Error Case ID	Predicted Label	True Label	Cause	Notes
CH-01	Juice	Chocolate	Chocolate was widely spread and thinned	Lost dark center, appeared diluted
CH-02	Ketchup (Tomato sauce)	Chocolate	Color shifted to reddish-brown under warm lighting	Yellow indoor light affected hue
CH-03	Coffee	Chocolate	Chocolate absorbed into fabric fibers	Flat brown appearance
CH-04	Wine	Chocolate	Low-light conditions reduced texture visibility	Dark uniform tone
CH-05	Dirt/Mud	Chocolate	Thick or dried chocolate formed rough texture	Texture similar to soil
CH-06	Dirt/Mud	Chocolate	Low contrast on dark fabric background	Boundary unclear
WI-01	Juice	Wine	Indoor lighting altered red tone	Appeared lighter than typical wine
WI-02	Coffee	Wine	Dim lighting darkened stain color	Texture details lost
JU-01	Wine	Juice	Juice highly absorbed into fabric	Color became too light

CO-01	Dirt/Mud	Coffee	Similar brown hue and irregular spread	Texture overlap
DI-01	Coffee	Dirt/Mud	Mud dried smoothly on fabric	Looked like dried coffee stain

1 Representative Failure Cases (Summary)

A total of representative failure cases were reviewed from validation and test results. These cases were selected to reflect recurring misclassification patterns rather than isolated errors.

- Chocolate stains confused with juice, ketchup, coffee, wine, or dirt
- Wine stains confused with juice or coffee under indoor lighting
- Juice stains confused with wine due to excessive absorption
- Coffee and dirt stains confused due to similar brown tones

These cases indicate that most failures were not random but clustered around specific visual conditions.

2 Error Type 1: Poor or Inconsistent Lighting

Description
Stains photographed under dim or warm indoor lighting frequently showed color distortion. Red or brown stains appeared darker or shifted in hue, leading to confusion between wine, coffee, chocolate, and ketchup.

Observed examples

- Wine → misclassified as coffee
- Chocolate → misclassified as wine or ketchup

Root cause

- Model relies heavily on color-based features
- Lighting changes altered hue and saturation

Improvement ideas

- Collect additional images under low-light and warm-light conditions
- Apply stronger lighting normalization at inference time
- Introduce color-augmentation focused on hue shifts

3 Error Type 2: Similar Background and Low Contrast

Description
When stains appeared on dark or textured fabric, the boundary between stain and background became unclear. This caused the model to confuse stains with dirt or miss texture cues.

Observed examples

- Chocolate → misclassified as dirt
- Coffee → misclassified as dirt

Root cause

- Low contrast between stain and fabric
- Limited texture resolution in lightweight models

Improvement ideas

- Expand dataset with darker fabric backgrounds
- Increase contrast-based augmentation
- Explore larger backbone models with stronger texture extraction

4 Error Type 3: Stain Absorption into Fabric

Description
Liquid stains such as juice were often absorbed into fabric fibers, resulting in faded colors and reduced stain boundaries.

Observed examples

- Juice → misclassified as wine

Root cause

- Reduced color saturation
- Loss of clear stain edges

Improvement ideas

- Include more absorbed-stain examples in training data
- Adjust confidence threshold for low-saturation predictions
- Combine color and shape-based feature emphasis

5 Error Type 4: Highly Spread or Smeared Stains

Description
When stains such as chocolate were spread widely or unevenly, their original visual characteristics were lost. This caused overlap with multiple stain categories.

Observed examples

- Chocolate → misclassified as juice, coffee, ketchup, or wine

Root cause

- Loss of thickness and texture cues
- Visual overlap with liquid-based stains

Improvement ideas

- Add controlled smear-variation samples

- Label sub-types of stain spread during data collection
- Explore multi-stage classification or confidence-based rejection