

Presentation for the 2022 International Symposium on Cocoa Research

6 December, 2022



Applying computer vision to cocoa bean cut test images: *towards an efficient and accessible tool for evaluating physical quality*

Prepared and Presented by Neil Slettehaugh

Cocoa of Excellence, Alliance of Bioversity International and CIAT, Rome, Italy

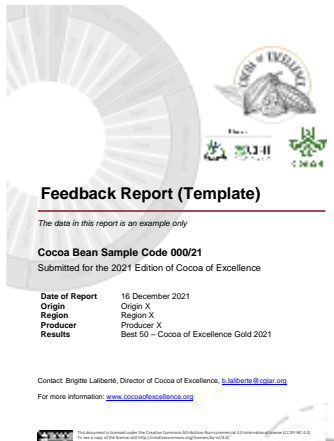
Co-authors: Andrew Meter, Dolores Alvarado, and Brigitte Laliberte

Cocoa of Excellence, Alliance of Bioversity International and CIAT



Cocoa of Excellence Awards

Overview



Feedback Report (Template)

The data in this report is an example only

Cocoa Bean Sample Code 000/21
Submitted for the 2021 Edition of Cocoa of Excellence

Date of Report: 16 December 2021
Origin: Origin X
Region: Region X
Producer: Producer X
Results: Best 50 - Cocoa of Excellence Gold 2021

Contact: Brigitta Labentz, Director of Cocoa of Excellence, labentz@cgiar.org
For more information: www.cocoaofexcellence.org

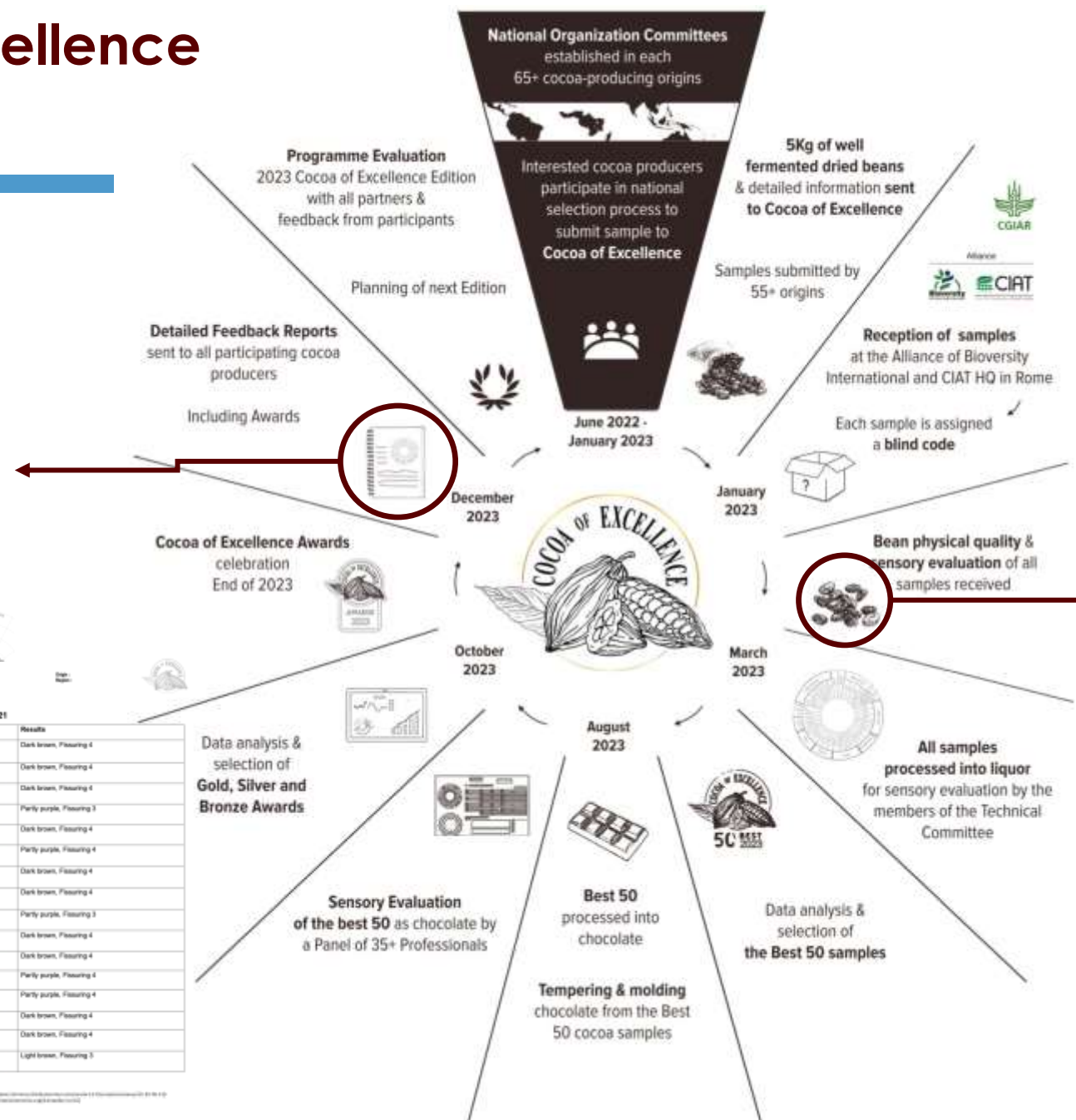
III. Physical quality evaluation results

External bean appearance	Description of appearance of whole beans
External bean appearance	Description of appearance of whole beans
Bean count (120g)	100 - Standard Beans
Average weight per bean (g)	1.0
Cracking beans (%) - see Note 2	1.0

Cut test results - see Note 6			
% puffed / chafed	28	% light brown	20
% partly puffed	38	% medium brown	20
		% dark brown	20

3C. Cut test photos of beans
CoEa Sample Code 000/21

A-side	B-side	Results
		Dark brown, Flavouring 4
		Dark brown, Flavouring 4
		Dark brown, Flavouring 4
		Partly purple, Flavouring 3
		Dark brown, Flavouring 4
		Partly purple, Flavouring 4
		Dark brown, Flavouring 4
		Dark brown, Flavouring 4
		Partly purple, Flavouring 3
		Dark brown, Flavouring 4
		Dark brown, Flavouring 4
		Partly purple, Flavouring 4
		Partly purple, Flavouring 4
		Dark brown, Flavouring 4
		Dark brown, Flavouring 4
		Light brown, Flavouring 3



Cocoa Bean Cut Test



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International Symposium on Cocoa Research (ISCR), 5-8 December 2022 Montpellier, France

Cocoa of Excellence Awards



Background

- Since 2009, Cocoa of Excellence Awards, held every two years:
 - Recognizes the work of cocoa farmers
 - Celebrates the quality and flavour diversity of cocoas produced around the world
 - Brings together leading sensory evaluation experts and the chocolate industry
 - Rewards producers of excellence
 - Provides individual, confidential, and detailed Feedback Reports
 - can be useful to producers interacting with potential buyers and chocolate makers
 - for samples with defects, recommendations may be provided when identified to a specific post-harvest process
 - Has accumulated an extensive library of cocoa bean cut test images
 - > 1,000 samples
 - > 55 origins

Cocoa Bean Cut Test Tool



Motivation

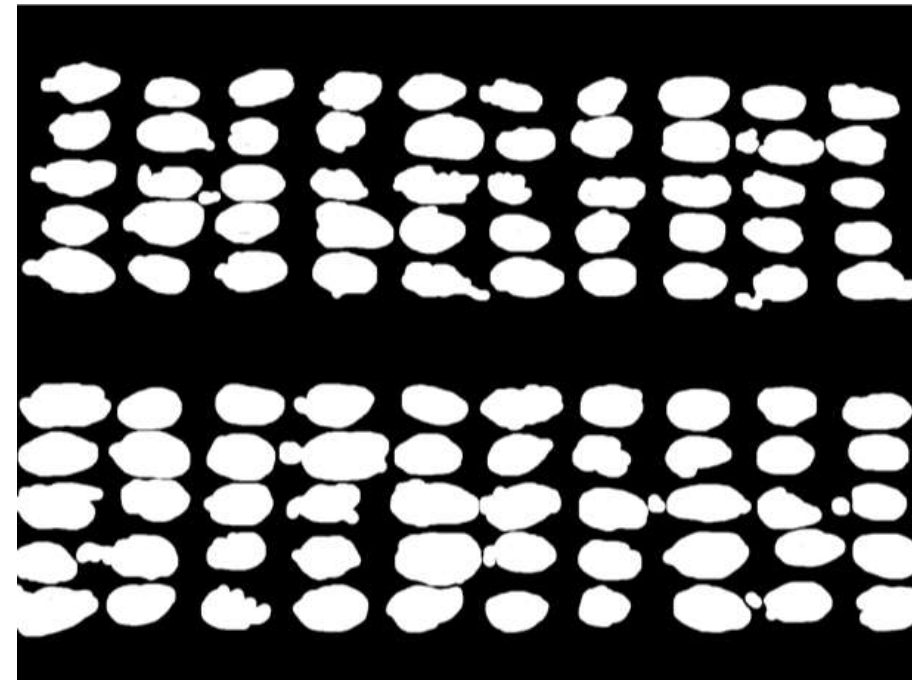
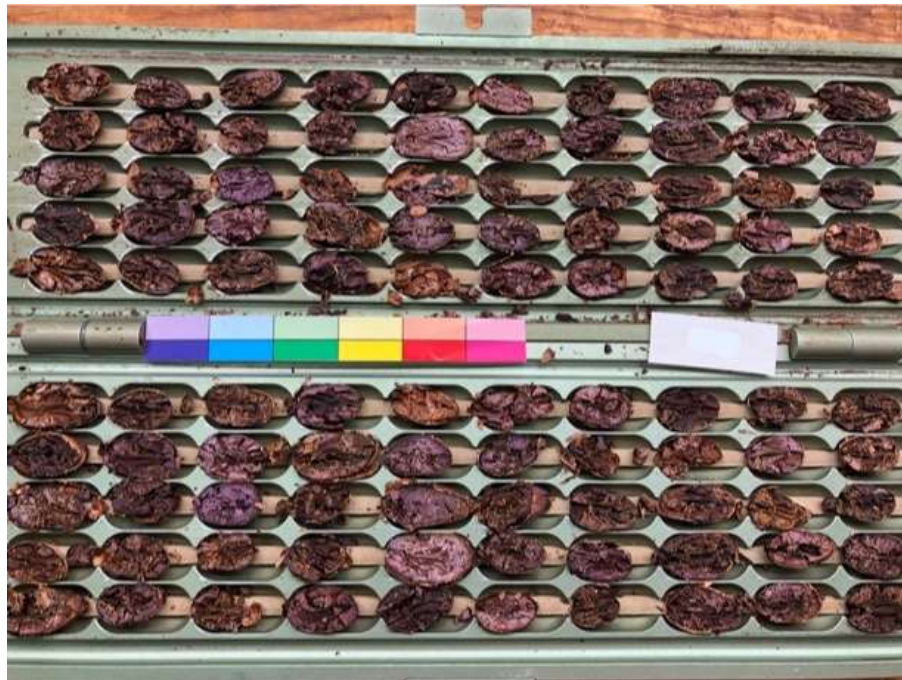
- The cocoa bean cut test is the most commonly used method to visually assess bean quality and provides information on:
 - the internal colour
 - any signs of diseases and pests
 - the degree of fissuring
- This information is also used to select optimum roasting conditions
- The visual assessment requires experience and a significant amount of time to process
- As image processing has been progressing rapidly, the objective of this research is to develop a tool by applying deep learning models to:
 - read images of these cut tests
 - classify them quickly and reliably
 - provide results in an automated report

Cocoa Bean Cut Test Tool



Methodology

1. Generate a collection of masked images representing a cross-section of cut bean physical properties (editions 2015 - 2021)

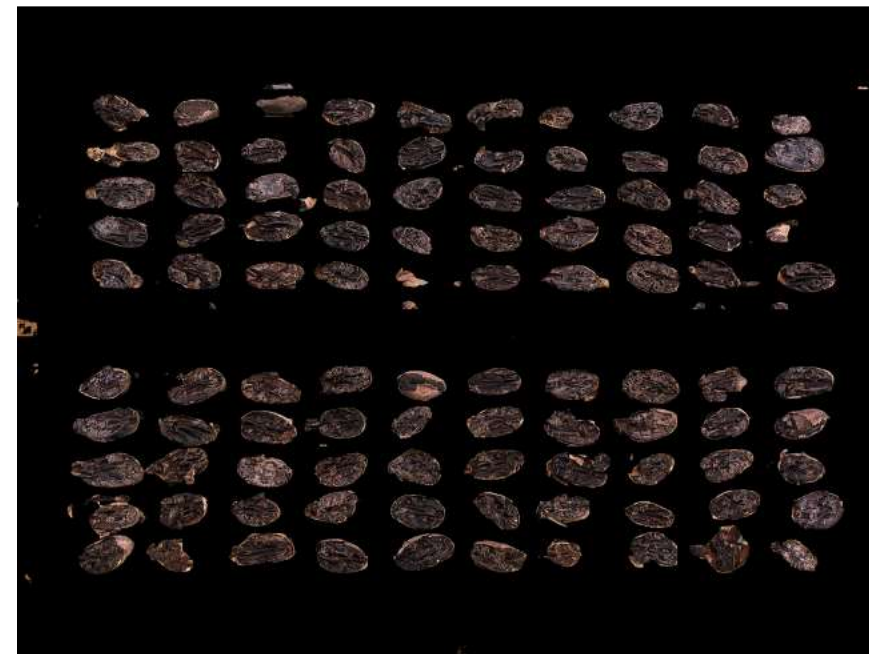


Cocoa Bean Cut Test Tool



Methodology

2. Train a convolution neural network (CNN) on image segmentation for identifying the cut beans
 - TensorFlow based UNet CNN
 - Optimize parameters for minimized loss function



Cocoa Bean Cut Test Tool



Methodology

3. Create a library of labelled cut bean images

- a. cut test images of samples from 2021 Edition
- b. expert evaluator to classify and label each individual cut bean
- c. >20,000 labelled images

Index	A-side	B-side	Empty	Insuffic. cut	Slaty	Purple Violet	Part Purple	Light Brown	Medium Brown	Dark Brown	Mouldy	Infested	Fissuring 1	Fissuring 2	Fissuring 3	Fissuring 4
20										X						X
21										X						X
22								X							X	
23							X								X	
24										X					X	
25							X								X	

Cocoa Bean Cut Test Tool



Methodology

4. Using this set of labelled images, train models on classifications:

- colour
- fissuring level
- defects



Dark Brown
Fissuring 4
No defects



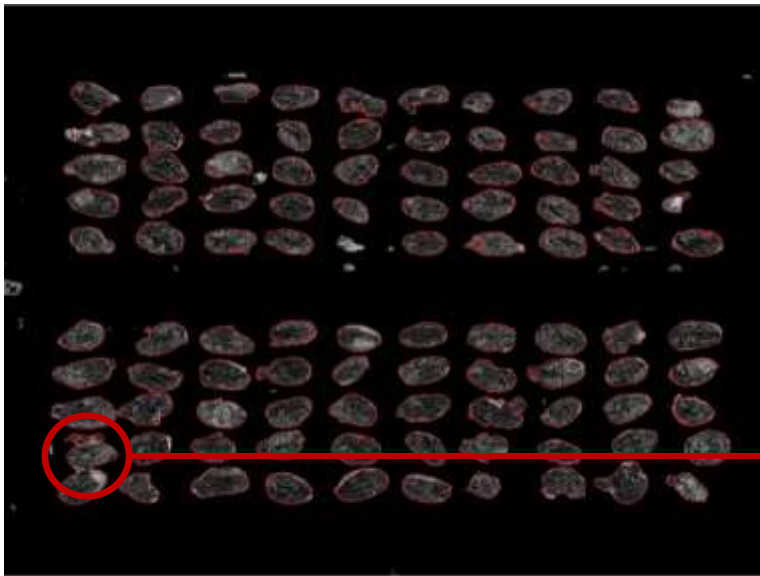
Medium Brown
Fissuring 3
No defects

Cocoa Bean Cut Test Tool



Methodology

5. Apply the models generated to:
 - a. segment a cut test image
 - b. identify each cut bean
 - c. classify cut bean physical properties, and
 - d. produce an automated report of the cut test.



Dark Brown
Fissuring 4
No defects

Property	Count	%
Total cut beans detected	50	100%
<i>Insuffic. cut</i>	2	4%
Purple Violet	0	0%
Part Purple	4	8%
Light Brown	0	0%
Medium Brown	0	0%
Dark Brown	44	88%
Slaty	0	0%
Mouldy	0	0%
Infested	0	0%
Mouldy & Infested	0	0%
Fissuring 1	0	0%
Fissuring 2	0	0%
Fissuring 3	3	6%
Fissuring 4	45	90%

Cocoa Bean Cut Test Tool



Results

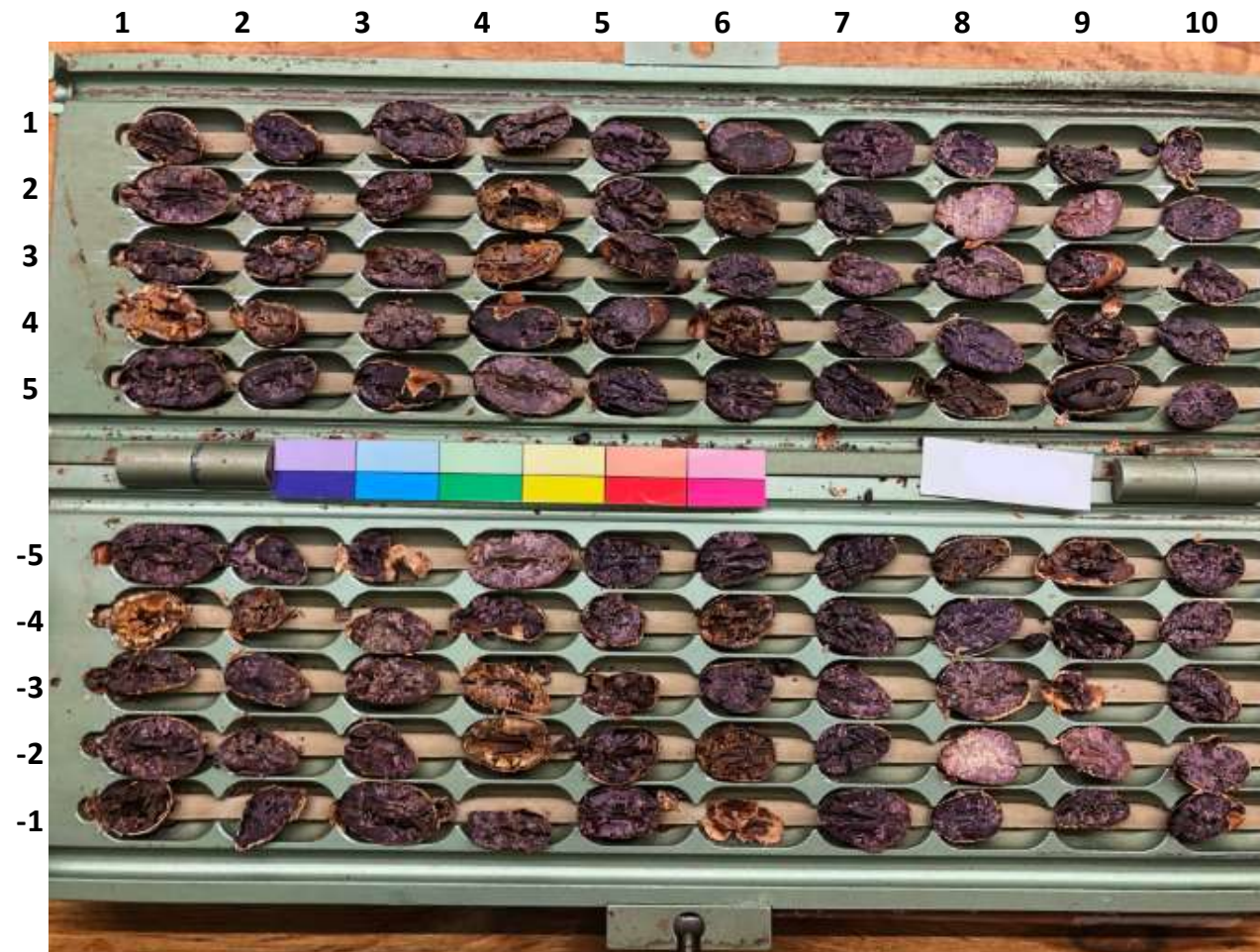
- Cut test cocoa bean segmentation model (training masks as ground truth values):
 - 97% test accuracy
- Classification models (expert labels as ground truth values):
 - Color: 78% accuracy
 - Image set biased toward dark beans
 - Training on a more balanced set (reduced number of images): 74% accuracy
 - Fissuring level: 73% accuracy
 - Biased toward higher fissuring levels
 - More balanced set: 67% accuracy
 - Defects: accuracy pending
 - artificially high due to greatly unbalanced dataset
 - global samples in Cocoa of Excellence cut tests trend toward high quality
 - working with partners for labelled defect images

Cocoa Bean Cut Test Tool



Reporting Cut test summary

Property	Count	%
Total cut beans detected	50	100%
<i>Insuffic. cut</i>	0	0%
Purple Violet	0	0%
Part Purple	31	62%
Light Brown	1	2%
Medium Brown	5	10%
Dark Brown	13	26%
Slaty	0	0%
Mouldy	0	0%
Infested	0	0%
Mouldy & Infested	0	0%
Fissuring 1	0	0%
Fissuring 2	1	2%
Fissuring 3	19	38%
Fissuring 4	30	60%



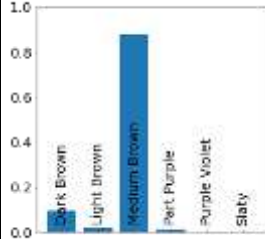
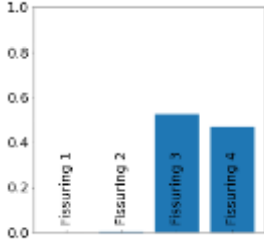
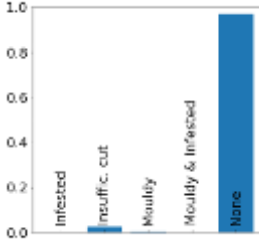


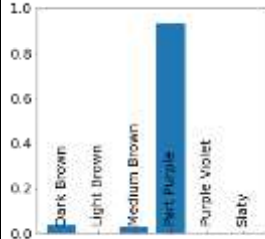
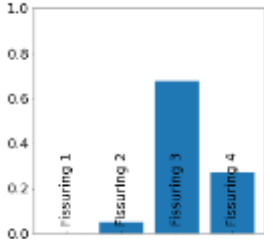
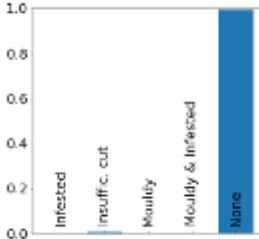


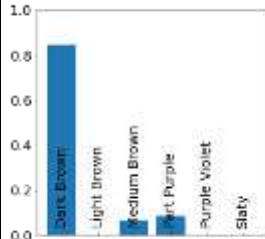
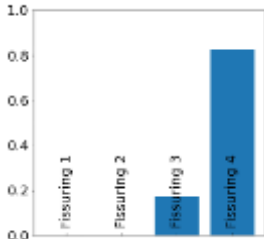
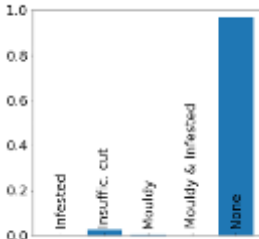


Cocoa Bean Cut Test Tool



Reporting

Cut bean predictions (combined probability)

index	col	row	Cut bean image side A	row	Cut bean image side B	Predicted classes	Probabilities Color	Probabilities Fissuring	Probabilities Defects																																				
22	2	3		-3		Medium Brown Fissuring 3 None	 <table border="1"> <tr><th>Color</th><th>Probability</th></tr> <tr><td>Dark Brown</td><td>0.1</td></tr> <tr><td>Light brown</td><td>0.05</td></tr> <tr><td>Medium Brown</td><td>0.85</td></tr> <tr><td>Part Purple</td><td>0.05</td></tr> <tr><td>Purple Violet</td><td>0.05</td></tr> <tr><td>Slaty</td><td>0.0</td></tr> </table>	Color	Probability	Dark Brown	0.1	Light brown	0.05	Medium Brown	0.85	Part Purple	0.05	Purple Violet	0.05	Slaty	0.0	 <table border="1"> <tr><th>Fissuring</th><th>Probability</th></tr> <tr><td>Fissuring 1</td><td>0.0</td></tr> <tr><td>Fissuring 2</td><td>0.05</td></tr> <tr><td>Fissuring 3</td><td>0.5</td></tr> <tr><td>Fissuring 4</td><td>0.45</td></tr> </table>	Fissuring	Probability	Fissuring 1	0.0	Fissuring 2	0.05	Fissuring 3	0.5	Fissuring 4	0.45	 <table border="1"> <tr><th>Defect</th><th>Probability</th></tr> <tr><td>Infested</td><td>0.0</td></tr> <tr><td>Inuff.c. cut</td><td>0.05</td></tr> <tr><td>Mouldy</td><td>0.0</td></tr> <tr><td>Mouldy & Infested</td><td>0.0</td></tr> <tr><td>None</td><td>0.95</td></tr> </table>	Defect	Probability	Infested	0.0	Inuff.c. cut	0.05	Mouldy	0.0	Mouldy & Infested	0.0	None	0.95
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Conclusions



- A segmentation model for cut cocoa bean images works well
 - Enables identification, classification and reporting
 - Can be utilized for the continued refinement of the tool itself
- Classification models can reasonably predict color and fissuring level
- More labelled defective bean images are required to train on
- Demonstrates a proof of concept for providing a digital tool to evaluate cut test images of fermented and dried cocoa beans which would:
 - Increase capacity of cocoa producers to get quick feedback – as currently provided in detailed feedback reports during the Cocoa of Excellence Awards
 - Improve cocoa farmers' understanding for potential adjustments to processes
 - maximizing quality of fermented and dried cocoa beans
 - thereby increasing their value potential in the marketplace
 - Such a tool would be useful for producers interacting with potential buyers and chocolate makers

Recommendations



- Expansion of the training images library to improve **balance** in the dataset
- **Protocols** for taking images when *using* the tool
 - lighting conditions
 - including a color reference
 - table / background
 - camera alignment
- Apply a **color-correction** scheme to images
 - Utilize color references included in cut tests
 - Validate enhanced predictions with expert evaluations
- Report **recommendations** / feedback based on cut test results

Acknowledgments



- Ed Seguine
 - Seguine Cacao Cocoa & Chocolate Advisors / Guittard Chocolate
- Darin Sukha, Krystal Daniel
 - Cocoa Research Center of The University of the West Indies, Trinidad and Tobago

Presentation for the 2022 International Symposium on Cocoa Research

6 December, 2022



Thank You

**Applying computer vision to
cocoa bean cut test images:
*towards an efficient and accessible tool for evaluating
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