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# Original article

# Effects of Temperature on the Color of Human Liver and Stomach in Silicone Plastination

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**Abstract**

***Background:*** Plastination is an innovative preservation technique that maintains the structural, visual, and textural integrity of biological specimens. This method is widely used in medical education and research to create durable and lifelike anatomical models. ***Objectives:*** This study aimed to assess and compare the color changes in human livers and stomachs plastinated under room temperature and cold temperature conditions, and to evaluate how temperature variations influence the final quality of plastinated specimens. ***Methodology:*** An observational study was conducted in the plastination laboratory of the Department of Anatomy, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, between September 2023 and August 2024. A total of twelve (12) human livers and twelve (12) human stomachs, obtained from embalmed cadavers, were included. The specimens were divided equally into two groups: a 'cold temperature group' and a 'room temperature group.' Six livers and six stomachs were allocated to each group. A standardized color chart was used to systematically observe and record color changes at different stages of the plastination process: fixation, dehydration, and forced impregnation. ***Results:*** At the fixation stage, livers displayed various shades of chocolate brown, and gallbladders appeared greenish, while stomachs exhibited deep brown coloration. Following dehydration, both the liver and stomach tissues became notably paler. After forced impregnation, a significant darkening of color was observed in all specimens. Over time, color continued to deepen, with specimens in the cold temperature group demonstrating more vibrant and stable coloration compared to the room temperature group. ***Conclusion:*** Temperature plays a crucial role in determining the final appearance of plastinated specimens. Cold temperature plastination preserved a richer and more consistent color, suggesting it may be more suitable for creating high-quality anatomical teaching models. Future research may explore further optimization of temperature settings for different tissue types.

***Keywords:*** Plastination, Biological Specimen Preservation, Cold Temperature, Room Temperature, Human Liver, Human Stomach, Anatomy Education, Color Stability, Tissue Preservation, Forced Impregnation.

## Introduction:

Anatomy forms the foundation of medical education by providing essential knowledge about the human body's structure and function.[1] Despite its importance, mastering anatomy poses significant challenges due to the subject's complexity.[2] Traditional teaching methods, including whiteboards, charts, and diagrams, often fail to capture the depth and spatial relationships necessary for comprehensive



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understanding.[3] Well-preserved anatomical specimens remain crucial for effective hands-on learning.[4] Historically, formalin-fixed human cadavers have been considered the gold standard in anatomy education.[5] However, formalin preservation exposes students and educators to hazardous formaldehyde, leading to allergic reactions, respiratory problems, and long-term health risks.[6] Additionally, formalin-treated specimens gradually lose their elasticity, natural color, and structural clarity, limiting their educational value. To overcome these limitations, Dr. Gunther von Hagens introduced plastination in 1977 at Heidelberg University, Germany. Plastination involves replacing water and fats in tissues with curable polymers, such as silicone, producing dry, odorless, durable, and non-toxic specimens that maintain their life-like appearance.[7] These specimens resist microbial growth, retain natural coloration, and can be handled safely without protective equipment, offering a superior alternative to synthetic models.[8] In Bangladesh, where average temperatures range from 24°C to 32°C, specimen preservation faces additional challenges. High ambient temperatures accelerate tissue decomposition and complicate the plastination process. Although cold-temperature plastination typically yields better-quality specimens, it requires significant energy and financial investment, making it less practical for resource-limited settings.[9] Developing an effective room-temperature plastination technique could provide a cost-effective and sustainable solution.[10]Given the rapid expansion of medical colleges in Bangladesh and the limited availability of cadavers, durable plastinated specimens could help meet the growing demand for quality teaching materials.[10] Recognizing this need, Bangladesh's first plastination laboratory was established in 2012 at the Department of Anatomy, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka. Building on previous work, the present study aims to compare the effects of room-temperature and cold-temperature plastination on human liver and stomach specimens. The key objectives are to observe color changes, maintain anatomical morphology, preserve structural integrity, and optimize the plastination process for widespread adoption. Through this research, we hope to develop practical, cost-effective methods to enhance anatomy education across Bangladeshi medical institutions.

**Materials and methods**

This observational study was conducted at the Department of Anatomy, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from September 2023 to August 2024. Twelve human organs (six liver and six stomachs) from donated cadavers were divided into two groups: cold temperature and room temperature.

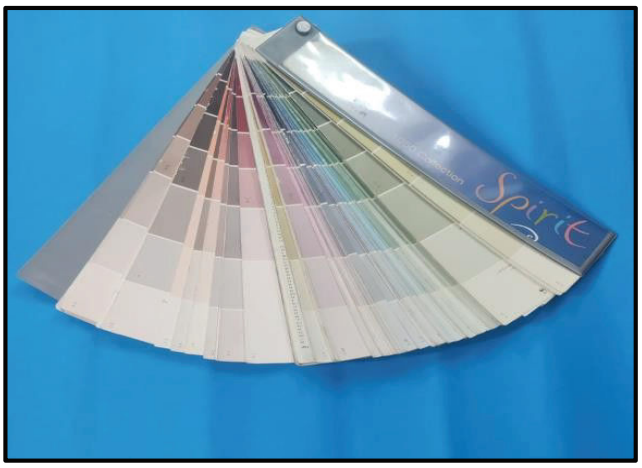


Figure 1 : The color chart used for determining color changes (Elite Paint & Chemical Industries Ltd., 1050 collection of spirit color chart).

The color changes of the liver (anterior surface and gallbladder fossa) and stomach (external surface and mucosal folds) were observed at each stage of plastination under both temperature conditions. Color was assessed visually and qualitatively by comparing with the authorized color chart (Elite Paint & Chemical Industries Ltd., 1050 collection of spirit color chart).The most closely matching color from the chart was recorded in daylight for each region. Color changes were measured and categorized by frequency for both temperature groups.

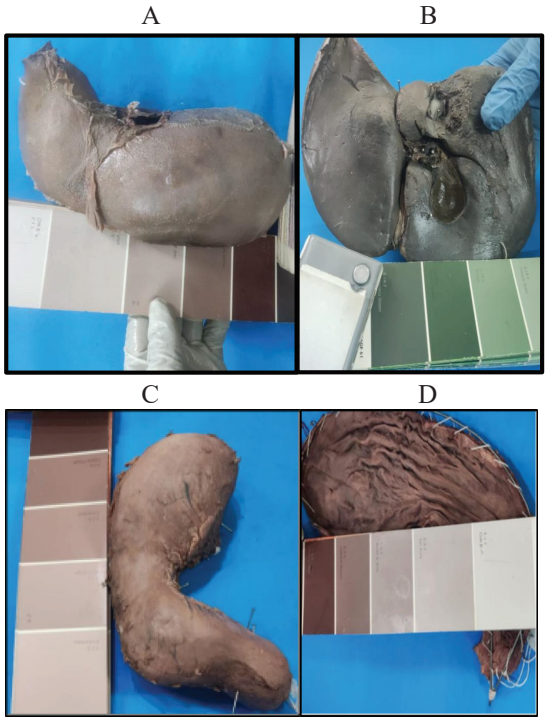


Figure 2 : Procedure for observing color changes. A) Comparison of the color of the anterior surface of the human liver with those of the color chart. B) Comparison of

the color of the fossa for the gallbladder with those of the color chart. C) Comparison of the color of the external surface of the human stomach with those of the color chart. D) Comparison of the color of the cut surface (mucosal fold) of the human stomach with those of the color chart.

For the liver, the anterior surface and gallbladder fossa were compared to the chart in daylight (Figure A and B). For the stomach, color was observed on the external surface and the mucosal fold of the cut surface (Figure C and D), and the most closely matching color was recorded.
The specific color changes observed were categorized by frequency for both temperature groups

### Ethical approval :

The study was approved by the Institutional Review Board (IRB) of Bangabandhu Sheikh Mujib Medical University *(No. BSMMU/2023/14377, Date: 26 –11 –23).*

### Result:

The changes in color were assessed by matching the specimens with a color chart. The percentage frequencies of various colors were calculated for each plastination stage across the two temperature groups.

### Observations of Color Changes

### Human Liver:

At the fixative stage, the liver displayed different shades of chocolate brown, with the fossa for the gallbladder appearing greenish. After dehydration, the liver color became slightly paler. Subsequently, it gradually darkened through the stages of forced impregnation and gas-curing.

### Human Stomach:

Initially, the stomach showed different shades of deep brown. This brownish tone was broadly maintained throughout plastination. After dehydration, the color lightened to a pale brownish tone and gradually darkened again during forced impregnation and gas-curing.

### Color Changes in the Room Temperature and Cold Temperature Groups:

### After Fixation:

- **Liver:**
  - Two colors were found in both the room temperature and cold temperature groups.
  - No colors were common between the two groups.
  - The largest differences in frequencies were:
    - *Room Temperature Group:* 0% for "Burke & Wills" and 66.67% for "Vienna Coffee."
    - *Cold Temperature Group:* 66.67% for "Burke & Wills" and 0% for "Vienna Coffee."
    - Similarly, 0% vs. 33.33% differences were found for "Taupe Tone" and "Drizzle."

- **Stomach:**
  - Two colors were found in each group, with "Jaffa Orange" common to both.
  - Largest frequency differences were 40% (Cognac Cream, room temp) and 40% (Flicker, cold temp).(See Figure 3 for percentage distributions).

    (See Figure 3 for percentage distributions.)

Table 1: "Distribution of Color Group Preferences Across Organs and Temperature Conditions"

| Organ | Group | Burke & Wills | Vienna Coffee | Taupe Tone | Drizzle | Jaffa Orange |
|---|---|---|---|---|---|---|
| Liver | Room temperature | 0% | 66.67% | 0% | 33.33% | |
| | Cold temperature | 66.67% | 0% | 33.33% | 0% | |
| Stomach | Room temperature | | | | | 100% |
| | Cold temperature | | | | | 100% |

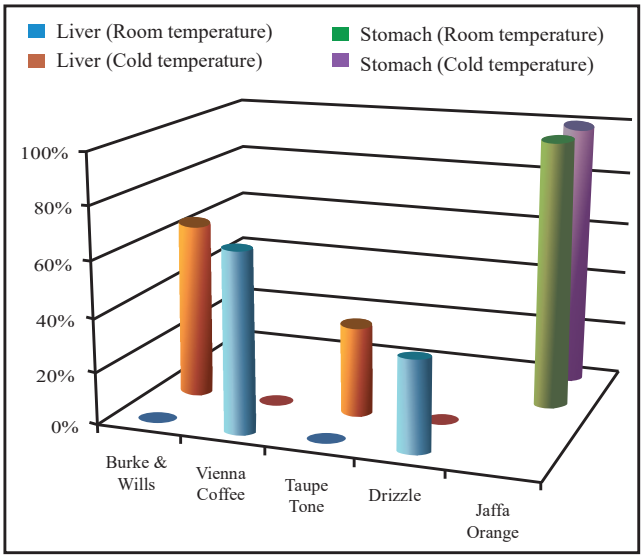


Figure 3: After-Fixation Color Distribution Percentages in Human Liver and Stomach under Room and Cold Temperature Conditions"

### After Dehydration:

- **Liver:**
  - Two colors in each group; no common colors.
  - Largest frequency differences:
    - *Room Temperature Group:* 0% (Cinnabark) and 66.67% (Castlemaine).
    - *Cold Temperature Group:* 66.67% (Cinnabark) and 0% (Castlemaine).
    - Also, 0% vs. 33.33% for "Blush Beige" and "Green Thumb."

- **Stomach:**
  - Two colors in each group; "Fire Princess" was common.
  - Largest frequency differences:
    - 50% (Early Pink, room temp) and 50% (Fresh Biscuit, cold temp).

    (See Figure 4 for percentage distributions.)

**Table for Dehydration Stage:**

Table 2 : "After Fixation Percentage Frequencies of Different Colors of the Organs of the 'Room Temperature Group' and the 'Cold Temperature Group': (A) for Human Liver; (B) for Human Stomach

| Organ | Group | Cinnabark | Castlemaine | Blush Beige | Green Thumb | Fire Princess | Early Pink | Fresh Biscuit |
|---|---|---|---|---|---|---|---|---|
| Liver | Room temperature | 0% | 66.67% | 0% | 33.33% | | | |
| | Cold temperature | 66.67% | 0% | 33.33% | 0% | | | |
| Stomach | Room temperature | | | | | 50% | 50% | 50% |
| | Cold temperature | | | | | | 0% | |

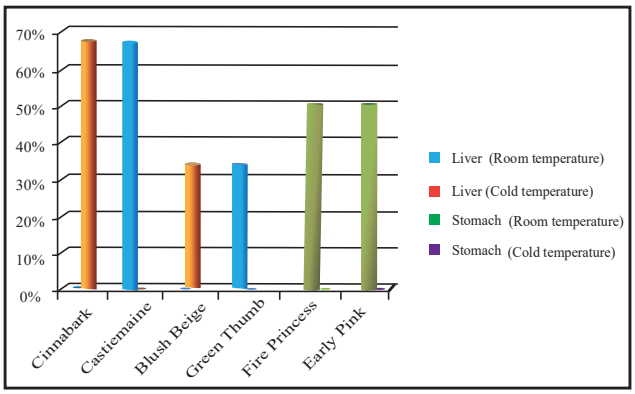


Figure 4 : After Dehydration — Percentage Frequencies of Different Colors of the Organs in the 'Room Temperature Group' and the 'Cold Temperature Group': Human Liver; Human Stomach.

**After Forced Impregnation:**

- **Liver:**
  - One color in the room temperature group; two in the cold temperature group.
  - No colors were common.
  - Largest differences:
    - 100% (Galleon, room temp) and 0% (cold temp).
    - Also, 0% vs. 33.33% for "Diva Rose" and 0% vs. 66.67% for "Cinna Swirl."
- **Stomach:**
  - Two colors in the room temperature group; one in the cold temperature group.
  - "Burnt Almond" was common to both.
  - Largest differences:
    - 40% (Burnt Almond, room temp) and 100% (Burnt Almond, cold temp).
    - 60% (Teddy Bear, room temp) and 0% (cold temp).
- (See Figure 5 for percentage distributions.)

Table 3 : After Dehydration: Percentage Distribution of Color Changes in Human Liver and Stomach under Room Temperature and Cold Temperature Conditions."

| Organ | Group | Galleon | Diva Rose | Cinna Swirl | Burnt Almond | Teddy Bear |
|---|---|---|---|---|---|---|
| Liver | Room temperature | 100% | 0% | 0% | | |
| | Cold temperature | 0% | 33.33% | 66.67% | | |
| Stomach | Room temperature | | | | 40% | 60% |
| | Cold temperature | | | | 100% | 0% |

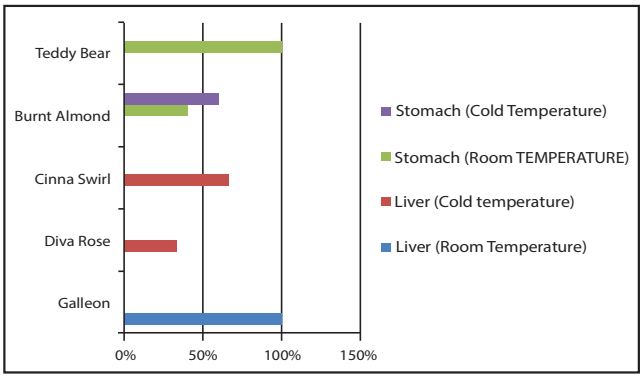


Figure 5 : "After Forced Impregnation — Percentage Frequencies of Different Colors of the Organs in the 'Room Temperature Group' and the 'Cold Temperature Group': Human Liver & Human Stomach.

**After Gas-Curing:**

- **Liver:**
  - One color in the room temperature group; two in the cold temperature group.
  - No colors were common.
  - Largest differences:
    - 100% (Sanctuary, room temp) and 0% (cold temp).
    - 0% vs. 33.33% for "Early Pink" and 0% vs. 66.67% for "Oakleaf Brown."
- **Stomach:**
  - Two colors in the room temperature group; one in the cold temperature group.
  - "Burnt Almond" remained common to both.
  - Largest differences:
    - 40% (Burnt Almond, room temp) and 100% (Burnt Almond, cold temp).
    - 60% (Honey Pot, room temp) and 0% (cold temp).
- (See Figure 6 for percentage distributions.)

Table 4 : "After Forced Impregnation: Percentage Distribution of Color Changes in Human Liver and Stomach Under Room Temperature and Cold Temperature Conditions."

| Organ | Group | Sanctuary | Early Pink | Oakleaf | Brown | Burnt Almond | Honey Pot |
|---|---|---|---|---|---|---|---|
| Liver | Room temperature | 100% | 0% | 0% | | | |
| | Cold temperature | 0% | 33.33% | 66.67% | | | |
| Stomach | Room temperature | | | | | 40% | 60% |
| | Cold temperature | | | | | 100% | 0% |

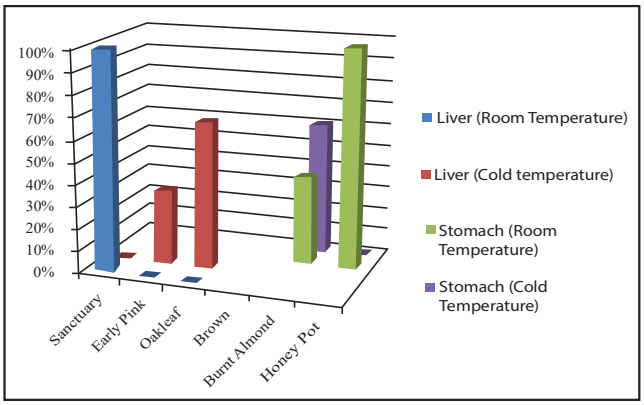


Figure 6 :"After Gas-Curing — Percentage Frequencies of Different Colors of the Organs in the 'Room Temperature Group' and the 'Cold Temperature Group': Human Liver & Human Stomach.

## Discussion

The study of color changes in human liver and stomach during the plastination process, particularly under different temperature conditions, provides valuable insights into the effects of temperature on tissue coloration and preservation. The results from the Fixation, Dehydration, Forced Impregnation, and Gas-Curing stages reveal distinct differences in color frequencies between the room temperature group and the cold temperature group, which can be attributed to the varying conditions of plastination at different temperatures.

At the Fixation stage, both liver and stomach samples exhibited color changes specific to the organ type and temperature group. For the liver, the room temperature group predominantly showed shades like Burke & Wills and Vienna Coffee, while the cold temperature group favored Burke & Wills and Taupe Tone. This difference suggests that fixation at cold temperatures may yield darker tones, potentially reflecting the effect of colder conditions on tissue properties. Similarly, for the stomach, both groups shared the Jaffa Orange color, with the room temperature group showing a preference for Cognac Cream, and the cold temperature group showing a preference for Flicker, demonstrating the effect of temperature on color transition in the stomach tissues.

At the Dehydration stage, the liver samples showed a significant shift in color frequencies, with the cold temperature group exhibiting a higher frequency of Cinnabark (66.67%) compared to the room temperature group, which showed a predominance of Castlemaine (66.67%). This shift highlights how dehydration affects the liver's color under different conditions. For the stomach, Fire Princess was a common color in both temperature groups, but differences in other colors, like Early Pink and Fresh Biscuit, were more pronounced under different temperature conditions.11The cold temperature group had a higher frequency of Fresh Biscuit, while the room temperature group had more Early Pink. These changes emphasize the effect of dehydration on the stomach's appearance, especially when subjected to different temperature conditions.[12]

The Forced Impregnation stage showed more pronounced temperature effects, particularly for the liver. The room temperature group showed a significant dominance of Galleon (100%), which was absent in the cold temperature group. In contrast, the cold temperature group exhibited the presence of Diva Rose (33.33%) and Cinna Swirl (66.67%). These differences underline how forced impregnation under cold conditions can result in more diverse color patterns compared to room temperature, likely due to the tissue's response to forced impregnation agents at varying temperatures. For the stomach, Burnt Almond appeared in both groups, but with different frequencies: the cold temperature group showed 100%, while the room

temperature group had 40%.[13] This suggests that the temperature during impregnation can influence the saturation of certain colors in the stomach tissue, with colder conditions likely enhancing certain color manifestations.

At the Gas-Curing stage, the liver samples showed marked differences in color frequencies between the two groups. Sanctuary was dominant at room temperature (100%), whereas the cold temperature group had Oakleaf Brown (66.67%) and Early Pink (33.33%). This suggests that gas-curing, combined with temperature differences, plays a critical role in determining the final color of the liver tissue. In contrast, the stomach samples showed more consistency in Burnt Almond, appearing in both groups but with a significantly higher frequency in the cold temperature group (100%). This finding could imply that cold temperature during gas-curing enhances color stability, particularly for certain shades.[14]

## Conclusion

The findings from this study underscore the significant impact of temperature on the plastination process, specifically during the stages of Fixation, Dehydration, Forced Impregnation, and Gas-Curing. The cold temperature group generally exhibited more varied and darker color patterns compared to the room temperature group, indicating that colder conditions influence the tissue's response to preservation agents and affect the final color outcomes. From a preservation standpoint, these findings could have practical implications for plastination techniques, especially when dealing with temperature-sensitive specimens. The clear differences in color frequencies between the two temperature groups suggest that cold temperature conditions may produce more stable and intense color contrasts, particularly in the liver and stomach tissues. Future studies could explore the underlying mechanisms that cause these temperature-induced color variations, potentially contributing to optimized plastination protocols for educational and research purposes. This study also highlights the importance of monitoring color changes during plastination, as it provides valuable data on how environmental factors like temperature can influence the preservation quality of specimens. Further research could delve into other temperature ranges or investigate other types of tissues to extend these findings and refine plastination methods for anatomical displays and educational resources.

## Conflict of interest

The authors declare that no conflict of interest exists.

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