Application of differential scanning calorimetry (DSC) in the analysis of lipstick thermal properties

1. Background

Lipstick is a common cosmetic product that has remained popular among a wide range of consumer demographics. Considering the highly competitive cosmetics market, successful lipstick products should be formulated to achieve certain standards which have become expected by the customer. Effective formulas typically deliver softness, non-toxicity, elasticity, uniformity in color and texture, and longevity.(1)

Although different lipsticks vary significantly in texture and color, their main components can be generally divided into eight categories: oils (30-50%), waxes (10-25%), butters (10-15%), fillers and texturizers (8-12%), pigments (5-20%), other additives (1-5%), fragrances (1-2%), and preservatives (1%).(1) The melting temperature of all these components can vary significantly, and lip products must also meet specific thermal requirements such as:

- ✓ Softening at surface body temperature (~35°C), and;
- ✓ Remaining solid at room temperature (~25°C).

Due to the different melting temperatures of each component, lipstick is prone to oil seepage (commonly known as "sweating") due to softening of the paste in a high-temperature environment. Therefore, heat resistance has become one of the key performance indicators to measure the quality of lipstick.(1)

The performance of lipsticks is closely related to the melting behavior of their components and the thermal transition temperature of the overall formulation. By accurately measuring these thermal transitions, differential scanning calorimetry (DSC) has become an indispensable key testing method in the cosmetic industry for lipstick development and quality control.(2)

2. Experiment

Five different lipsticks (labeled A-E) were selected as samples and tested using AMI's **DSC 600 differential scanning calorimeter**. Approximately 15 mg of sample was cut from each lipstick paste, placed in a sealed aluminum crucible, and capped. The experiment was conducted in an inert N_2 atmosphere with a heating rate of 10 °C/min and a temperature range of -90 °C to 140 °C to encompass the melting point range of major components.

3. Results

The DSC results are shown in Figure 1 and Table 1, which show that all five lipsticks have multiple endothermic peaks in the low temperature range of -90 °C to 140 °C. Among them, the melting peaks

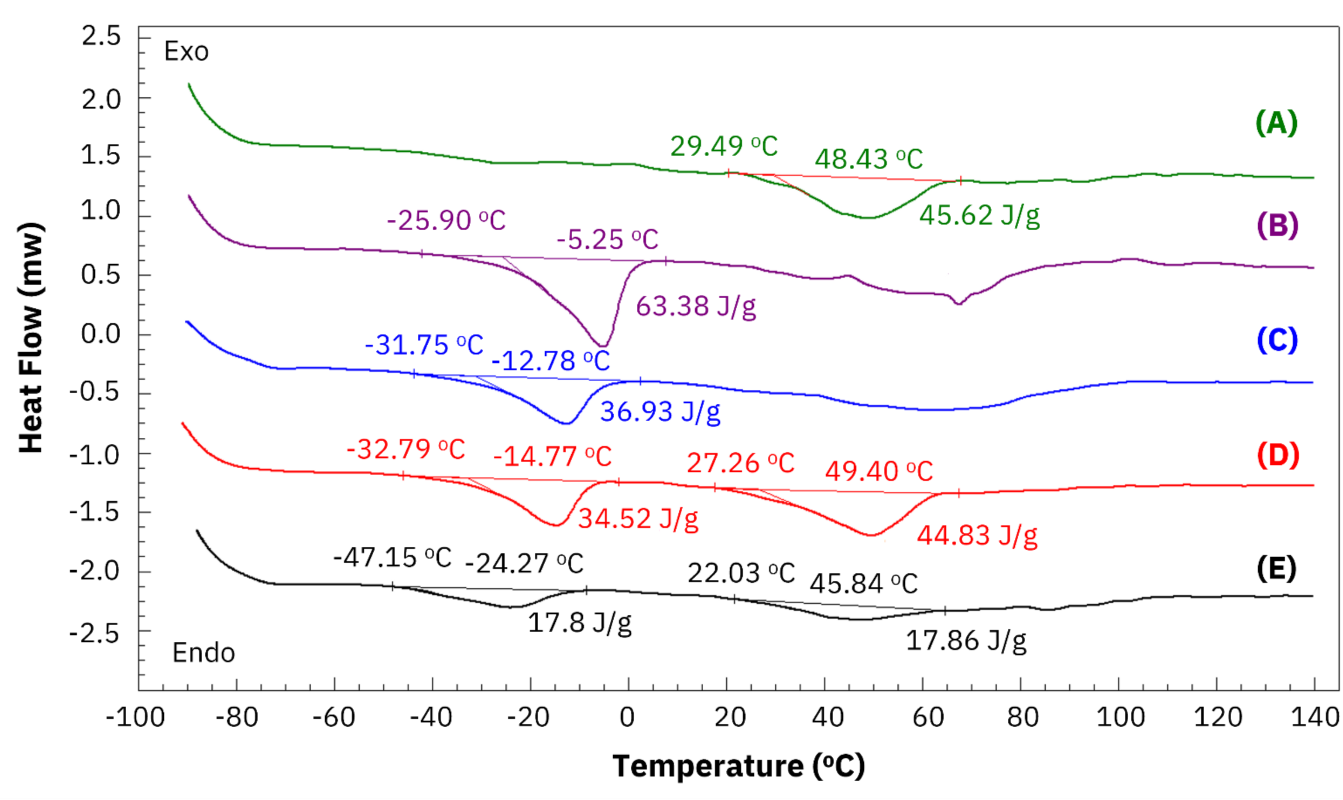


Figure 1: DSC thermograms for lipsticks A (green), B (purple), C (blue), D (red), and E (black)

in the low temperature region (below 0 °C) may derive from the low-melting oil components of some liquid oils or esters. The melting peaks in the range of 40-70 °C are likely waxy components with relatively low melting points compared to commonly used waxes like beeswax (T_m ~ 65 °C) or polyethylene (T_m ~ 90 °C).[1]

The DSC curve of lipstick A (Fig. 1, green curve) shows only one melting peak, indicating that the formula mainly consists of a single base ingredient. This endothermic peak, likely corresponding to its main structural component (such as wax or silicon-based materials), is located at 48.43 °C. The melting point is higher than room temperature, but still close to the body temperature (35 °C) and ambient summer temperatures, depending on the region. Therefore, it has poor high temperature and heat resistance but adequate spreadability.

Lipstick	Lower Temp. Melting Peak (°C)	ΔH (J/g)	Higher Temp. Melting Peak (°C)	ΔH (J/g)
A	-	-	48.43	45.62
B	-5.25	63.38	*	*
C	-12.78	36.93	*	*
D	-14.77	34.52	49.40	44.83
E	-24.27	17.8	45.84	17.86

* denotes peaks that were observable but too weak to integrate

Table 1: Results from DSC thermograms for lipsticks A-E

The melting peak of lipstick B (Fig. 1, purple curve) at -5.25 °C was sharp, and the enthalpy value was high at 63.38 J/g. This indicates that lipstick B has a significant amount of oil components, which are easier to apply but more likely to “sweat” in summer. However, small melting peaks in the range of 40 to 80°C can also be observed for lipstick B, which indicates that a small amount of higher melting point wax was added to the formulation to enhance heat resistance. While this added wax may improve thermal properties, the addition of high melting point wax also increases the hardness of the paste.

Lipstick C (Fig. 1, blue curve) was primarily oil-based (T_m = -12.78 °C) but also contained a weak, broad peak between 40 and 80 °C, which may indicate a small amount of wax added to the oil-based formula. With only a small amount of hard wax added, this formula may exhibit a balance between heat resistance and softness.

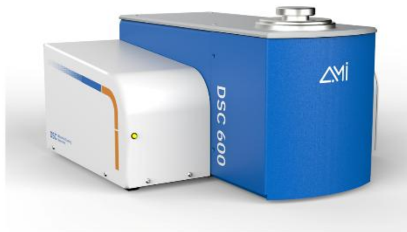
Lipstick D (Fig. 1, red curve) displayed two melting peaks (-14.77 °C, 49.40 °C) with similar enthalpy changes (34.52 J/g, 44.83 J/g) indicating roughly equivalent oil and wax components. This gave the lipstick good high temperature stability, but the high wax content could lead to the paste being hard.

Lipstick E (Fig. 1, black curve) shows a wide and short melting peak at -24.27 °C in the low temperature region, indicating the existence of a multi-component eutectic system, which may be a mixture of silicone oil and alkanes. At the same time, the melting peak is observed in the higher temperature area with a peak of 45.84 °C, indicating that lipstick contains waxy components that can maintain a solid state at room temperature but have a relatively low melting point, which means that it is easy to soften at high temperatures but has insufficient heat resistance.

4. Conclusions

The melting temperature and enthalpy value of each component measured by the DSC curve are the key thermal performance indicators for evaluating the high-temperature stability and low-temperature spreadability of lipsticks. Analysis by differential scanning calorimetry (DSC) using the **AMI DSC 600**, shown in Figure 2, can clearly reveal the differences in the melting properties of their components. The **DSC 600** offers high sensitivity and user-friendly software at an accessible price.

- ✓ High-sensitivity heat flow sensor
- ✓ Temperature control accuracy ± 0.01 °C
- ✓ Intuitive software interface



DSC 600

*Figure 2: Highlight of **DSC 600** by **AMI***

5. References

(1) Rigano, L. and Montoli, M. Strategy for the development of a new lipstick formula. *Cosmetics*, **2021**, *8*, 105.

(2) Pan, S. and Germann N. Thermal and mechanical properties of industrial benchmark lipstick prototypes. *Thermochim. Acta*, **2019**, *679*, 17833