Effect of Strain on Fat Bloom in CBS Compound Chocolate

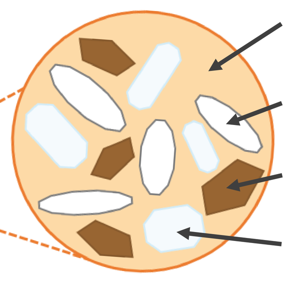
HIROSHIMA UNIVERSITY

Kazuki Kimura, Haruhiko Koizumi, Satoru Ueno

Graduate School of Integrated Sciences for Life, Hiroshima University, Higashi-Hiroshima, Japan

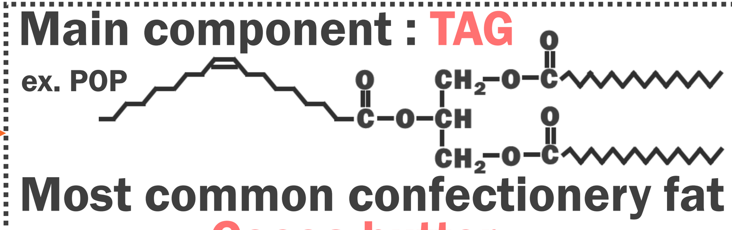
Introduction

Ingredients



- Confectionery fat
- Milk powder
- Cacao mass
- Sugar

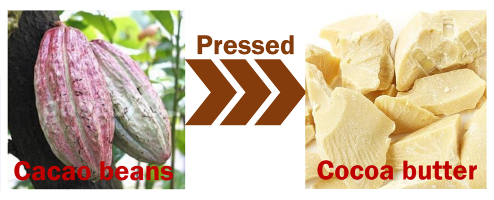
Main component : TAG



Most common confectionery fat
Cocoa butter

Cocoa Butter (CB)

・・・Fats contained in cocoa beans



Advantage
Crystal polymorph : Form V ⟫ Optimum texture for chocolate

Disadvantage
Cacao beans : Production instability ⟫ Cocoa butter : Supply instability, High price

→ Cocoa butter substitutes is also widely used

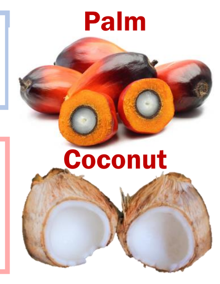
Cocoa Butter Substitutes (CBS)

・・・Raw materials : Palm kernel oil, Coconut oil

Compared to CB

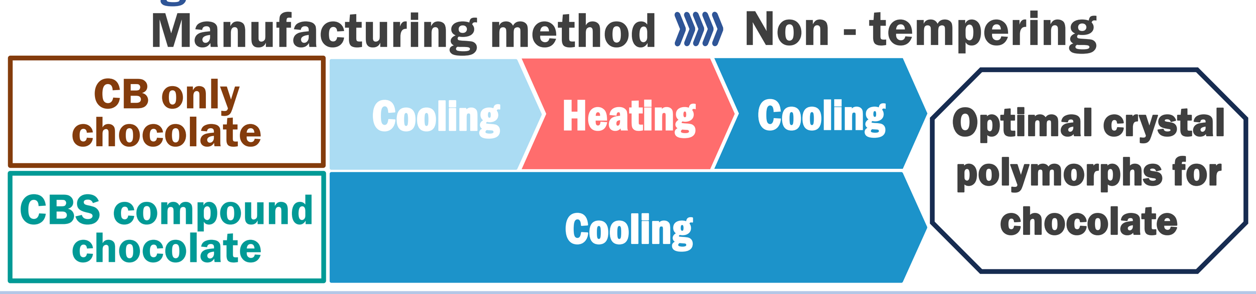
Advantage
Low cost and stable production ⟫ High availability

Disadvantage
Inferior taste and flavor ⟫ Must be mixed with CB
Compound chocolate



CBS Compound Chocolate

Advantage
Manufacturing method ⟫ Non - tempering



Disadvantage
Long-term storage
Fat bloom
Quality degradation

Fat Bloom

■ Example of quality degradation due to fat bloom
- ✓ Surface discoloration to white
- ✓ Melt in the mouse worse
- ✓ Rough texture

■ Causes of Fat Bloom in chocolate
① Polymorphic transition from metastable to most stable form of CB during long-term storage
② Melting of metastable crystals and growth of the most stable crystals due to temperature rise, etc. ⟫ Granular crystallization

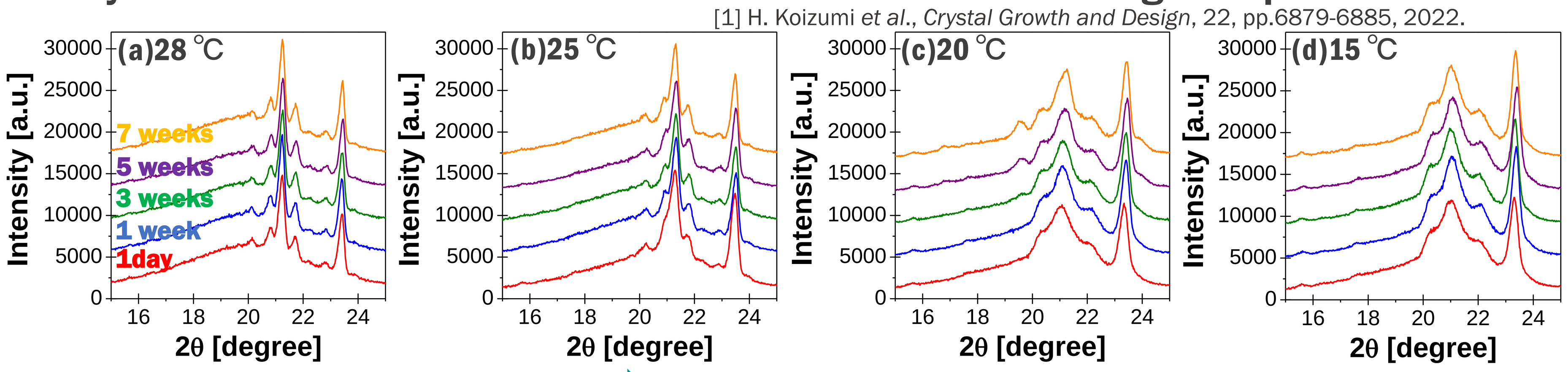
■ Fat Bloom in CBS compound chocolate

Metastable form β' ⟫ (Polymorphic transition) ⟫ Most stable form β ⟫ Fat bloom

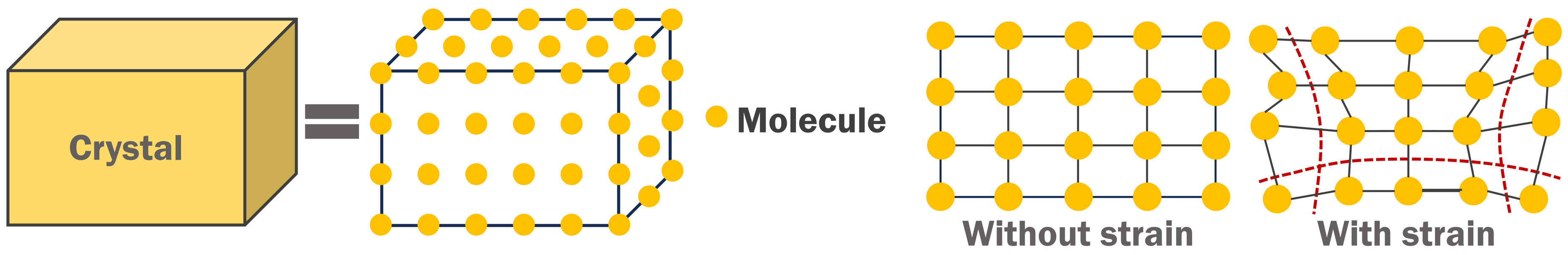
Previous Study

■ X-ray diffraction measurements of CBS stored at different storage temperatures [1]

[1] H. Koizumi et al., Crystal Growth and Design, 22, pp.6879-6885, 2022.



Different storage temperatures ➡ Broadening of X-ray diffraction profiles
➡ Strains in the crystal may have changed.



Strain in crystal —Influence→ Stability of crystal —Influence→ Cause of fat bloom / Phase transformation

However.... quantitation of the strain accumulated in the CBS was not achieved

Purpose

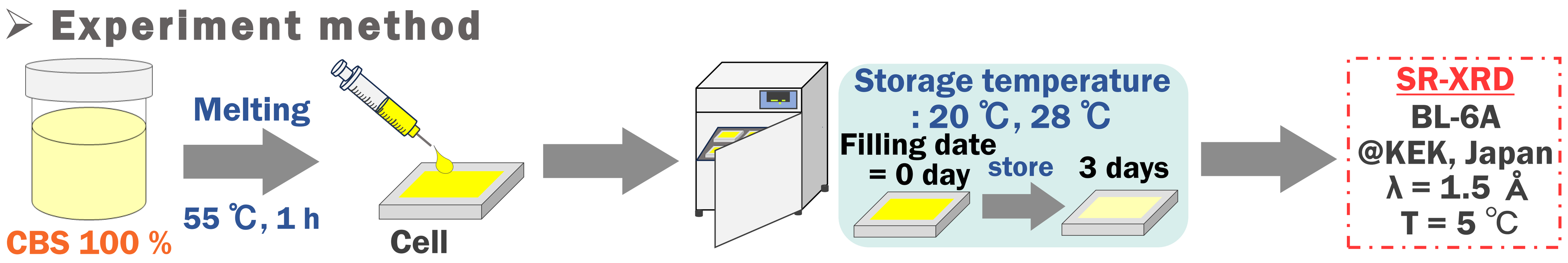
Aiming to suppress fat bloom of CBS compound chocolate by focusing on the difference of strain accumulated in CBS depending on storage temperature and quantifying the strain.

Experiments

1. Synchrotron X-Ray Diffraction(SR-XRD)

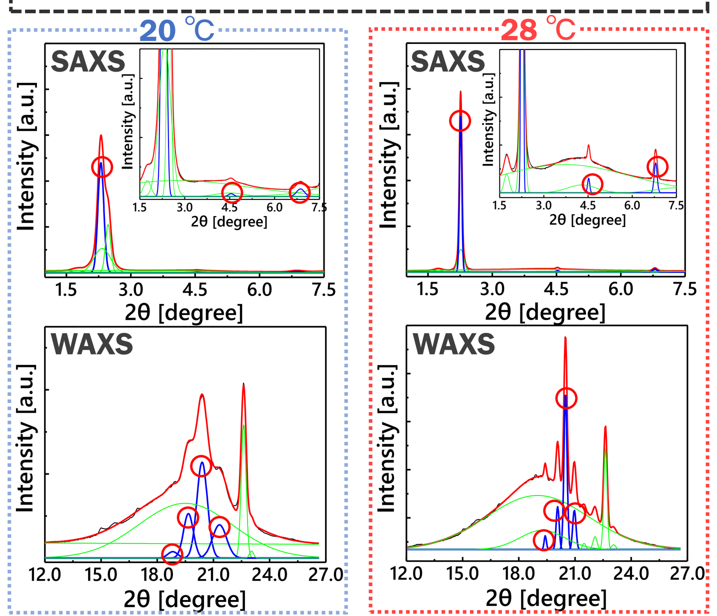
Experimental objective: Calculate strain from the half-width of the diffraction peak

Experiment method



How to calculation of strain

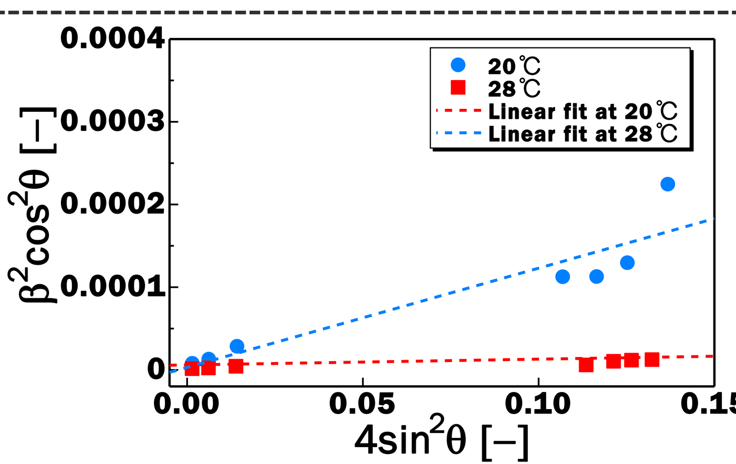
Peak analysis
Software 〉 Origin Pro
Function 〉 Gaussian function



Williamson-Hall method

$$\beta^2\cos^2\theta = 4\varepsilon^2\sin^2\theta + \kappa^2\lambda^2/D^2$$

β : FWHM θ : Bragg angle ε : Strain
κ : Scherrer's constant (=0.9)
λ : Wavelength(=1.5 Å) D : Crystallite diameter



Strain calculation Result[2]

Storage temperature [℃]	Strain ε [-]
20	$3.31\times10^{-2}(\pm0.03\times10^{-2})$
28	$0.80\times10^{-2}(\pm0.95\times10^{-4})$

[2] H. Koizumi et al., CrystEngChem, 25, pp. 4562-4567, 2023.

About CBS β' form ...
Storage temperature high
➡ Strain accumulated in crystal low

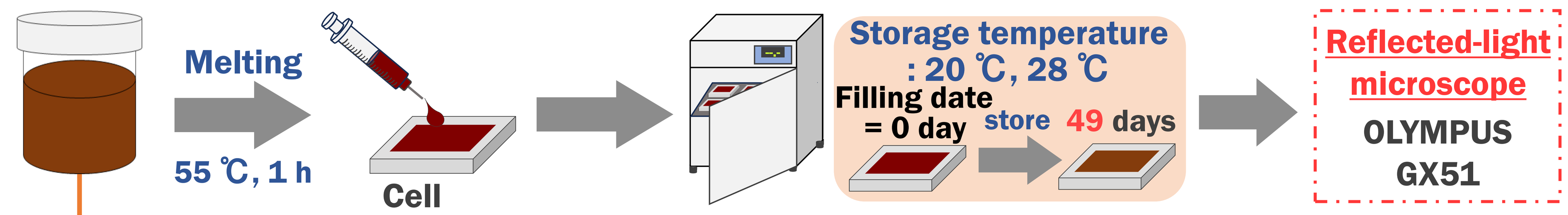
⟫ Strain changes with storage temperature

Further Investigation ⇢ Differences in fat bloom development at different storage temperatures

2. Reflected-light Microscope

Experimental Objective: Observation of Fat Bloom in CBS Compound Chocolate

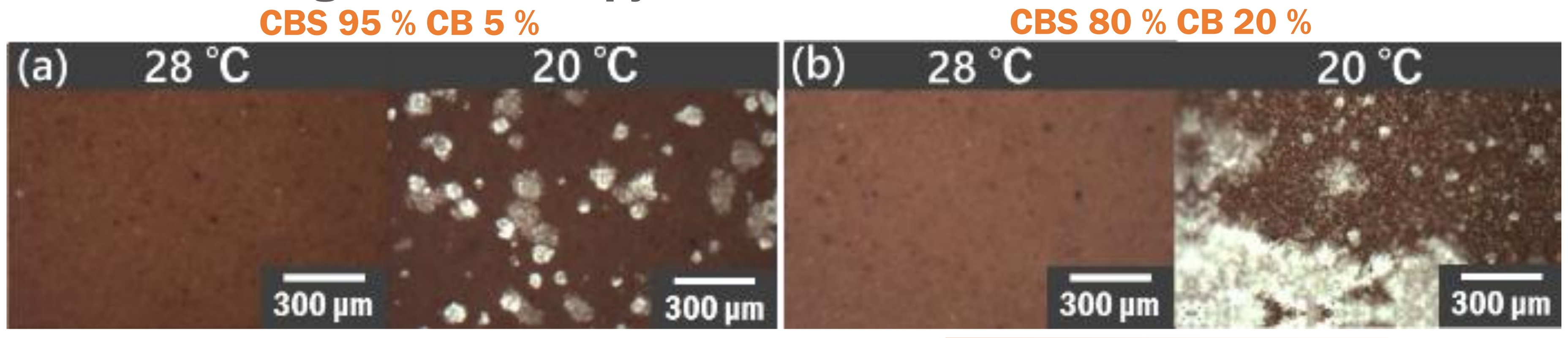
Experimental method



1. CBS 95 % CB 5 %
2. CBS 80 % CB 20 %

CBS compound chocolate is prone to fat bloom at CB higher 5 %

Reflected-light microscopy observation results



High ◀ Storage temperature ▶ Low
Low ◀ Strain ▶ High

Storage temperature High ➡ Fat Bloom did not occur

Storage temperature High ➡ Strain Low ➡ Polymorphic transition Slow

Higher storage temperatures inhibit polymorphic transition of CBS compound chocolate and prevent fat blooming

Discussion

Why strain slows polymorphic transition

Assumption
- Crystals that are entirely in the metastable form β', some of which transition to the most stable form β
- The β-type crystals that form are spheres

● If β' form has no strain

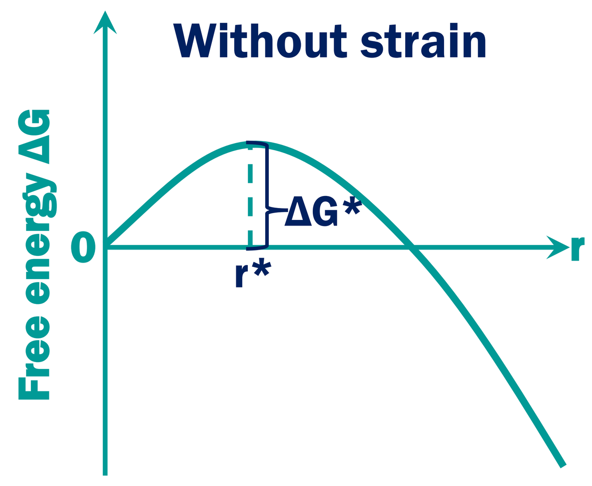
Critical nuclear radius r*

$$r^* = \frac{2\gamma}{\Delta G_v}$$

Activation energy barrier ΔG*

$$\Delta G^* = \frac{16\pi}{3}\frac{\gamma^3}{\Delta G_v^2}$$

γ : Interfacial tension
ΔG_v : Free energy difference between β' and β per unit volume



● If β' form has strain

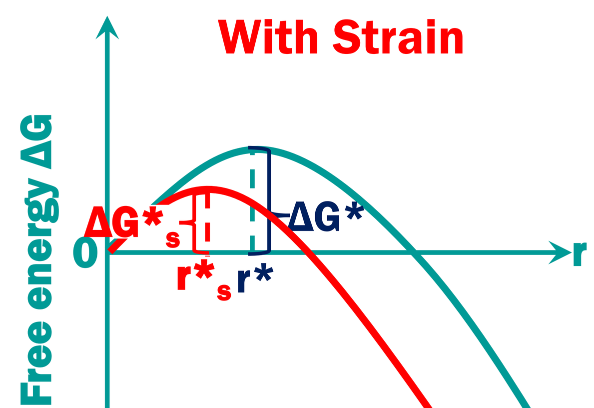
Critical nuclear radius r*

$$r^*_s = \frac{2\gamma}{\Delta G_v + G_v^S}$$

Activation energy barrier ΔG*

$$\Delta G^*_s = \frac{16\pi}{3}\frac{\gamma^3}{(\Delta G_v + G_v^S)^2}$$

G_v^S : Free energy of strain per unit volume



Strain accumulates ▶ r*,G* Decrease ▶ Polymorphic transition Easily occurs

Conclusion

✓ Strain of CBS β' form

Different storage temperatures
⟫ Strain accumulated in β' form crystals also changes
⟫ The higher the storage temperature, the smaller the strain

✓ Effects of Strain on Fat Bloom

Long-term storage under conditions of high storage temperatures
⟫ Smaller strain slows the polymorphic transition rate
⟫ Fat bloom is reduced
⟫ Fat bloom was suppressed even in compound chocolate containing more than 5% CB, which is known to be prone to fat bloom

This research will lead to the development of a tastier and less expensive CBS compound chocolate with a higher concentration of CB