvi Koren,[8] an expert in ancient dyes and **historical techeiles dyeing**, modified Pliny's recipe by introducing an alkaline substance that acted as a reducing agent. According to Koren, Pliny's mention of "salt" likely referred to an alkaline salt. However, Koren concluded that the ancient dyeing method, as described in Pliny's writings and as replicated in his own experiments, **could not produce a sky-blue shade** from the *Murex* using natural materials alone.

This conclusion was based on several factors:

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[2] Rambam, Hilchos Tzitzis 2:1; Ramban, Bamidbar 4:6
[3] Rashi, Maseches Sotah 17a (s.v. *Shehatcheiles Domeh Layam*)
[4] Tiferes Yisrael, *Kofas HaRochlim*; R. Yitzchak Herzog (in *Sefer HaTecheiles*, pp. 421-423)
[5] Rashi, Maseches Shabbos 26a (s.v. *Veliogvin*);
Aruch, entry *Chilazon*;
Ramban, Shemos 28:2;
Radbaz, Shu"t, siman 1825.
[6] Maseches Menachos 42b
[7] Pliny the Elder, *Natural History*, Book IX, §§ 60-65, 124-140.
[8] See, for example, from the Koren selection – *New Chemical Insights into the Ancient Molluskan Purple Dyeing Process* (2013).

- The ancient dyeing process was carried out in opaque ceramic vessels, preventing sunlight from affecting the dye.
- A gentle **reduction process**, necessary for achieving a blue shade, requires a completely sealed vat to block oxygen. This setup also prevents sunlight from penetrating the dye vat, ultimately resulting in **a purple or bluish-purple dye** rather than a sky-blue shade.

A 2011 experiment conducted by **Roy Hoffman** following Koren's method produced similar results. Hoffman concluded that obtaining a sky-blue dye from *Murex trunculus* **through simple dyeing alone was not possible**. A **secondary process**—steaming the purple-dyed wool—was required to shift the color toward blue.[9]

However, Koren's research was based on an adaptation of **Pliny's incomplete description**. The original text itself does not actually provide a workable dyeing method, as it lacks the necessary ingredients to achieve any dyeing at all.[10] Therefore, Koren's results do not definitively prove whether *Murex trunculus* could or could not have been used to produce **techeiles** in antiquity.

On the other hand, the **Talmud Bavli** explicitly mentions the addition of ingredients to the dye vat. Since it does not specify which substances were used, any **naturally available ingredient** that an ancient dyer might have reasonably used remains a possibility. This appears to be the approach taken by **many early Torah scholars**.[11]

During my research on **techeiles**, I discovered that **Rabbi Shlomo Teitelbaum** had identified a **natural recipe** using **lime and fruit sugar**, which enables dyeing *Murex trunculus* to a **techeiles** shade **through an entirely natural process**.

I reached out to my colleagues at **Ptil Tekhelet**, Mr. Yoel Guberman and Baruch Sterman, requesting permission to research the *techeiles* dye derived from the *Murex trunculus*. At the same time, I also asked **R' Yechezkel Toporovitz** to provide me with an extract from the *Murex* glands in his possession.

The research findings, as detailed below, **clearly demonstrate** that it is possible to obtain a **techeiles** shade from *Murex trunculus* **through a fully natural process**—even **in a light-sealed vessel** and even when dyeing **at night**, without requiring additional steaming or other post-processing methods.

I would like to express my gratitude to:

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[9] Roy Hoffman, *Zehus HaTecheiles – Mimtza'im Chadashim* (2012), pp. 12 and 15.
[10] Koren, *ibid.*;
Nira Carmon, *Ta'asiyat Ha'Argaman B'Atikah*, p. 88;
Zohar Amar and David Iluz, *Tzvi'as Techeiles Al Pi HaRambam U'Shimush B'Samemanei Tzvi'ah Tiv'iyim* (in *HaMa'ayan*, vol. 206, p. 47).
[11] Rashi, Maseches Menachos 42b (s.v. *u'Samemanim*);
Rambam, Hilchos Tzitzis 2:2.

- **R' Shlomo Teitelbaum**, for his support and detailed guidance regarding the recipe.
- **Yoel Guberman and Baruch Sterman** of **Ptil Tekhelet**, for generously providing the *Murex* glands and wool, and for their extensive explanations on modern dyeing methods.
- **R' Yechezkel Toporovitz**, for supplying the gland extract and for his insights into contemporary dyeing techniques.

And above all, to the **Creator of the World**, for the **Siyata Dishmaya** that guided every stage of this dyeing process.

Dyes and Dyeing

Since this article focuses on the various processes involved in dyeing, it is appropriate to first explain, in simple terms, the nature of dyes and the dyeing process.

The **substance used for dyeing** is called a **dye**, which is a **chemical compound found in many natural materials**. In addition to its **pigment**, which provides the color, a dye also contains a **natural mordant** that enables it to bind to wool fibers.

However, **not everything colorful in nature is a dye**. Sometimes, a substance contains only pigment but lacks a mordant, making it unsuitable for dyeing. In other cases, the color comes from a **protein-based or organic material** that has **no dyeing properties whatsoever**—examples include the ink of the **cuttlefish**, the secretion of the **Janthina snail**, or the **Sea Hare**.[12]

Three Methods of Dyeing in Antiquity

In ancient times, textiles were dyed using **three different techniques**, depending on the **type of dye** and the **fabric**:[13]

1. **Direct Dyeing** – This method involves **soaking** natural dyes, such as walnut husks or pomegranate peels, in water and **immersing wool for several days** until it absorbs the color. However, this dyeing process has a **major drawback**: the color fades over time, especially when exposed to **washing** or **strong sunlight**, which **dissolves and breaks down the dye molecules**.

2. **Dyeing with Mordants** – This method is used for pigments **that lack a natural mordant**. To **fix** the dye onto the wool, a **mordant—**such as **alum** or **fermented urine—**is added to the wool or the dye bath. The mordant **binds the pigment to the fibers**, making the color more permanent. However, **even this method is not completely stable**, as the dye **fades over time** when the mordant deteriorates.

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[12] Shlomo Krodu, *Pigment Mah Hu*;
Rabbi Tavger, *Be'al Peh*, and in the article *HaTecheiles*, p. 322.
[13] Zohar Amar, pp. 40-41;
Roy Hoffman, p. 10.

3. **Vat Dyeing (Reduction and Oxidation)** – This technique is used for **insoluble dyes**, such as **indigo**, which **do not dissolve in water**.[14] Since these dyes **cannot be applied directly**, they must first be **chemically reduced** to a **soluble form** before being applied to the wool. Once the wool is removed from the vat, exposure to **oxygen** in the air **re-oxidizes and fixes the dye**, ensuring a **long-lasting bond**.[15]

    - **In ancient times**, natural **indigo dye** was reduced by **fermenting it in a heated vat with stale urine**, allowing bacteria to break down the dye into a **soluble**, colorless liquid.
    - **In modern times**, industrial dyeing uses **sodium hydroxide** to create a basic environment and **sodium dithionite** as a **strong reducing agent**, which works within minutes.[16]

The *Murex Trunculus*

When researchers analyzed the chemical composition of the dye obtained from the *Murex trunculus*, they discovered that it **consists of several different pigments**:

- **Indigo (IND)** – a **blue dye**
- **Monobromoindigo (MBI)** – a **purple dye**
- **Dibromoindigo (DBI)** – a **reddish dye**[17]

Since **none of these pigments are water-soluble**, the correct method for dyeing with *Murex trunculus* is through **reduction and oxidation**.

In 1983, **Professor Elsner** successfully **reduced *Murex trunculus* dye** using a **modern chemical reducing agent—sodium dithionite**. Later, he discovered that **exposing the reduced dye vat to sunlight** could produce a **techeiles** hue.

However, since **Professor Elsner's method relied on modern chemical processes**, his discovery **could not serve as definitive proof** that this was the ancient method used for producing **techeiles**.

Natural Dyeing by Koren and Edmonds

[14] According to Koren (*oral communication*), garments dyed with indigo using the earliest methods (as was done in Egypt according to the description in the Stockholm Papyrus) were exclusively for burial shrouds and similar uses, as they were not intended to be washed with water.
[15] In the reduction process, dye molecules receive hydrogen atoms from the reducing agent, breaking the chemical bond of the dye. This allows the color to dissolve in water and penetrate the wool fibers. Conversely, in the oxidation process, which occurs after the wool is exposed to air, the molecules absorb oxygen atoms from the air, reconnecting and binding back onto the wool proteins.
[16] Roy Hoffman, p. 9.
[17] Zohar Amar, pp. 43-44.

When researchers initially attempted to reduce the dye according to Pliny's description[18] of the dyeing process, the dye did not undergo reduction, as the necessary substances for reduction were missing.
Since Pliny's dyeing description was incomplete, researchers attempted to modify the recipe by adding wood ash, lime, fermented urine, and similar substances.

Koren[19] and Edmonds[20] were the first to publish a successful natural reduction of the dye vat by adding wood ash as an alkaline agent, along with mollusk flesh, which, combined with moderate heat, led to the growth of bacteria that reduced the vat.

However, while Edmonds published that he succeeded in dyeing a blue shade even without covering the vat from sunlight, Koren published that the result was always a purple shade.

Later, Roy Hoffman conducted a natural dyeing experiment based on Koren's formula, and he only obtained a purple shade, even when exposing the vat to sunlight.

Jewish Dyeing with the *Chilazon Techeiles*

In the **Talmud Bavli**, there is a description of the dyeing process of **Jewish techeiles**, where it states that ingredients were added to the dye vat along with the blood of the *Chilazon*, and that the vat was boiled.[21] After cooking, they checked whether the dye was ready for dyeing.

[18] Pliny described the dyeing process from mollusks using various stages of boiling and heating:

The dye-bearing veins are soaked in salt for up to three days, with fresher material producing a stronger color. Then, they are boiled with water in lead vessels at a low temperature, heated indirectly through a pipe extending from a distant furnace, until the flesh detaches from the vein. On the tenth day, a piece of clean wool is dipped into the vat as a test. The dye is then filtered, and if further boiling is needed, the process continues. Finally, wool is immersed for five hours and then dipped again until it fully absorbs the dye.

Further in his account, Pliny noted that in the dyeing process using *Murex brandaris* alone, to achieve the *Conchyliated* hue (which research identifies as *techeiles*), urine was added in equal proportion to the water.

[19] Koren 2005 'The first optimal all-Murex all-natural purple dyeing in the eastern Mediterranean in a millennium and a half'
[20] J. Edmonds, 'Tyrian or imperial purple dye', Hist. Dyes Ser., 7 (2002)
[21] It should be noted that in the Talmudic manuscripts, there is no mention of *boiling* (*hartaḥa*); this term was introduced into the text according to the tradition of the Geonim. It is difficult to determine the exact meaning of *hartaḥa* in this context, as the term appears in the Talmud and Rishonim with various meanings:

- As literal boiling (Rashi, Bava Kama 4b).
- As fermentation (Rashi, Taanis 30a; Bava Metzia 92b).
- As extensive cooking (Ran, Nedarim 51a).
- As melting or dissolving (Rashi, Shabbos 74b).

Since the **specific ingredients** were **not detailed**, the great early scholars, **Rashi and Rambam**, explained that this referred to **the general method of dyers**, not necessarily specific ingredients, and they described various substances that were likely used by dyers of their time.

From this, even though the **exact process used by Jews to dye techeiles** is **not known**, if **natural dyeing agents** are found that allow for **techeiles dyeing from the Chilazon**, then the dye would be **valid**.

Indigo 1+2+3

In France, an **expert in ancient dyeing**, **Michel Garcia**, studied many **ancient indigo dyeing recipes**, and ultimately found a **simple reduction formula** based entirely on **natural substances**, such as **lime and fruit sugar**.

This formula is based on a **1+2+3 method**, meaning:

- **1 part** indigo
- **2 parts lime (builders' lime)**
- **3 parts fruit sugar** (naturally found in **honey, dates,** etc.)

Although this recipe was primarily developed for **plant-based indigo**, **R' Shlomo Teitelbaum** successfully used it to **dye *Murex trunculus* with a techeiles shade**.

Techeiles Dyeing with Honey and Lime[22]

Since **Koren and Edmonds disagreed** about the possibility of obtaining a **techeiles shade** from *Murex trunculus* through natural dyeing, I sought to investigate the matter as much as possible.

I requested **Murex dye** from **Yoel Guberman and Baruch Sterman** of **Ptil Tekhelet**, and at the same time, I requested a **Murex gland extract** from **R' Yechezkel Toporovitz**.

After receiving the materials, I conducted **many experiments**, testing:

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[22] The use of honey in *Argaman* dyeing is mentioned in Plutarch's account of Alexander the Great's conquest of Persia from Darius. He describes treasures found in the palace of Susa, including fabrics around 200 years old, dyed in *Argaman*, still gleaming as if freshly dyed. He attributes this preservation to the use of honey in the dyeing process (*Plutarch, The Life of Alexander*, Paragraph 36).

Additionally, purple-stained lime was discovered as evidence of *Argaman* dyeing in excavation dye pits at Tel Dor (*Leonard Lanigan, Evidence of Dyemaking at Tel Dor, Israel*, Annual Meeting of the American School of Oriental Research, November 1990).

- **Different temperatures**
- **Different vessels**
- **Different concentrations**
- **Dyeing during the day and at night**

Experimentation and Findings

Initially, I attempted **boiling the dye vat**, following the wording in the Talmud: **"Umartechinan" (we boil it).** However, I discovered that boiling for **more than a few seconds** typically **destroys the pigment**.

Ultimately, I settled on **two primary heating methods**:

1. **Fast heating method**
    - Boiled the vat at **70-80°C** for **15 minutes**.
    - Transferred the vat to **low heat** (**40-50°C**) for an **additional hour** using a candle warmer.
2. **Slow heating method**
    - Maintained the vat at **40-50°C** for **several hours or days** using a **candle warmer**.

When the vat was ready, I:

- **Soaked wool for one hour** for a **lighter shade**.
- **Soaked it for several hours or a full day** for a **darker shade**.

Conclusion

I found that this **recipe worked well**, producing a **techeiles shade from *Murex trunculus***

- **Without laboratory equipment**
- **Without additional post-dyeing treatments** (such as steaming)

Thus, I concluded that **techeiles could be dyed naturally**, without requiring modern chemical processes.

Dried vs. Fresh Glands

During the dyeing process, I observed a difference between the **Ptil Tekhelet** dye and the **Murex gland extract** provided by **Toporovitz**.

- The **Ptil Tekhelet** dye **always produced a blue or bluish-gray hue**.

- The **Toporovitz gland extract** mostly resulted in **purple or pink shades**, and only after **a prolonged boiling process in a glass vessel under sunlight** did it yield a **blue shade**.[23]

After inquiring with both **Ptil Tekhelet** and **Toporovitz**, I discovered that the **difference in dye properties** was due to **different processing methods—**and possibly also the **natural habitat of the mollusks**.

Since the **Murex trunculus** is a **protected species** in Israel, techeiles organizations must **import it from abroad**. To reduce import costs, they bring **only the dye chunks**, rather than the entire mollusk.

There is a fundamental difference in **processing methods** between **Ptil Tekhelet** and **Toporovitz**, as follows:

- **Ptil Tekhelet's Method**:

    1. After **cracking the shell**, they **separate the dye gland** from the mollusk's flesh.
    2. The liquid extract is **exposed to oxygen**, where it reacts with enzymes from the mollusk's flesh.
    3. The glands are then **boiled briefly** to obtain concentrated dye without flesh.
    4. Finally, the dye is **dried under sunlight for several days**, forming solid chunks.
- **Toporovitz's Method**:

    1. The glands are **frozen immediately** after being cut from the mollusks.
    2. The frozen glands are shipped and **kept in frozen storage**.
    3. Before dyeing, the glands are **soaked in water** to allow the dye to develop naturally.

Conclusions

1. It is possible to dye **from *Murex trunculus*** using **natural reduction**, with **materials available in ancient times**, such as **lime and fruit sugar**, without requiring laboratory equipment.

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[23] I once left the extraction from Toporovitch to dry in the sun for about three days. Then, I placed it on low heat with lime for four days, followed by adding sugar and continuing to cook for another two days. After that, I carried out the dyeing process for several hours—all of this in a glass vessel exposed to the sun. The resulting dyed fabric had a turquoise blue hue.

[Further testing is needed to determine what caused the color to appear—whether it was the prolonged sun exposure before dyeing, the low-heat cooking over several days, or the sun exposure during the dyeing process in a glass vessel.]

The **reduction process using lime and fruit sugar is stable**, allowing for dyeing in an **open vat**, where **oxygen can enter freely** from the vat's opening without affecting the process.

The **reduction is so stable** that **a second batch of wool can be dyed in the same vat** (**"second dye"**) even **several days later**, without adding any new ingredients—simply by reheating the vat.

2. **Dyeing with glands**

   Dyeing with dried glands (Ptil Tekhelet's method):

   - Produces a **blue-techeiles hue naturally**, **without requiring post-dyeing steaming**.
   - The dye shade **remains stable**, whether dyed at **high or low heat, during the day or at night**.

   Dyeing with fresh (non-dried) glands (Toporovitz's method):

   - Initially **produces purple or pink shades**.
   - Achieving a **techeiles hue** requires **prolonged boiling** and **extended exposure to sunlight**.
3. It is difficult to determine **what exactly causes the color shift from purple to blue** when using **dried glands (Ptil Tekhelet's method)**.

   - The **initial boiling process**, which removes flesh and concentrates the dye, **may** play a role in altering the final hue.[24]
   - However, since **boiling is brief** and the **dye quantity is large**,[25] it seems more likely that the **sun-drying stage** is the key factor.
   - It is possible that **sunlight affects the dye more significantly than previously known**, and that **even solid dye chunks undergo a color transformation from purple to blue when exposed to the sun—**not just when the dye is in its reduced state.

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[24] According to Dr. Ziderman, heating *Argaman* dye (in its solid state) before the dyeing process already causes a shift in hue from purple to blue (*"Bathochromic Effect of Heat on 6-Bromoindigo"*, 2003).

This claim requires thorough testing—specifically regarding the duration of heating needed to induce the color change and how it relates to the quantity of dye being heated together.

[25] In the *Ptil Tekhelet* production process, the glands extracted from 50 kg of mollusks are boiled in a 30-liter pot, with heating stopping just before reaching a full boil.

In contrast, in Ziderman's research, only one gram of dye was heated.

Another possible factor is **the natural habitat of the *Murex trunculus***. The **geographical origin of the mollusk**[26] may influence the dye's composition, as described by **Vitruvius**, who noted that **purple dye shades varied in different regions**.[27]

4. There is **no clear tradition** regarding how Jews historically extracted **techeiles** from the *Chilazon*.

    - It is likely that their methods for **extracting the dye, preparing it, and dyeing wool** differed from **modern industrial processes** used today with *Murex trunculus*.

    However, **according to the rulings of the great Rishonim**, the **ingredients used in dyeing follow the general practice of dyers**. Since it has now been **proven that *Murex trunculus* can produce a techeiles shade through a natural reduction process** using **materials available in ancient times**, it appears that even **modern dyeing methods are valid**—and there is **no requirement to dye specifically using historical or fully natural techniques**.

Detailed Recipe

Dye Preparation

Ingredients:

- For every **1-5 grams** of dye, add:
    - **10 grams of lime** (calcium hydroxide)
    - **15 grams of fruit sugar**[28]

Fast Dyeing Method:

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[26] The dye used by *Ptil Tekhelet* comes from mollusks imported from Croatia, whereas Toporovitch sources his from Greece. According to Yoel Guberman of *Ptil Tekhelet*, the Greek mollusks contain a higher concentration of bromo in their pigment composition, which likely makes the purple hue more dominant.

Recently, I heard from Toporovitch that in Tunisia, the *Argaman* mollusk naturally produces a blue hue. This phenomenon is currently under investigation.

[27] *De Architectura* 7.13

[28] After confirming that dyeing with honey is possible, I used concentrated fruit sugar (available in health stores) in most of my dyeing experiments, as it is easier to handle.

1. Place the **Murex dye and sugar** into a **1-liter metal container**.
2. Add **300 mL of warm water (40-60°C)** and stir for **30 seconds**.
3. Add the **lime** and carefully stir for another **30 seconds**, ensuring no air enters.
4. Heat the mixture for **15 minutes** over **medium heat (70-80°C)**.
5. Carefully add **another 300 mL of lukewarm water**, stir gently, and transfer the container to a **candle warmer (50°C)** for **an additional hour**.

Slow Dyeing Method:

1. Place the **Murex dye and sugar** into a **1-liter metal container**.
2. Add **500 mL of warm water (40°C)** and stir for **30 seconds**.
3. Add the **lime** and carefully stir for **30 seconds**, avoiding air exposure.
4. Place the container on a **candle warmer (50°C)** and let it cook for **5 hours to a week**.

Dyeing Process

1. Ensure the vat temperature is **40-60°C**.
2. Insert **well-squeezed wet wool** into the vat:
   - **For a lighter shade:** Soak for **one hour**.[29]
   - **For a darker shade:** Soak for **several hours**.
3. Occasionally stir the wool gently.
4. After removing the wool, **rinse thoroughly under running water** to **oxidize the dye** and remove any excess materials.[30]

Images of Various Dyeing Results

Dyeing with Dried Glands (Ptil Tekhelet Method)

1. **At night, in darkness**, boiled for a few minutes at **medium heat (80°C)**, then **one hour at 50°C → Blue shade with purple undertones** (Image #1).
2. **During the day, rapid boil for 1 second (100°C), then high heat (90°C) for an hour → Blue shade** (Image #2).

[29] If after an hour the dye produces a light hue, the wool can be dipped again for another hour to achieve a stronger color. There does not seem to be a concern of *tzava sheini* (second-stage dyeing) as mentioned in *Menachos* 42b, since *tzava sheini* applies to new wool dyed in a vat that has already been used to dye other wool, as explained by Rashi (s.v. *u'mishum shenitnuh*). Here, however, the same wool is being re-immersed to absorb more dye, which aligns with the explanations of Rashi and the Rashba (ibid.), ensuring that the primary hue of the *chilazon* remains in the wool.

[30] Rabbi Teitelbaum immerses the dyed wool in vinegar to help the color set onto the wool.

3. **During the day, low heat (60°C) for one hour in sunlight → Blue shade** (Images #3-4).

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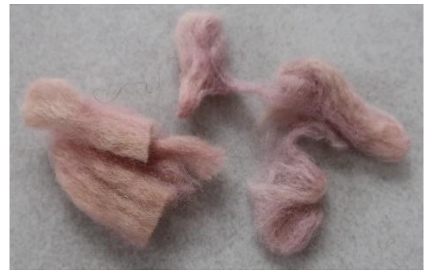
 תמונה מס' 2	 תמונה מס1
תמונה מס' 4 	 תמונה מס' 3

Boiling for several minutes at full boil destroys the dye.

Dyeing with Fresh (Non-Dried) Glands (Toporovitz Method)

5. **Full boil for 2 seconds (100°C), then high heat for an hour → Pink shade** (Image #5).
6. **Low heat (45-50°C) for an hour in sunlight → Pink shade** (Image #5).
7. **Low heat for a full day in sunlight (40°C) → Royal purple shade** (Image #6).
8. **Second wool dyeing in the same vat after one day → Light purple shade** (Image #7).
9. **Glass container in sunlight, with lime at low heat (40°C) for 4 days, then sugar added and boiled for another 2 days → Turquoise blue shade** (Image #8).
10. **Boiling for 30 minutes at full boil destroys the dye**.

 Picture # 6	 Picture # 5
 Picture # 8	 Picture # 7