A direct sourcing model based on key quality metrics for Costa Rican cocoa

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Aim of study

With the market segment of flavour cocoa continuing to suffer from a massive oversupply, with buyers unwilling to pay higher prices for premium cocoa, innovative solutions are needed to help smallholders of premium cocoa access markets. As a producer of recognized high-quality cocoa with a small export market, the Costa Rican cocoa bean market is expected to offer cocoa showing unique profiles and meeting quality standards for export, but lacking buyers. This project aims to create a testing protocol that can be applied locally in a cheap, speedy and simple manner to create a quality profile for cocoa beans, a feedback loop for processors to help them understand their cocoa quality and digitally map these beans to create a direct sourcing model based on these profiles. Interviews confirmed the need to improve the connection between suppliers and buyers. Cocoa samples from farmers lacking buyers showed very interesting flavour profiles, proving there is untapped potential in Costa Rican cocoa.

Material and methods

Data collection took place in Costa Rica from January to February 2019 and between October and December 2019. Farm visits were conducted, interviews carried out, samples obtained and analyzed. Between both trips, contact was established with the various stakeholders and the study was planned in more detail. All analytical tests were carried out at the campus Omar Dengo of the Universidad Nacional in Heredia. 500g samples of fermented, dried cocoa beans were collected from 18 different smallholders via 4 different traders. 10 farmers were from the regions of Upala and San Rafael de Guatuso, the others from Puerto Viejo, Matina (Limón), Pavas, Bijagua and La Fortuna, Guacimo, and along the border to Panama and to Nicaragua. The beans in the Upala batch were collected from the areas La Victoria, Cuatro Locas, Yolillal and Pavas. All of these beans had been prepared and bagged ready for export.

To help determine and identify which criteria was deemed relevant for quality measurements by the industry, two industry partners were consulted. Their values were compared with the document Cocoa Beans: Chocolate & Cocoa Industry Quality Requirements, (End & Dand, 2015). The publication The De Zaan Cocoa Manual (ADM, 2006) served as an additional reference. The following overview of reference values for export was summarized:

Category	Quality criteria from End & Dand, 2015	De Zaan Cocoa Manual
hysical Characteristics	Maximum percentage of beans Mouldy: Grade I: 3% Grade II: 4% Slaty: Grade I: 3% Grade II: 8% Insect damaged, germinated or flat: Grade I: 3% Grade II: 6%	Number of defects Number of broken beans
Physical Characteristics	Beans uniform in size and on average at least 1g in weight	Bean count per 100g
Physical Characteristics	Be well fermented	Degree of fermentation
Physical Characteristics	Good grade = <5% slaty or defective beans Fair grade = <10% slaty or defective beans	Colour
Flavour	Free from off-flavours, particularly smoke, mould, excessive acidity, excessive bitterness and astringency	Flavour
Cocoa Butter Characteristics	Fat content of 55-58% (dry nib basis)	Fat content
Cocoa Butter Characteristics	Free fatty acid content less than 1%	Fat quality
Physical Characteristics	Ca. 7%, at the maximum 8%	Moisture content
Physical Characteristics	Shell content of 11-12%	Shell content
Physical Characteristics	Beans uniform in size	Uniformity
Food Safety and Wholesomeness	Essentially free from live insects	Insect and rodent infestation
Flavour	pH value	value between 5 and 7
Food Safety and Wholesomeness	Salmonella content	detection of salmonellosis
Food Safety and Wholesomeness	Cadmium content	> 1mg/kg

A literature review of 53 papers was conducted in order to find adequate testing methods for the defined criteria. The papers were sorted by test, then scanned and disregarded if judged not further relevant. The remaining papers were sorted according to citation metrics. The methods were copied into a file and carefully analyzed for implementation. This analysis was conducted and rated according to:

- Ease and speed of implementation
- Proven record of method (mention in different papers with successful results)
- Limits in testing method due to infrastructure or material lacking
- Amount of knowledge and/or training
- Relevance for industry requirements

Based on this criteria, methods from the following papers were used:

Author	Name of paper	Published in
Ilangantileke S, Wahyudi T & Bailon MG, 1991	Assessment Methodology to Predict Quality of Cocoa Beans for Export	Journal of Food Quality, 14, 481-496.
Jinap S, Thien J & Yap TN, 1994	Effects of drying on acidity and volatile fatty acids content of cocoa beans	Journal of Science in Food and Agriculture, 65, 67-75.
Guehi T et al, 2008	Impact of cocoa processing technologies in free fatty acids formation in stored raw cocoa beans	African Journal of Agricultural Research, 3, 169-176
Shamsuddin SB & Dimmick PS, 1986	Qualitative and quantitative measurement of cacao bean fermentation	Proceedings of the Symposium Cacao Biotechnology, 55–78
Gourieva K.B. & Tserrevitinov O, 1979	Method of evaluating the degree of fermentation of cocoa beans	USSR Patent 64654
Muñoza MS, Cortinaa JR, Vaillant FE & Parraa SE, 2020	An overview of the physical and biochemical transformation of cocoa seeds to beans and to chocolate: Flavour formation	Critical Reviews in Food Science and Nutrition, 60 (10), 1593-1613
Rojas K, Mencia Guevara A, Hernández Aguirre C & Vargas Martínez A, 2019	Transformaciones bioquímicas asociadas a la calidad de algunos grupos genéticos de cacao (Theobroma cacao L.) mediante un proceso de fermentación controlada	
Hernandez C, Viera I, Morales-Sillero A, Fernandez-Bolanos J & Rodríguez-Gutiérrez G, 2017	Bioactive compounds in Mexican genotypes of cocoa cotyledon and husk.	Journal of Agricultural and Food Chemistry, 240, 831-839
Frauendorfer F & Schieberle P, 2006	Identification of the Key Aroma Compounds in Cocoa Powder Based on Molecular Sensory Correlations	Journal of Agricultural and Food Chemistry, 54 (15), 5521-5529

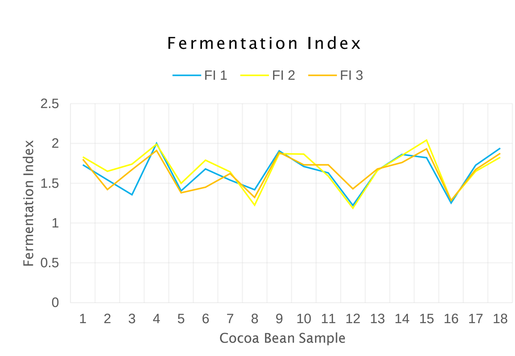
For average weight,100 beans were counted out at random and weighed on a high-precision scale. The weight was noted and the average weight per bean calculated. This was carried out in 2 trials. The average of both trial averages was used as a reference value.

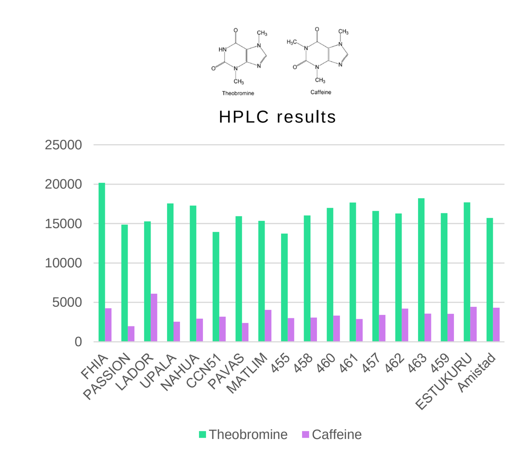
Humidity content of beans was measured using a WILE humidity meter. Two trials were conducted per sample, and even a third trial if the values differed from each other in any of the samples.

The pH value was calculated by weighing 10g of cocoa powder and mixing it in an Eppendorf test tube. The mixture was stirred for about 10 min and the pH value then measured by means of a pH meter.

For FFA content,15 g of cocoa beans were de-husked. Due to the worry that the cocoa could be heated up in the process of grinding and therefore alter in fat content, the method of Guehi *et al* (2008) was adapted and the beans were ground by hand using a mortar and pestle. 10g of cocoa powder was added to an Eppendorf vial and washed 3x with hexane, which was removed using a rotary evaporator until a sample of 5g (weight of cocoa butter, W in formula) of cocoa fat was left. This was dissolved in 50ml of diethyl ether/ethanol mixture (1:1, v/v) neutralized by phenolphthalein. Titration was carried out with 0.1N alcoholic KOH solution used and V was noted.

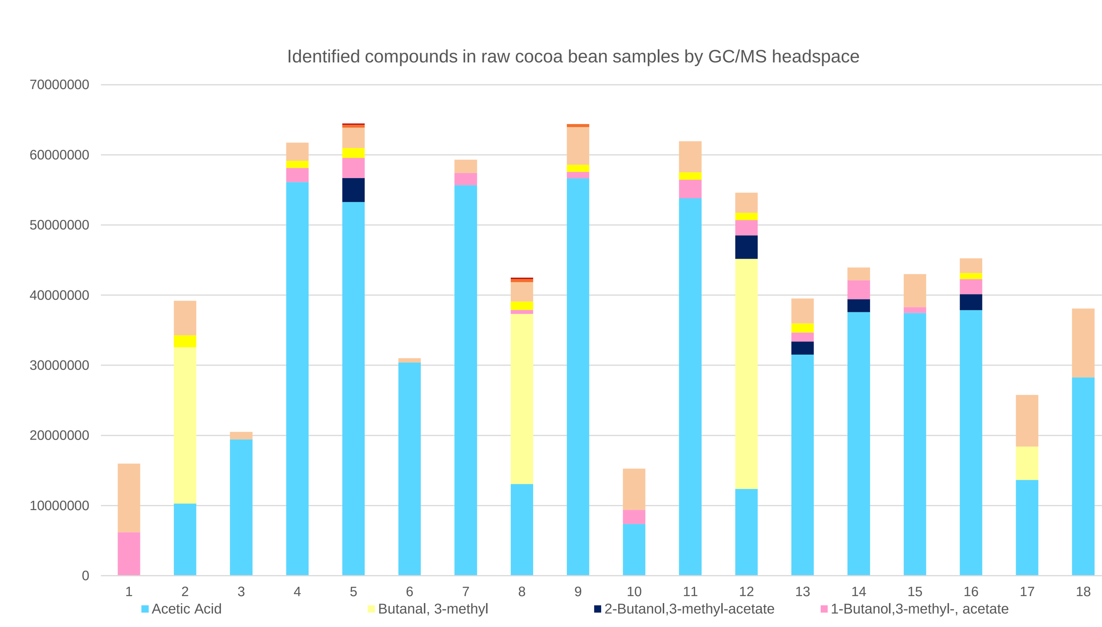
FFA (% oleic acid) was calculated as follows: Free Fatty Acid %=(28.2*V*N)/W





For fermentation index, 0.5g of freeze-dried ground beans were added to 50ml of fermentation index solution (97 parts of methanol ± three parts 30% HCl), then covered with aluminium foil to keep light from entering and stored at 8°C for 18h. Solutions were subsequently filtered to remove any solids and levels were adjusted with the solution to 50ml. Absorbance values were measured by spectrophotometer at 460 nm and 530. 3 replicates were carried out. Fermentation index was calculated as follows: $FI=A_{460}/A_{530}$

HPLC was measured by method of Rojas (2019), using standard solutions of caffeine, (-)epicatechin, theobromine, glucose, fructose, lactic acid, acetic acid and ethanol (Sigma-Aldrich, 99%) The reagents used were hexane, methanol and acetic acid. Grains intended for the analysis of the phenolic compound (epicatechin) and methylxanthines (theobromine, caffeine) were lyophilized (OPERON lifolizer model FDU-7006) for 48h, at Oatm and -83° C. Samples were subjected to extraction with 10ml of methanol-water (ratio 15:6), then placed in an ultrasonic bath at 40° C for 20 minutes and centrifuged at 7830 rpm for 10 minutes. This process was repeated 3x per sample, supernatants were combined and levelled to 27.5 ml and the supernatant then centrifuged again for 10 min at 25° C/7380 rpm. It was filtered through 0.45μm filters and finally incorporated into the HPLC vial.

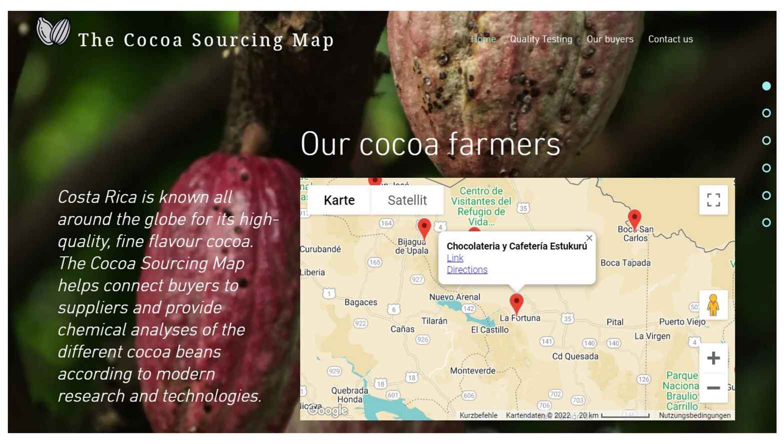


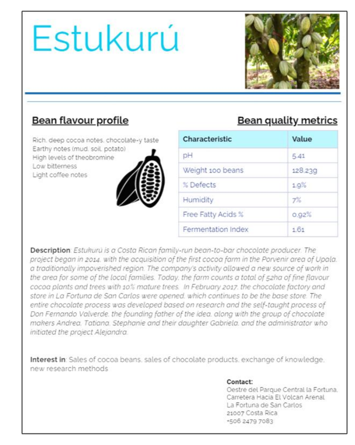
For GC/MS headspace analysis, 2g of cocoa was introduced into a vial, sealed and then exposed in the Agilent 7697A headspace autosampler (HS) at 70 °C in oven for 20 min. 130 °C and 150 °C were set for loop and transfer line. Analysis of volatiles extracted from cocoa powder was performed using an Agilent 7820A gas chromatography–mass spectrometer (GC–MS) in automatic injection mode, on a low polarity fused silica column, 30mm length × 0.25mm internal diameter × 0.25μm film thickness (19091S-433UI, Agilent, Palo Alto, CA, USA). Injection temperature was set at 250 °C. Oven temperature was set at 60 °C for 3 min, increased to 120 °C at a rate of 10 °C/min and then at a rate of 20 °C/min to 200 °C for 6 min. The carrier gas was high purity Helium at 1 mL/min (split injection mode). The selective mass detector was a quadrupole (Agilent, Model 5977b) at the temperature source at 230 °C and the total ion current (70 eV) was recorded in the mass range from 50 to 350 m/z (scan mode) using no solvent delay and a threshold of 150. Volatiles in the headspace were identified according to linear retention indexes (LRIs) and by comparing their mass spectra with the MS database via the NIST 2008 library, Volatile Compounds in Food and Pherobase. By help of literature, aroma notes were identified for the samples as followed:

1	banana, fruity, vanilla, caramel, strong earthy notes
2	rich cocoa, chocolaty, grassy notes, earthy
3	slightly bitter, earthy, potato
4	bitter, grassy, fruity, earthy notes, vanilla
5	bitter, complex, sweet, fruity, banana, rose, honey, flowery, vanilla, caramel
6	slightly bitter, astringent, earthy, potato
7	bitter, astringent, earthy, fruity, caramel
8	rich cocoa, chocolaty, complex, rose, honey, flowery, light fruity notes, grassy
9	bitter, light fruity notes, vegetable, grassy, earthy, fruity, light rose notes
10	fruity, earthy notes, light vanilla notes
11	bitter, fruity, grassy, earthy, vanilla
12	rich cocoa, no astringency, chocolaty, fruity, sweet, banana, earthy, vanilla, caramel
13	bitter, fruity, sweet, caramel
14	banana, fruity, sweet, slightly bitter, caramel
15	lightly sweet, earthy, slightly bitter
16	banana, fruity, sweet, bitter notes, vegetable, earthy notes, caramel
17	bitter, rich cocoa, chocolaty
18	rich cocoa, earthy

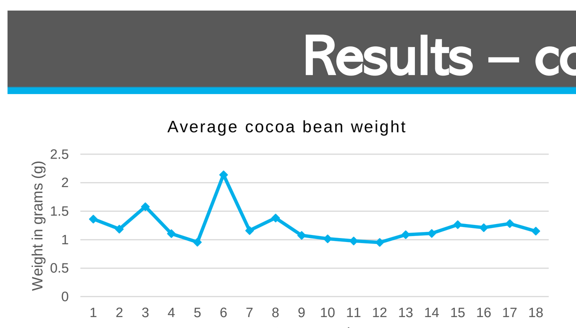
The quality metrics were summarized and mapped digitally on an open-source online platform with the handle www.cocoasourcingmap.com, which includes an overview of the project as well as a map with locations of all cocoa farms involved in the project. In cases where the involved processor has an own website, the prospective websites were linked.

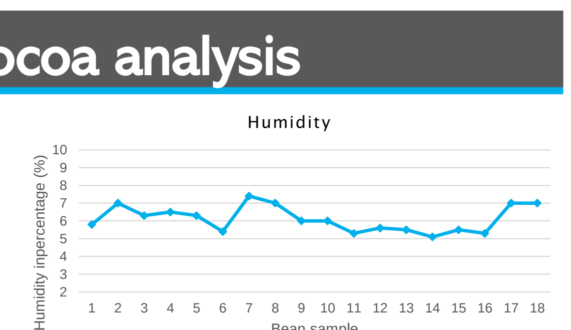
To comply with data protection rules, no contacts of non-businesses were included. As many of the smallholders do not ferment or dry their own beans, they were grouped in cooperatives by lots, as the lots could not be differentiated from one farmer to the next. Fact sheets were created containing the information of the individual lots and uploaded with farmer's consent. Before being published, fact sheets were provided to the farmers to check and give consent.

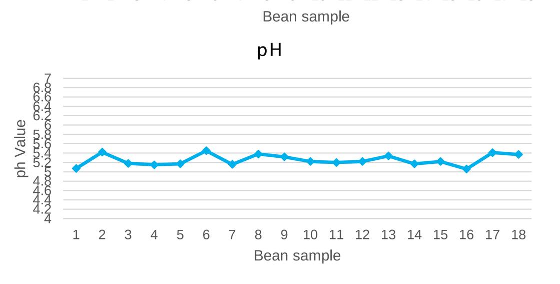


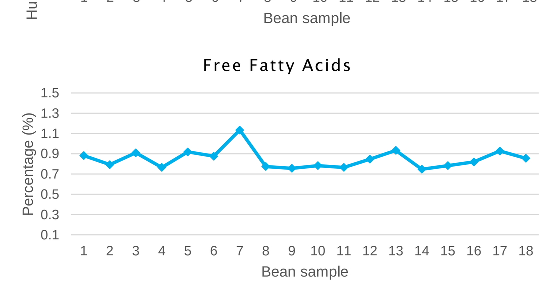


Results – cocoa analysis

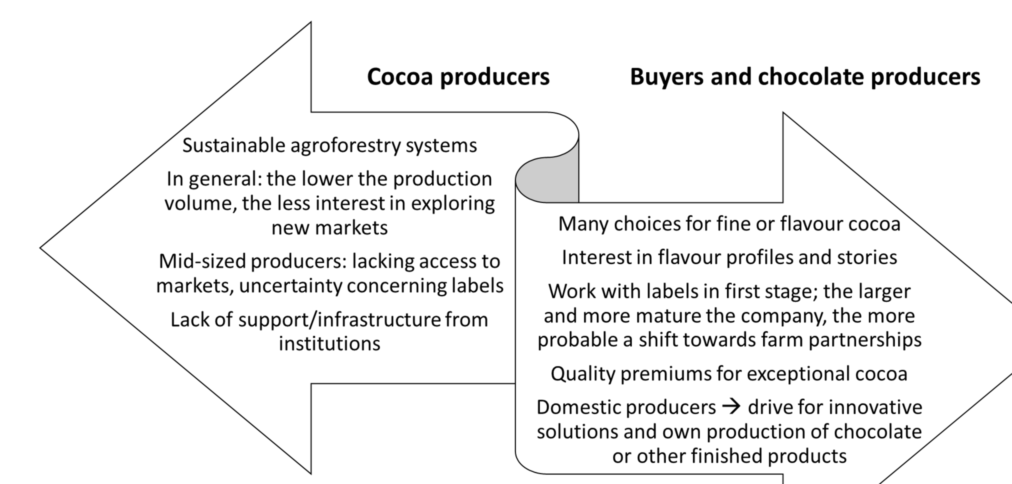








Results – qualitative interviews



Interview results showed that the problem of an oversupply of flavour cocoa and the struggle to find buyers is acute. In order to boost long-term sustainable cocoa production, it is important that these producers can be linked to buyers. To efficiently tackle this issue, multi-stakeholder solutions are required. The interview partners further confirmed that due to an oversaturated market, selecting a new sourcing partner would require unique and interesting flavour profiles, an interesting story behind the beans and an easy and hassle-free process of ordering and shipping.

The farm visits and individual interviews with smallholders showed a great level of interest in the quality tests and the suggested with overwhelmingly positive feedback. While one of the large-scale processors believed they understood the underlying processes «pretty well», most of the others admitted they did not know exactly what occurred during post-harvest practices. « I know what my beans should look like, what they feel and smell like » remarked one farmer. Another stated that they received feedback from buyers. « They tell me when my beans are not good enough but not more » There was no indication of a feedback loop or any of kind of similar feedback system. One of the traders confirmed this by saying « I hear from them if the samples don't pass inspection, which is very rare. If everything is good, I hear nothing » and another went so far as to say: « No feedback is good feedback. »

Discussion

Overall, nearly all of the tested cocoa lots showed good to very good results with low levels of defective beans and free fatty acids and humidity in the desired range, indicating good drying practices. All samples could be classified as slightly acidic, with pH values on the lower range of the scale compared to measures from literature and industry. GC/MS headspace results showed a selection of different fruity and floral notes for the beans, as well as rich cocoa aromas and earthy, soil notes. Acetic acid could be detected in almost all of the samples. Cocoa beans showed distinct differences in most cases regarding total amount, concentration and composition of volatile sensory compounds. One lot which had not previously been exported showed a high amount of flavour notes contributing to a complex flavour profile. This can be seen as an indication that the lacking access to markets and lack of buyers leads to cocoa of high quality going to waste. The testing protocol showed that the industrial quality metrics can be established with the infrastructure provided by the research institutions. The only test which did not prove to yield the necessary or expected results was the Fermentation Index. While this method has proven to be very useful in pilot projects to measure fermentation levels for beans of the same variety, it did not prove to be ideal when comparing cocoa beans of different genotypes sourced from different processing facilities and can only serve to measure fermentation levels of very small samples.

GC/MS headspace holds promising future possibilities which could serve to further strengthen the cooperation between research institutions, the farmers and the industry. Further research is necessary to explore the optimal testing modes for the GC/MS headspace methodology and to further understand the role of volatile and non-volatile compounds in the development of flavour profiles and aroma notes.

Conclusion

Following these findings and recommendations, a subject of continuous future importance in moving towards a promising future for the country's cocoa production is better implementation of farmer training. While farmers and smallholders are usually well connected and maintain good relationships to their trading partners, many smallholders and farmers have no idea about how post-harvesting practices impact the final product. Interviews showed that farmers lack adequate information on impacts of genetic varieties, soil composition and farming and harvesting methods on the bean and its further flavour development. This study illustrates the lesser described problem of the struggle for smallholders to connect to buyers willing to pay higher prices and quality premiums for more exclusive cocoa beans. This issue can have problematic consequences, such as a growing risk of cocoa farmers in Costa Rica turning their backs to the unprofitable agricultural commodity in favour of other, more environmental-unfriendly but more profitable crops, such as pineapple. It is therefore recommended to strengthen the feedback loop between research institutions and their scientists and the farmers and processers.