PHENOMENAL COCOA

Discovery and Valorization of Infinite Fine Cocoa and Chocolate Traits

The Magic of Reality

Albertus Eskes

Copyright Page

ISBN

Albertus Eskes

albertuseskes@gmail.com

Cover Photo

Theobroma cacao and the

Efecadepatos Chameleon

are both able to

Mimic Faraway Attractive features

Key words

- *Genetic Fresh Fruit Sensory Trait Diversity*
- *Induced Fine Flavor Variation*
- *Evolution and Domestication*
- *Cocoa Health Services and Alkalization*
- *Enhanced Fermentation Technology*
- *Transformation of Bulk into Fine Cocoa*
- *Chuncho and Brazilian Cocoa Varieties*
- *Specialty Cocoa Market Paradigm Changes*

PHENOMENAL COCOA

Content

PHENOMENAL COCOA

1. Summary

This book describes the following discoveries of hitherto unknown quality features of ***Her Majesty Cocoa***:

a. ***Sensory traits of fresh cocoa fruits are related to chocolate fine-flavor traits****;*

b. Chocolate sensory traits can be modified by addition of aromatic substances to the fermentation mass ("***TropMix***" discovery) allowing for ***unlimited chocolate sensory diversity;***

c. *Selection* for fine-flavor varieties can be done ***simply and rapidly*** by evaluation of fresh-fruit flavors and aromas;

d. Fresh fruit sensory surveys in Peru and Brazil revealed *43 cocoa fresh fruit flavors and aromas that are combined into* ***72 unique sensory profiles***;

e. Cocoa unveiled that ***all cocoa varieties, including bulk varieties, are fine-flavor varieties*** because all cocoa genotypes express some type of fresh fruit

fine-flavor and aroma traits when fermented with adequate methods;

f. Thirty-one cocoa fresh fruit sensory traits are apparently *full flavors and aromas mimicking perfectly other fleshy fruit and floral plant sensory traits;*

g. *Theobroma cacao* has not developed ***its own specific sensory profile*** like all other fleshy fruits have done;

h. T. cacao unveiled the following two ***fresh fruit product discoveries*** that allow for valorization of the numerous cocoa fresh fruit flavors and aromas:

- ***CacaoNuts (2017):*** 100% "Whole Fruit" product without bitterness and astringency, expressing a strong nutty flavor and fine cocoa pulp flavors and aromas,
- ***CococaPerfume (2018):*** expresses cocoa fresh fruit aromas such as Jasmine, Herbal, Rose and Violet. Persistence is 8-12 hrs. as that of the Channel 5 perfume.

i. ***Last but not least,*** cocoa unveiled recently a revolutionary new fermentation technology, named "***Anima***" (***=Soul***) that transforms bulk and fine-flavor cocoas into extra-fine cocoas.

The potential of Anima is to:

- Boost and diversify specialty cocoa production, and to

- Create ***worldwide large scale fine cocoa bean production segments that do not require the destructive "Dutching" process. Anima products will be 400% healthier and much more savory than the majority of the current industrial cocoa products.***

The above findings warrant important paradigm changes with regard to fine cocoa origins, production and consumption concepts. Fine cocoas will not anymore be directly related to origins, as cocoas worldwide can be transformed into fine cocoas. These include perspectives for ***increased cocoa sustainability*** based on a potentially worldwide increase in cocoa quality and health services and therewith in farmgate prices.

Furthermore, our mainly empirical observations and discoveries ***should invite innumerous scientific studies to be carried out*** aiming at explaining the many challenging sensory quality features of ***Phenomenal Cocoa*** and of ***Anima fermentations***.

2. Introduction

2.1. T. cacao Learnings

During my discovery quest of ***Phenomenal Cocoa*** I could not escape some general learnings:

1. *My first lesson was that the* ***best teacher about Cocoa is Cocoa*** *itself.* It is sufficient to be in contact and listen to her.
2. *Secondly, one should not be limited by pre-existing ideas or dogmas if one wants to discover new things about cocoa.* ***Fortunately, my imagination was not hindered by pre-existing knowledge.***
3. *Thirdly, I learned that it is* ***better to walk alone than accompanied****: alone I can break the rules, accompanied the rules risk to break me.*
4. *Fourthly, all* ***significant discoveries are based on empirical observations, including intuition and emotion, not on science****.*
5. *Fifthly,* ***I could not do any inventions about cocoa, I only just could discover what cocoa had invented long time ago.***

The findings expressed in this book are entirely based on these five axioms.

2.2. Fine and Bulk Cocoas

This book is very much about the ***recognized differences and unrecognized similarities between fine and bulk cocoas***.

Bulk cocoas generally produce strong chocolate flavor while fine cocoas produce less strong ***chocolate flavor but produce axillary flavors and aromas***, such as caramel, almond, fresh and mature fruit, spicy, herbal and floral.

This book demonstrates how phenomenally diverse cocoa is in its fine fresh fruit flavors and aroma production, present in fine cocoa varieties as well as in bulk cocoa varieties. These flavors and aromas enter the beans during fermentation and can be expressed in the chocolates, ***depending on the efficiency of the fermentation technique*** as well as on the chocolate processing method.

2.3. Anima fermentation technology

We then present here a ***revolutionary fermentation technology, called Anima,*** that transforms bulk into fine cocoas. Anima eliminates bitterness and astringency and incorporates the fresh fruit flavors and aromas of any variety in the beans during fermentation, allowing for expression of these flavors and aromas in chocolates.

*This means not more nor less than accepting the fact that all cocoa varieties are fine varieties when using the **Anima** fermentation technology.*

2.4. Presentation of Topics

Before getting into serious cocoa fresh fruit sensory trait descriptions, I wish to define the words ***flavor and aroma*** as they are used mostly in this book. ***Flavor is used here mainly to express fruity flavors*** but also as *basic flavors (acidity, bitterness and astringency), honey/sweet/caramel flavors and nutty flavors*. ***Aromas*** are not only used to express floral aromas but also other aromas identified in

our studies of fresh fruit sensory traits such as *herbal, cinnamon, vanilla, basil, yeast, mint, spices and malt. Typical cocoa flavors as present in chocolates is not dealt with in this treatise.*

I firstly present the reasons why there are supposedly still today 25 times more "bulk" cocoa varieties in the world than "fine" varieties. Only two decades ago, cocoa selection for fine quality appeared to be an impossible task:

1. One reason was that studies on ***cocoa fresh fruit flavors and aromas were completely neglected.***
2. Another reason was that there was ***no adequate technology to select individual trees*** for fine cocoa qualities.
3. Thirdly, there was no ***uniform concept in the cocoa industry sector about which quality traits*** should be selected with priority. Longtime, ***cocoa fat content and strong chocolate flavor*** were the only traits considered, and maybe still are the same main traits considered today.

The findings reported in this book are outdating the above statements and invite the entire fine-flavor cocoa community and industry to follow exiting new paths ***towards large quantities of more savory and much more healthy cocoa products (see Anima).***

The book presents firstly my discovery in 2007 of the direct ***relationship between cocoa fresh pulp flavors and aromas with sensory traits of fine chocolates***. Until then it was erroneously considered that all flavors and aromas in cocoa products were born from precursors formed during fermentation.

On one hand, this has led us to discover the ***"TropMix"*** method patented in the EU in 2009 (WO/2009/103137A2).

This consists of ***modifying fine flavor traits in chocolates by adding aromatic substances to the cocoa mass during fermentation*** described in Chapter 6.

On the other hand, the fresh fruit sensory trait relationship with fine chocolate sensory traits invited us to carry out ***surveys on identifying genetic new cocoa fresh fruit sensory traits*** in fine as well as in bulk varieties.

The ***first systematic survey*** carried out in 2015/16 led to the discovery of 40 fresh cocoa fruit sensory traits in the fine Chuncho variety in Cusco, Peru. Many of these were later identified also in commercial "bulk" and fine varieties in Brazil in 2017-2019. Valorization of these identified traits could potentially create much more ***diversified and enlarged fine-flavor cocoa quality markets***.

I then present a large Chapter called "***Fine Cocoa Magical Mystery Tour***" with more than 20 Stops Over. Each reveals specific surprising and often mysterious quality features of ***Phenomenal Cocoa*** expressed in different cocoa producing countries which are compared to features of other fleshy fruit species including wine grapes.

A Chapter is dedicated to ***cocoa fresh bean stress reactions*** which are expressed as rapidly increased bitterness and astringency intensities. These are likely related to the ***natural cocoa seed defense mechanisms*** in the wild and likely also to the ease with which raw beans with low basic flavors can be obtained during fermentation.

Afterwards, I present three significant discoveries:

- ***CacaoNuts,***
- ***CocoaPerfume*** and the
- ***Anima fermentation technology***.

These discoveries only make full sense because they ***allow for valorization*** of the large cocoa fresh fruit flavor and aroma panoply identified before.

The ***CacaoNuts*** consist of 100% ***nicely tasting*** "***Whole Fruit" natural cocoa beans*** but ***do not have any bitterness nor astringency*** while containing ***twice as much as anti-oxidants*** as the best natural chocolate.

The ***CocoaPerfume*** comes in ***six or more fragrancies***, such as lily, jasmine and rose. The persistence on the skin of the rose CocoaPerfume is 12 hours, equaling that of the Channel 5 perfume!

These two products can be simply and exclusively made on cocoa farms. Once markets will have been created for both products the sustainability of cocoa farming can be expected to become improved.

Last but not least, I am presenting the ***Anima fermentation technology*** discovered between 2017 and 2019 in Brazil. **"*Anima*"** means *"**Soul**"* (in many religions) as well as *"**Spirit of the Forest**"* (in Africa).

Anima transforms bulk and fine cocoas in extra-fine cocoas. This new technology allows for expression of the large number of flavors and aromas of fresh cocoa fruits discovered as being part of ***Phenomenal Cocoa.***

Anima chocolates also express strong ***caramel and almond*** flavors that recall the pure Criollo chocolate sensory traits. This means in a way to go ***"Back to the Future of Criollo Cocoa"*** by using Anima fermentations. ***Anima's cheap and relatively simple usage would allow it to become the pillar of a future mainstream fine cocoa market segment.***

Importantly, Anima beans do not need the commonly applied ***Dutching*** process in cocoa industries. Dutching eliminates negative sensory traits (acidity, bitterness and astringency)

but also all positive features (flavors, aromas and 80% of the anti-oxidants). So, Anima beans have the potential to ***modify the entire cocoa market reality*** by creating mainstream fine cocoa production chains. Such would allow to produce ***high quality cocoa products with* ca. *400% higher health services than found in current industrial cocoa products.*** These considerations should receive large interest from cocoa industries and from consumers once they become aware of the enormous quality and health potential of Anima cocoas.

Working with Cocoa is never just technical, it involves *intuitive, passionate and lyrical instincts* that I am releasing here in three poems revealing the true subjective nature of ***Her Majesty Cocoa*** regarding:

1. Her ***Feminine*** nature,
2. Her ***Flavor and Aroma Identity,*** and
3. Her pathway towards the end ***of the Glacial Cocoa Era***.

It is also a pleasure for me to intermingle the text with extracts of ***"Sentences Unlike Sentences"*** (*Statements Unlike Judgements*) that present wisdoms inspired by ***Phenomenal Cocoa*** about causal and consequential truths that let us reflect about life opportunities

I wish you a pleasant reading of this treatise on ***Phenomenal Cocoa***. I trust that in the end you will agree to her Majesty's Status as identified by me!

3. Cocoa is a Woman Being

Cocoa is "The Cocoa"!

Cocoa is Mysterious

Cocoa is Affectionate

Full of Feminine Flavors

Full of Feminine Aromas

Cocoa has a Skirt

Made of leaves, and

Cocoa has for sure a PLACENTA

Of a Woman

It took me 40 years to unveil Her Secrets

It was the *Inca* Cocoa

Called "Chuncho" (="From the Forest")

That invited me to Know Her Better

In Cusco, Peru

I discovered first that Chuncho was
Not the "Food of God"

But rather it was the food of the

Native "Matsigenkas" ("*Human Beings*")

That Savored ever Since

And Still Savor Her Pulp

And Her dry Beans Today

That they Sold once to the *Incas*

It was the "Human Beings"

That choose the most Delicious Cocoas

Planting them in the "*Gardens of the Matsigenkas*"

Around their Dwellings in the Forest

With 40 *SuperNatural* Flavors and Aromas

That Chuncho revealed to me

By Opening, Smelling and Tasting

Its Sweet Fresh Fruits

The Pandora Wish Boxes

It was the *Incas* that consumed

The beans of the "Human Beings"

In Spiritual Sessions

Together with the Bitter but Divine Coca Leaves
Dominated by the Female Sweetness
Of the Aromatic Chuncho Cocoa Beans
Of the "*Human Beings*"
Which is a Game of Domination
Between the Sweet Feminine Cocoa
And the Bitter Masculine Coca
A Divine Drug Full of Love

Cocoa is the "Soul of the Woman"
Cocoa is also the "Spirit of the Forest"
She is the "Ánima" that Animates
The Souls of the Male and Female Human Beings

Cocoa, Food of the *Incas*
And of the "*Human Beings*"
And of all *Other Human Beings*
Should receive a New Specific Name
Instead of *Theobroma cacao* Linaeus
(= "Food of the Gods")
It should be "*Humanbroma cacao* Eskes"
(= "Food of the Human Beings")

"Broma" means also Joke in Spanish

But Cocoa is not a Joke at all!

A Joke is the Human Being

That does not like the

***Cocoa Woman Being*!**

Ceramics Sculpture by Albertus Eskes

According to an Original
Leonard da Vinci Drawing of a

Woman as Perfect as Cocoa

4. Common Notions on Fine Cocoa Qualities

4.1. Fine and Bulk Cocoas

The cocoa (*Theobroma cacao* L.) market distinguishes between "bulk" and "fine-flavor" cocoas with bulk cocoa representing 95% of the world cocoa market. The fine-flavor cocoa might correspond currently to *ca.* 220,000 tons annually. The bonus paid to farmers for fine-flavor cocoas varies from +15% to +300 % (Pipitone, 2016).

Fine-flavor chocolates have generally variable fruity flavor and/or flower/spicy aroma expressions, besides the typical “cocoa” flavor. Chocolates from bulk cocoa varieties fermented traditionally do generally express just cocoa flavor (Pipitone, 2016) but no fine-flavor traits.

In this treatise on fine cocoa flavors and aromas I do not include the typical cocoa flavor.

Fine-flavor cocoa has historically been provided by the Criollo, Trinitario and Nacional varieties. More recently also by hybrids with the SCA6 genotype (TSH clones in Trinidad) are included. Furthermore, varieties fermented with ***innovative fermentation technologies*** are considered as fine flavor cocoas (see *eg*. ***Anima*** fermentations later on).

4.2. Recognized Expressions of Fine Cocoa Flavor Traits

Fine-flavor cocoa varieties express variable fruity flavor and/or aroma traits. Each fine chocolate may have its specific sensory traits identified by different chocolate connoisseurs in very different ways. Main sensory descriptors used in chocolate evaluations are *acidity, bitterness, astringency, sweet/caramel, nutty/almond, fresh fruit, brown fruit, woody, spicy and floral* (Sukha and butler, 2005).

Additional descriptors vary widely in identity depending on the more or less trained cocoa connaisseurs. Two student panels tasting six dark chocolates identified with low discriminative power the following axillary sensory traits (Thamke *et al.*, 2009): *citrus, herbal, plum, cinnamon, earthy, mint, olive and vanilla*. Barry Calebaut developed a more complete chocolate sensory trait wheel with the following aroma descriptors: *lavender, rose, violet, jasmine, liquorice, clove, cinnamon, ginger, nutmeg, black pepper, coriander, rosemary, woody, whiskey, rummy, tobacco, mushroom, olive, bergamot, tamarind, mandarin, orange, lemon, lime, strawberry, raspberry, cherries, grapes, coconut, banana, mango, pineapple, pear, apple, peach, apricot, figs, dates, raisin, prunes and vanilla.*

So far, there has been no consensus about the origin of the different aroma identities of chocolates.

4.3. Cocoa Fine Quality Selection until 2015

Variation for fine flavor traits has longtime been considered with exclusive reference to the three traditional fine cocoa varieties ***Criollo, Trinitario and Nacional.*** These display the following five sensory traits: *caramel and nutty in Criollo, fresh fruit and floral in Trinitario and fruity, herbal and floral in Nacional*. When interested in developing fine cocoa production the trend has been to recuperate and/or extend plantations with one of these varieties.

Cocoa industries have always stressed and still do stress the interest of selecting varieties that display high “cocoa” flavor intensities in their chocolates. It is generally considered that commodity varieties, such as the African varieties, display higher cocoa flavor intensities than the traditional fine cocoa varieties.

Identification and selection of fine cocoa traits has been hampered by (Lockwood and Eskes, 1995):

1. ***Lack of knowledge on the diversity, on the expression and on the genetic basis of fine flavor traits,***
2. ***Differences in quality objectives among chocolate manufacturers,***
3. ***Lack of efficient individual tree screening methods, and***
4. ***Expensive evaluation of chocolate qualities considering the need of sensory panels***.

Objective breeding towards fine-flavor quality varieties over the last century has probably been restricted to the ***phenotypic selection*** over the last 50 years of the TSH varieties in Trinidad that do express high-quality multiple-trait pulp and chocolate sensory profiles. Such can be considered to have been a collateral consequence of the fortuitous use of flavorful parental varieties in the TSH breeding program that aimed mainly at yield potential and disease resistance including SCA6, Trinitario and some Forastero genotypes.

The selection for yield and resistance alone has occasionally resulted in lower than average bulk cocoa quality, as is the case with the CCN51 clone selected in Ecuador in the 1980’s.

4.4. Neglect to Cocoa Pulp Sensory Traits

The mucilaginous cocoa pulp is composed of spongy parenchymatous cells containing cell sap rich in sugars (10 to 13%), pentosans (2 to 3%), citric acid (1 to 2%), and salts (8 to 10%). The main role attributed to cocoa pulp has been to provide the ***essential substrate for microorganisms*** to develop, during fermentation, the chocolate flavor precursors that react forming cocoa flavor components during the roasting process (Figueira *et al*., 1993). Most chemical studies on cocoa aromatic substances and are related to the numerous precursors and compounds of the typical cocoa aroma in chocolates.

More recently, there have been a few publications on volatile organic compounds (VOCs) present in cocoa pulp (Pino *et al.* 2010; Kadow *et al.* 2013; Chesnik *et al*. 2018 and Castro-Alayo *et al*., 2019) that are not be related to chocolate aroma. These consider mainly the presence of aroma VOCs or precursors present in pulp or produced in pulps during fermentation, but *without considering the predominant full flavor and aroma nature of pulp sensory traits found in our studies.*

The ***effect of cocoa pulp sensory traits on fine-flavor chocolate*** qualities has only more recently received attention by our empirical studies. Visitors to cocoa plantations might be familiar with the broad variation in cocoa pulp flavor and aroma. The most conspicuous variation is for acidity and sweetness. A few clones such as SCA6 and EET62 have been known since long to have very flavorful and aromatic pulp.

Our Chuncho survey (Eskes *et al*., 2018; see further down) represents the ***first systematic study in*** **Theobroma cacao** ***demonstrating the feasibility of genetic single-tree***

diversity evaluations and selection for pulp and raw bean flavors and aromas in any genetically diverse cocoa population.

5. Pulp Sensory Traits Are Fine Chocolate Traits

5.1. Discovery

Regular tasting of cocoa pulp by me in 11 cocoa producing countries led in 2007 to the assessment that:

"***Countries that Produce Fine Cocoas and Chocolates Grow Varieties that Have Nice Cocoa Pulps*".**

Examples of countries that grow cocoa varieties with nice pulp are Trinidad, Ecuador, Venezuela and Peru. These countries are well-known for their fine and specialty cocoa production.

This reasoning lead to the hypothesis of a:

"***Fine-flavor Pulp* vs *Fine-flavor Chocolate Relationship (Eskes et al. 2007 and 2012)"***.

An extreme case was that of ***Trinidad*** with very delicious complex fresh pulp flavors that I savored every time when visiting the country as a special snack. At that time, Trinidad received a bonus of 200% paid for the fine TSH varieties. This is one of the highest bonuses paid worldwide.

So, according to my hypothesis, ***varieties with nice pulp produce fine cocoa beans that may well fetch higher cocoa prices.***

5.1. Traditional Fine Varieties

Well-known pulp and chocolate sensory traits (Sukha and Butler, 2005) of commercial fine-flavor varieties are presented in Table 4.1. These are uniformly expressed in trees within uniform varieties (Criollo, Nacional and the Sca6 clone), demonstrating the ***genetic nature of such sensory traits***.

The chocolate sensory profiles "***caramel", "fresh fruit", "floral, fruity" and "brown fruit/raisin/floral"*** are apparently related to the pulp sensory profiles ***"very sweet", "Lemon", "Jasmine, fruity" and "Muscat grape/lily"***, respectively. Ancient Criollo pulps and chocolates both do not express fruity flavors nor aromas.

These comparisons confirm the existence of a ***pulp flavor and aroma vs chocolate fine-flavor relationship***, be it with certain modifications such as the grape flavor of SCA6 that is transformed into the related brown fruit/raisin flavor. Such transformation is likely caused by the chocolate processing method including the roasting process. The ***nutty Criollo chocolate flavor is not present in the fresh pulp*** and is supposedly formed only during post-harvest processing.

Table 5.1. Comparison of known chocolate and pulp sensory traits for traditional fine-flavor cocoa varieties and for SCA6

Variety	Pulp flavor/aroma	Chocolate flavor/aroma
Ancient Criollo	Very sweet, no flavors nor aromas	Caramel/honey, Nutty
Trinitario	Citrus flavor, balanced sweet/acid pulp, Jasmine	Fresh fruit, floral
Nacional	Jasmine, fruity sweet pulp, herbal	Floral, Fruity, herbal
SCA6 (clone)	Muscat grape flavor, Lily aroma	Brown fruit or raisin, Floral

5.3. Opportunities

The pulp *vs* chocolate sensory trait relationship that we discovered opened two great opportunities for valorization of sensory traits in the fresh fruit pulp environment:

1. ***Modification of the pulp environment by adding foreign substances (TropMix method),***

and

2. ***Rapid evaluation of new fine-flavor cocoa varieties based on pulp sensory studies.***

6. TropMix Technology

Modification by *Simply* Adding Natural Aromatic Substances During Fermentation (WO/2009/103137A2 and Eskes *et al*., 2012)

6.1. Scope

Research Gate calculated that the ***"Eskes et al. 2012"*** paper ("*Evidence on the Effect of the Cocoa Pulp Flavor Environment during Fermentation on the Flavor Profile of Chocolates"*). ***has been read by 1500 persons*** in 9 years as compared to an average of 100 reads for each of my other 150 publications. **This is explained by the innovative character of the paper.** Curiously enough, nobody ever contacted me on the paper or had any questions. This is the reason for me to reproduce here the most important part of the paper, ie. ***obtaining of fine flavor cocoas by addition of natural aromatic substances during fermentation of bulk cocoas (TropMix).***

6.2. Objective

The objective of the study was to determine the effect of the cocoa pulp flavor environment on the final flavor of the nibs and/or chocolates prepared from the fermented and dried cocoa through adding of aromatic pulp of three fruit species and of one spice to the wet beans of the Forastero cocoa variety Amelonado during the fermentation process called "***TropMix".***

6.3. Methods

Pulps extracted from fruits of two aromatic tropical fruit species, *Theobroma grandiflorum* (Cupuaçu) and *Anona muricata* (Soursop Graviola or Guanabana), were used in mixtures with cocoa beans under micro-fermentation conditions. The fermentation mass was

made up of wet cocoa beans of the Amelonado cocoa type ("Comum" variety) from the farm "Boa Sorte" in Uruçuca, South Bahia, Brazil. The Amelonado variety, when fermented traditionally, displays generally little or no fruity flavor nor aroma.

The fermentations were carried out in a wooden box of 50x50x50cm that was filled with healthy Amelonado wet cocoa beans. The fermentation mass was turned at 48, 72, 96 and 120 hrs and total fermentation duration was 6 days. The micro-fermentations were carried out by placing one kg of wet cocoa beans, mixed with an equal quantity of aromatic pulps of Cupuaçu and of Soursop, in polystyrene netted bags in the middle of the fermentation mass. The treatments were applied, each with two replicates, at 24 hrs and 28 hrs after initiation of the fermentations:

- *Treatment 1 (control).* Micro-fermentation of a sample of one kg of Amelonado cocoa beans inserted inside the mass at 24hrs.
- *Treatment 2.* Two micro-fermentations with Cupuaçu pulp placed in the middle of the fermentation mass at 24 hrs.
- *Treatment 3.* As treatment 2 at 48 hrs.
- *Treatment 4.* Two micro-fermentations with Soursop pulp placed in the middle of the fermentation mass at 24 hrs.
- *Treatment 5.* As treatment 4 at 48 hrs.

The micro-fermented and sun-dried cocoa bean samples produced by these five treatments were sent to Montpellier, France, in May 2007, where raw bean nib flavor traits were assessed in May 2007 by me and by Sophie Assemat at CIRAD. Cocoa liquors and 65% cocoa finished chocolates were made by Ed Seguine at the Guittard Chocolate Company in September/October 2007 with beans from the five treatments.

Ed Seguine carried out a descriptive sensory evaluation of the liquor and chocolate samples and the chocolates were sent by Guittard to Montpellier in November 2007. The chocolate samples

were evaluated for flavor traits by me and by Sophie Assemat and for preference by an amateur public jury in Montpellier early 2008.

6.4. Additional fermentations

The inventors applied separate fermentations of Amelonado cocoa beans (the same as used in Example 1) alone or mixed with another four natural flavorings. The four flavorings used were three juices made with fresh pulp of aromatic fruits species (*Theobroma grandiflorum* or Cupuaçu, *Annona muricata* or Soursop and *Genipa americana* or Genipa) and one juice made with ginger rhizomes (*Zingiber officinale*). The fermentations were carried out in polystyrene boxes, the bottoms of which were pierced to allow fermentation fluids to drain away. Small holes were also present in the lateral walls and in the lids of the boxes to allow for adequate aeration during the fermentation process. The size of the boxes was 28 l for the mixed cocoa/fruit-juice fermentations and 8 l for the mixed cocoa/ginger-juice fermentation as well as for the control treatment (fresh cocoa beans alone). The fruit pulps and ginger rhizomes were transformed into concentrated juices in a blender by using a minimum amount of water. The juices were added to the cocoa beans 48 hrs. after the start of the fermentation process in the amounts of 10% (v/v) for the fruit juices and 5% (v/v) for the ginger juice. The cocoa beans were turned four times, at 48 hrs., 72 hrs., 96 hrs. and 120hrs after the start of the fermentation. After 6 days (144 hrs.) the fermentations were stopped and the cocoa beans were dried in the sun for 8 days until reaching about 8% humidity.

Sensory evaluations of the nibs of the dry beans were carried out by two experienced cocoa researchers familiar with the taste of fermented and dried cocoa beans and with the flavors of the added fruit pulp and ginger juices.

6.5. Results

The nibs obtained from the mixed cocoa/fruit-juice fermentations possessed fruity flavors resembling the flavors of the respective fruits used (Table 6.1). The nibs of the dry beans of the mixed cocoa/fruit-juice fermentations were somewhat bitterer and more astringent than the nibs of the control fermentations.

The main effect of the aromatic pulp addition during the cocoa fermentation process was related to fruity flavor traits (Table 6.1). The effect of the Cupuaçu pulp appeared to be stronger than that of the Soursop pulp. This is in agreement with the intensity of the typical flavors of these fruit species, with the Soursop flavors being milder than the Cupuaçu flavors.

The addition of aromatic pulps also appeared to reduce cocoa flavor intensity and to increase the astringency of the chocolates. These secondary effects might be caused by transfer of astringency from the aromatic pulps to the cocoa beans, or due to a modification in the fermentation conditions caused by the addition of the aromatic pulps. High levels of astringency have been associated with low intensity of cocoa flavor in other studies on cocoa quality.

The slight fruity flavor identified in treatment 1 (control) appeared to be complex in nature. It might in fact be a mixture of the flavors from Cupuaçu and Soursop, which resulted from some transfer of fruity flavors between the micro-fermentation bags.

6.6. Effect of the timing of the micro-fermentations

The slightly stronger fruity flavor intensity found in the nibs as well as in the chocolates for micro-fermentations initiated 48hrs instead of 24hrs after the beginning of the fermentation process (Table 6.1) might well be related to the germination process of the cocoa beans. The speed of uptake of soluble compounds by the cotyledon during fermentation is governed by the opening of the testa, as caused by

the germination of the cocoa beans occurring during the first two days of the fermentation process.

The ***additional fermentations*** carried out in polystyrene boxes resulted in similar modifications of the respective nibs, demonstrating that 5-10% fruit juice is enough to modify the flavor of the nibs. In later experiments we have even found significant effects with 3-5% fruit juice and even less than 0.5% for spice additions.

6.7. Applications

The pulp vs. chocolate fine-flavor relationship has opened the way for two important applications:

1) Chocolate flavors can be modified ***simply, but substantially,*** by ***adding natural aromatic substances to cocoa beans during the fermentation process.*** The further development of such an innovative way to produce cocoa liquors and chocolates with enhanced and/or modified flavor profiles is expected to have important ***commercial applications***. It would also provide new opportunities for the use of regional aromatic tropical fruit pulps that are often under-utilized and under-valued ***to create "Terroir" products.***

2) ***Rapid and simple screening*** of germplasm and of breeding populations for pulp characteristics are warranted ***to select cocoa varieties that display good potential for known as well as for new fine flavor traits,***

Table 6.1. Results of sensory evaluation carried out at CIRAD, Montpellier, of cocoa beans and chocolates obtained from Amelonado cocoa beans fermented alone (Treatment 1), or in mixture with pulp of Cupuaçu (Treatments 1 and 2) and of Soursop (Treatments 4 and 5) added to the cocoa beans 24 or 48hrs after initiation of the fermentation process, respectively.

Treatment	Flavor type	Nibs (0-5 scale)	Chocolates (0-5 scale)
1	Fruity (complex)	0	1
	Cocoa flavor	-	3
	Astringency	-	1
2	Fruity (Cupuaçu)	2	4
	Cocoa flavor	-	2
	Astringency	-	2
3	Fruity (Cupuaçu)	3	5
	Cocoa flavor	-	2
	Astringency	-	3
4	Fruity (Soursop)	1	2
	Cocoa flavor	-	2
	Astringency	-	4
5	Fruity (Soursop)	2	3
	Cocoa flavor	-	2
	Astringency	-	3

Comment 1

The only recurrent problem with the first generation of TropMix fermentations were the relatively high levels of bitterness and astringency as a collateral effect of fruit additions. This was the main reasons why we developed the accelerated Anima fermentation technology that eliminates bitterness and astringency even in the presence of fruit juices and/or spices (See later on).

Comment 2

Research Gate revealed that the Eskes* et al. *2012 publication has been read by 1600 people whereas any other publication of mine received in average only 50-100 reads. This apparent recognition of the innovative nature of the publication was not followed by any questions or comments.

Comment 3

ValRhona in 2016 launched two TropMix products, one with orange flavor from Madagascar and one with passion fruit from Brazil. The company presented these products as obtained by double fermentation which is intrinsic part of the TropMix patent claims. Until today they insist on social media that they have invented the method during 10-year studies!

7. Sentences Unlike Sentences 1

(Statements Unlike Judgments)

To Make a Mistake
Is Human
To Insist in the Mistake
Is Devilish

What Bothers Me
Is People that do not Bother

I Prefer to Bother
Than to Accommodate

If All of Us
Would be Able To Bother
With Some Cause
The World Would be
Less Bothering

An Accommodated World Dies
Long Live a Bothering World

The Delight is Infinite
Satisfaction has a Short Duration

An Unsatisfied Man
Is a Hell for his Wife

It is Easier to Meet a Delightful Woman
Than a Delightful Man

Anything You do in Life
Do it Full of Sense
The Feast of Senses Makes Sense

Better Enjoying
A Short Life
Than an
Unhappy Long Life

Black is the Color of Life
White is the Color of Death
Red the Color of Energy
According to Sacred African Traditions

I am not Here not There
Which is the Best Place
For a Flying Dutchman To Live

Becoming Older
Is Becoming Younger

If Cacao Cured Two
Chronical Diseases of Mine
Why not
My Third Disease?

The Objective in Live
Is to Attain Emptiness
Of the Spirit
And of the Body

Before Dying The Emptiness
Is Waiting for Us As a Prize
After a Life Lived Full of Life

The Emptiness
Is Full of Chaotic Energy
Of the Origin
And of the End of Life

Emptiness is the Plenitude
Where the Empty Persons
Arrive After Death

Nothing Can Impede
The Human Being
From Being Happy
Except His Own Stupidity

The Principle
Of Logic
Is Illogic

In the Same Way
As the Origin
Of the Universe Was Chaos

8. Genetic Fine Cocoa Quality Determinations

8.1 Supposed Environmental Effects

Some six month ago I assisted a video featuring a famous French fine chocolate maker walking inside a CCN51 plantation in Ecuador where he buys raw beans from. In the video he exclaims: "*How good to see the cocoa trees associated with aromatic timber trees and flowering plants. All these* ***environmental flavors and aromas will be expressed by the cocoa beans and chocolates made from these beans***".

He expressed the widespread believe that fine cocoa flavors and aromas are born from environmentally determined factors.

How erratic this is was shown by us when we identified a very large number of genetic flavors and aromas in the Chuncho variety in Cusco, Peru (Eskes et al., Agrotropica 30: 157. 2018, On line) (See further down). However, the most common comment to our publication was, *eg.* when demonstrating the mandarin pulp flavor in more than 10 cocoa trees: ***"But there must have been mandarin trees in the neighborhood of the mandarin flavor expressing cocoa trees".*** Unfortunately for our interviewers there were no such trees in the far neighborhood of the trees expressing all 40 fresh fruit flavors and aromas.

So, there are no environmental effects on flavors and aromas. These effects must therefore be genetic.

Exceptions may be occurring when cocoa wet beans or dry beans come in contact with aromatic substances during processing. I once saw pods of the Nacional variety in Ecuador being opened in a field with the strong ***spicy coriander plants*** growing commonly in between the cocoa rows that may enter into contact with the wet beans during pod breaking contaminating them with their aroma.

Nestlé doing a sensory study on "Arriba" flavors in the 1990's was convinced of a ***spicy flavor in Nacional chocolates***. This might have been due to what I had seen in Nacional fields. "Pure" Nacional does generally only express floral (jasmine), herbal and fruity as genetic flavors and aromas.

Happily, ***Cocoa decided to express its fine cocoa flavor and aroma traits in its most simple way: as simply inherited qualitative genetical traits that are very easy to select for (see below).***

8.2 Fine and Bulk Cocoas

The cocoa (*Theobroma cacao* L.) market distinguishes between "bulk" and "fine-flavor" cocoa with bulk cocoa representing 95% of the world cocoa market. The fine-flavor cocoa might correspond currently to *ca.* 220,000 tons annually. The bonus paid to farmers

for fine-flavor cocoa varies from +15% to +300 % (Pipitone, 2016). Fine-flavor chocolates have generally variable fruity flavor and/or flower/spicy aroma expressions, besides the typical “cocoa” flavor. Chocolates from bulk cocoa varieties fermented traditionally do generally express just cocoa flavor (Pipitone, 2016). Fine-flavor cocoa has historically been provided by the Criollo, Trinitario and Nacional varieties and, more recently, by hybrids with the SCA6 genotype (TSH clones in Trinidad) and also by bulk varieties fermented with ***innovative fermentation technologies*** (See ***Anima*** fermentations later on).

9. Simple Cocoa Quality Selection

By Pulp Fine Flavor and Aroma Traits (Eskes et al., *2007 and 2012)*

19.1. Introduction

Cocoa breeding is complex, as many traits need to be selected for simultaneously. Traditional selection for special flavor attributes is a laborious and time-consuming process that requires collaboration between breeders, specialists in post-harvest technologies, sensory specialists and chocolate manufacturers. Most cocoa selection programs do not have the capacity to carry out routine sensory evaluations of liquors or chocolates made with individual genotypes (trees) in their collections or in the breeding populations. These factors reduce the efficiency and speed of progress in the selection of fine flavor cocoa types, especially if this trait is to be combined with good yield and resistance to diseases. Therefore, the use of a quick method to identify special flavor traits of cocoa genotypes would be very useful in more effective comprehensive cocoa breeding.

The first objective of the current study is to ***assess if variation in sensory traits of the pulp in ripe cocoa pods from different genetic origins are related to the known variation of fine flavor traits of different cocoa varieties.***

The second objective is to identify how selection for the pulp flavor and aroma traits can be best included into the cocoa breeding activities.

9.2. Methods

In September 2007, an experiment on flavor attributes of ripe pulp of 9 different cocoa types from the cocoa genebank of the

Universidad Nacional Agraria de la Selva in Tingo Maria, Peru, was carried out. The varieties chosen included genotypes that are known to vary for fine flavor attributes (Table 9.1).

- EET 62 is associated with the Arriba floral flavor;
- ICS1 is a typical Trinitario with fruity flavor;
- The CCN51 clone is known as a bulk cocoa variety with acid pulp and bitter/astringent fresh beans;
- The Ucayali (U) and Huallaga (H) clones represent sub-spontaneous and cultivated origins collected in the Huallaga and Ucayali river basins, respectively The Huallaga accessions appear to be mainly true "Forasteros" while the Ucayali accessions are somewhat related to SCA6.

Two ripe pods of each of nine clones were collected in the morning and placed in the laboratory for sensory evaluation of the pulp and beans in the afternoon. The panel consisting of six persons scored on a 0-5 point scale:

- intensity of volatile Aroma (odor) when opening the pod,
- pulp Acidity,
- pulp Sweetness,
- pulp Astringency,
- bean Bitterness/Astringency,
- Fruity pulp flavor,
- the type of Fruity flavor, and
- overall Preference

The panelists had been given previous experience in evaluating pulp flavor differences in the field.

9.3. Results

9.3.1 Pulp sensory traits are discriminative varietal traits

Discrimination level between the 9 varieties was high for all traits (P=0.05), with group means varying from a to d (Table 9.1). Discrimination between varieties was highest for pulp astringency (F=13.8) and lowest for pulp sweetness (F=3.5). Differences

between panelists were not significant for overall preference, pulp acidity and pulp sweetness suggesting that these traits were evaluated in a uniform manner by the panelists. Overall preference scores were positively related to pulp odor, flavor and sweetness

Table 9.1. Sensory preference and associated traits for pulps of nine cocoa genotypes evaluated in 2008 in UNAS, Tingo Maria, Peru, by six panelists

Clone	Pulp description	Preference
EET 62	Aroma, fruity and sweet	**4,3 a**
Pandora 1	Sweet, Soursop flavor	**3,2 b**
ICS 1	Sweet/acid, citric (lemon)	**2,7 bcd**
U 43, 45, 53	Sweet and intermediate flavor	**2,6 bcd**
H 56, 60	Astringent, acid, low fruity	**2,1 bcd/d**
CCN 51	Astringent, acid, low flavor, very bitter/astringent bean	**2,0 cd**

intensities and negatively, but not significantly, to acidity and astringency (Figure 9.1). Pulp acidity and astringency and bean bitterness/astringency were positively correlated with each other and negatively correlated with pulp sweetness. Highest average pulp preference scores were obtained for EET62 (sweet pulp, strong flavor and odor, high preference). Preference of the clones differed significantly and varied from 1.8 (CCN51) to 4.3 (EET62).

The PCA in Figure 1 shows *on the one hand* that ***bean bitterness, pulp acidity and pulp astringency*** were related among each other and to the CCN51, H56 and H60 clones. These clones received Preference scores of 2.0, 1.8 and 2.3, respectively, with a *mean of 2.3*. ***This is in agreement with the "Forastero" type of the H56 and H60 varieties and with the bad quality reputation of CCN51.***

On the other hand, the PCA shows that ***Sweetness, Preference, Flavor and Odor*** were correlated and related to the EET62, ICS1,

PAN1, U45, U53 and U43 clones. These clones received Preference scores of 4.3, 2.7, 3.2. 2.8, 2.8 and 2.3, respectively, with a *mean of 3.0*. ***This is in agreement with the known Fine Flavor clones EET62, ICS1 and PAN1 (Soursop flavor) and would be in agreement with the U clones having very sweet pulp and being genetically related to the fine flavor Sca6 clone.*** The two extreme clones with contrasting pulp traits were CCN51 vs. EET62.

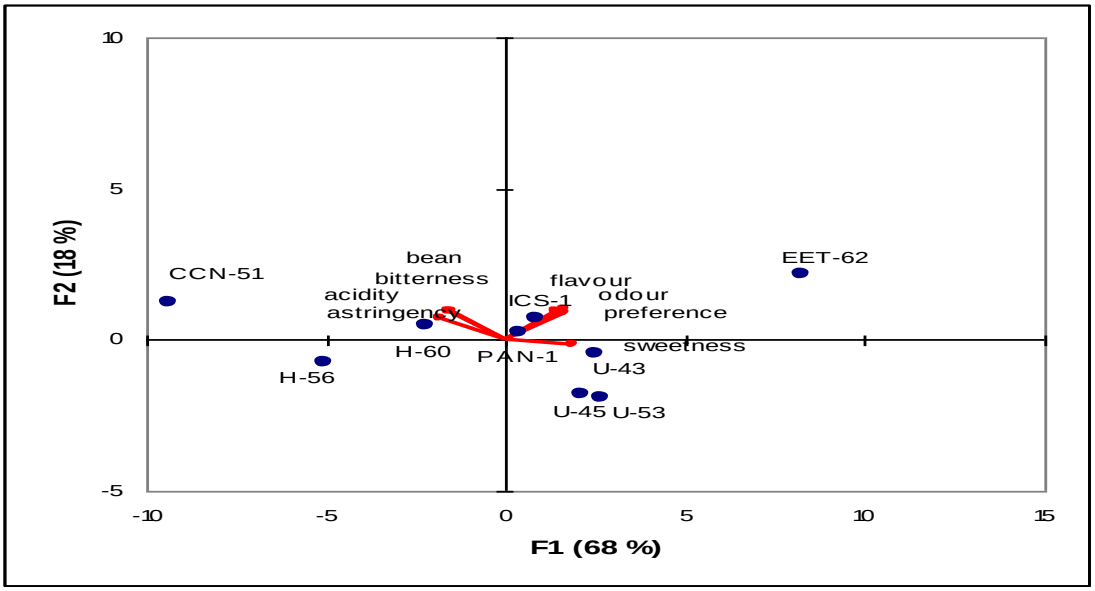
The above results show that cocoa pulp flavors and aromas have a direct genetic origin and that they reveal the degree of fine flavor traits present in each variety.

9.4. Simple Cocoa Quality Selection Approaches

The results suggest that different pulp flavors have substantial effects on the flavors of cocoa nibs and of chocolates. *This is evidence of the possibility to rapidly and efficiently select new cocoa varieties for specific flavor traits based on tasting of cocoa pulps, at least with respect to the highly variable aromas and fruity flavors that can be found among cocoa genotypes, such as identified here in PAN1 (Soursop), ICS1 and EET62 (Jasmine).*

Identification of such typical fruity or floral cocoa pulps would permit to substantially enhance the capacity to identify possible brand-new flavors and also to speed up selection for known flavors and aromas in cocoa

Figure 9.1: Principal Component Analysis plot for five sensory traits of the pulp and for bean bitterness of nine cocoa varieties. *The percentages between brackets indicate the percentage of variation explained by axis 1 (F1) and axis 2 (F2).*



9.4.1. Rapid selection of fine flavor cocoa genotypes in diverse populations

According to or results, the genotypes with most preferred cocoa pulps appear to be of direct interest for pre-selection of fine flavor cocoa. Preferred pulps tend to be sweet and show quite intense, diverse types of floral and/or fruity flavors. If the interest is to carry out screening of fine flavor genotypes in diverse populations (germplasm collections, double crosses, farm populations, *etc*.) a start can be made by rapid screening of the genotypes for pulp preference. Field screening can be done by one or two persons opening at least two ripe pods of each genotype in the field and by subjective scoring of preference, indicating presence of special flavors. The most preferred genotypes can subsequently be evaluated by a more detailed method (see below).

9.4.2 Rapid identification of known fine flavor cocoa genotypes in segregating populations

Complex crosses are required in cocoa breeding to try to select for genotypes with known fine flavor attributes (fruity, floral), high yield and resistance to diseases or pests. Pre-selection for the specific quality traits can be carried out by field screening for pulp flavor attributes of individual trees (***see 8.3.***). However, the observers need to have a good idea of the flavor attributes of the type of quality that is to be selected for. Therefore, the flavor attributes of the control varieties that have the required quality traits need to be well known to the observer. For example, based on the results of our study, if the objective is to select for the typical Trinitario "fresh fruit" flavor, the pulp that one would select for should have medium to high acidity and sweetness, associated with the fresh-fruit flavor of the ICS 1 pulp.

9.4.3 More detailed evaluation of pulp flavor traits

Detailed evaluation of pulp flavor traits may be necessary for special studies, such as to relate different pulp flavor traits with fine flavor attributes in fermented and dried cocoa beans and in roasted cocoa products. The method could be similar to the one used in our study, with possible adaptations as required for specific objectives. In general, it will be necessary to have a trained panel of four to six members and to apply two to four replicates depending on the importance of the study. The flavor traits are scored on a 1-5 point scale, where 1 = absence of the trait, 3 = medium intensity of the trait and 5 is high intensity of the trait.

Each replicate would include the following steps:

1. Collection of ripe pods of the test genotypes.
2. Simultaneous collection of ripe pods of control genotypes, which can be representatives of known fine-flavor types (*e.g.*

ICS 1, SCA 6, Nacional) and of commercial varieties grown locally with or without fine flavor traits (Amelonado, IMC 67, CCN 51, *etc*.).

3. Opening of the pods in the laboratory and placing of the pulp in numbered plastic boxes that are closed to contain the pulp odor. The pulp is best left for one or two hours to adapt to the environment and to attain uniform temperatures.
4. Observation of the intensity and type of odor of the pulp is done after opening the lid of the plastic box by each member of the panel.
5. Tasting of the pulp of two or three beans is followed by scoring of the degree of sweetness, acidity, astringency and intensity and type of flavor (different types of fruity and floral, using the control varieties as standards for known flavors).
6. The overall preference of the pulp based on the above traits is scored afterwards.
7. Alter peeling of two beans, the cotyledons are scored for the intensity of bitterness and astringency.

Data analysis may involve linear statistics as applied in our study (ANOVA, correlation studies, PCA) to establish associations between traits and between control and test genotypes.

10. Sentences Unlike Sentences 2

The Best Place in the World
Is Where you Live

Innovating Sustainably is
Combining Existing Things
With Ourselves

Any Significant Discoveries
Are not Scientific but Empirical

The Best Chocolate is
The Cocoa Bean

Very Serious Stories Require
To be Told
As Very Serious Jokes

The Biggest Ideas
Are the Smallest Ideas

Big Problems are Big
Big Solutions are Small
Very Big Problems Require
Very Small Solutions

If Ideas have Moved Dutch Windmills
Why not Civilizations?

If Very Big Ideas
Have moved

Violent Revolutions
Then Small Ideas can Move
Sustainable Evolutions

If Too Big Ideas have Moved
Hate and Inquisition
Then we need Very
Small Ideas to move Happiness

Don't Worry
Be Happy

All civilizations should become
As Evolved as Indian Civilizations by
"Working Less to Be Happier"

In Order to be a Happy Adult
You Have to be a Child
A Happy Child has to be a Child too

A Happy Person
Is Often also Un-Happy

Orderly Lifes
Need Un-Orderly Lifes
To Live Together in Harmony
(Yin and Yang)

11. First Example of Fresh Fruit Flavor and Aroma Selection

Unique Example of the Use of Pulp Fine Flavor Traits Selection Criteria in Cocoa Breeding

(García Carrión et al.*, 2012)*

Between 2005 and 2010, the area cultivated with cacao in Peru grew significantly due to high demand and good prices in the international market, but average yields have remained low. Plant breeding efforts to obtain new materials have continued but have not yet been sufficient to increase the productivity of cacao in Perú. Sixteen years ago, the program of cacao improvement of the Universidad Nacional Agraria de la Selva - Tingo María, began by selecting parents to create hybrids and to select superior clones which will soon be released on account of their productivity, tolerance to main diseases and ***superior quality***.

Eight new hybrid trees (B, C, D, E, F, G, H and J) were selected based on their ***superior fine flavor pulp qualities***. The trees labelled as B, C, D, E, F y G, showed intensities from medium to high for floral and specific fruity flavors, highlighting the "E" (U-68 x IMC-67) x CCN-51 and "G" (U-68 x IMC-67 x ICS-95) trees, for their strong intensity of floral aroma. In addition, these were characterized by low to very low scores for acidity, astringency and bean bitterness intensities.

The "F" (EET-62 x U-1) and "H" (U-68 x IMC-67) x CCN-51 trees, were selected for their strong fruity flavor. The "H" tree, was

also selected for its low to very low undesirable flavors. Finally, the "J" (U-68 x IMC-67 x ICS-95) tree, is noted for mid-range fruity flavor intensity and with low to very low undesirable flavor characteristics.

As shown above, the implementation of a national cacao improvement program with focus on clone selection for *productivity, quality and climate change* ***will be able to advance most quickly with regard to the quality objective.***

12. Pulp Sensory Traits Identified Between 2007 and 2017 Outside la Convención, Peru

Between 2007 and 2017 twelve hitherto unknown cocoa pulp flavor and aroma traits (Table 12.1) were discovered outside La Convención, Peru, as a result of limited pulp assessment exercises carried out by three cocoa scientists in seven locations in Trinidad, Peru, Ecuador and Brazil.

The most common pulp flavor encountered was ***Soursop*** identified in all seven locations and in widely different cocoa varieties.

The ***mango/rose*** profile was found in Brazil in a clone that originated from the Ecuador Amazon (EET397) and was introduced into Brazil for its witches' broom resistance.

The astonishing ***fresh banana flavor*** was discovered in Trinidad in 2008 in an old Trinitario plantation with predominating pulp sensory variation for sweetness and acidity.

Five sensory traits (Banana, Soursop, Jasmine, Citrus and Annona) were identified in Amazon genotypes, as verified with molecular markers (Zhang, 2014) in Satipo, Junin, Peru.

Recently it was shown that the formerly widely grown Amelonado variety in Brazil harbors the ***Jasmine aroma*** which was very

surprising. Amelonado has generally been considered as a "bulk" cocoa variety, in contrast with the fine-flavor Ecuadorian Nacional variety that also displays the same Jasmine aroma. Other Brazilian clonal varieties also showed fine flavors and aromas, *eg* the CEPEC 2008 clone with Soursop flavor and Rose aroma.

Beans from the Old Trinitario "Banana" flavored tree (Table 12.3) were transformed into chocolates by Ed Seguine. Three cocoa quality specialists described the chocolate flavor as follows:
"*The Banana flavor was detectable from the mid-session*" (Kamaldeo Maharaj, 2010),
"*The chocolate comes across with Banana skins/strings astringency*" (Ed Seguine), and
"*The long lasting aftertaste remembers that of a Banana jam* (Albertus Eskes).

This suggests that naturally occurring pulp sensory traits in cocoa may be transformed into very original and interesting chocolate fine-flavor traits.

The most interesting lesson from these 23 pulp flavor and aroma traits found in very different genetic populations and in different countries is that likely cacao pulp flavor and aroma diversity can be found anywhere in the world. This means that great potential exists to select efficiently for new interesting pulp flavors and aromas anywhere in the world.

Table 12.1. Twelve sensory profiles found in cocoa pulps in seven locations outside La Convención in Peru between 2007 and 2017

Year	Flavor/aroma trait	Cocoa population	Country
2007	Soursop*	Amazon collection INIAP	Quevedo, Ecuador
2007	Soursop*	Pandora clone from Colombia	Tingo Maria, Peru
2008	Mango/Rose*	EET397 from Ecuador	Bahia, Brazil
2008	Banana*	Old Trinitario	Trinidad
2009	Soursop*	French Guiana collection	Bahia, Brazil
2010	Soursop**	Old Trinitario	Trinidad
2012	Mandarin, Soursop and Grape*	Piura "White" or "Criollo" variety	Piura, Peru
2012	Banana, Soursop, Jasmine, Citrus, Annona***	Amazon genotypes***	Satipo, Peru
2017	Soursop, Rose, Lily, Grape, Red Fruit, Citrus, Ingá and Jasmine*	15 clones plus Amelonado	Bahia and Espirito Santo, Brazil

***Eskes A.B. ; **Maharaj K, 2010; ***Cruz and Zhang, 2014**

13. Sensory Treasure of the Inca Cocoa from Cusco, Peru

(Eskes *et al.*, Agrotropica 30: 157. 2018)

Before presenting the enormous fresh fruit flavor and aroma diversity identified in the Chuncho cocoa variety we place it in the background and context of:

a. the native Chuncho variety history,

b. what is known about the Chuncho's frugivores and the Chuncho domesticators, the native Matsigenkas,

13.1. The native Chuncho cocoa variety

"Chuncho" ("from the jungle") cocoa is native to the La Convención province (Urubamba valley) in the Cusco region in Peru. Reports exist on the trade of cocoa beans by the native Matsigenkas (=Human Beings) with the highlanders before and during the ***Inca Empire*** (Johnson and Johnson, 1996). Chuncho cocoa was cultivated already in the XVI century, but occurring also spontaneously in association with the Matsigenkas (Aparicio, 1999). This tribe has always had a special interest in consumption of Chuncho fruit pulp (Gade, 1975 ; Missioneros Dominicos, 2009) and also of slightly fermented and roasted raw beans. Rozas (1861) cited by Aparicio (2000) describes native cocoa in the valley of "high quality, noble and healthy" while Paz Soldan (1852), cited by Gade (1975), labels Chuncho cocoa from the Echerate Estate as "the best cocoa in the world". Chuncho cultivation increased between 1850 and 1890 with the arrival of immigrants from Cusco (Encinas, 2008). Chuncho acreage culminated in the 1980s with 14,000 ha and a production of 10.000 tons. The acreage of Chuncho has thereafter declined to *ca* 11,000 ha with production of 2600

tons currently, which is due to low productivity (150-250 kg/ha), ageing trees and competition from CCN51 and from other replacement crops. Chuncho is becoming more and more used as a source for fine and extra-fine cocoa receiving significant bonusses up to 100-150%.

Traditional farmers consume pulp juices from selected Chuncho trees which is a practice not known to occur elsewhere in the world. Our pulp and bean survey was therefore focused on Chuncho trees used by farmers for juice production. “Common” Chuncho beans express already interesting unspecific flavors and aromas (Condori Cruz, 2015). Chuncho pulps are generally sweet with low acidity and astringency. Even when unfermented or little fermented, Chuncho beans are neither acid nor bitter nor astringent which is a unique feature within “Forastero” cocoas. However, they may become so with fermentation duration of more than four days (Condori Cruz, 2015).

Among the 10 currently recognized major genetic groups of *Theobroma cacao* (Motamayor et al., 2008), the Chuncho variety is part of the “Contamana” group including SCA6. SNP marker studies showed however a closer genetic relationship of Chuncho with native accessions from the Madre de Dios and Beni river basins (Cespedes-Del Pozo et al., 2017) that are geographically related. The within Chuncho molecular diversity can be considered as moderate to high as compared to that of other native cocoa varieties (Zang, 2014).

13.2 T. cacao *frugivores and the Matsigenkas*

Ripe cocoa pods do not drop off the tree and do not open (indehiscent fruit). Consequently, evolutionary dispersal of cocoa seeds must have depended on frugivorous animals. Together with color, specific odor is considered to be a key fruit trait for attracting frugivores (Barry, 2009 ; Dominy et al., 2001 and 2004 ; Nevo et al., 2015). Important *T. cacao* frugivory-related traits are (Van Roosmalen, 2008): *1. Ripe fruit adherence to the tree, 2. Thick fruit*

husks, 3. Strong seed adherence to the pulp, 4. Nutritious and sweet fruit pulp, and 5. Frugivore swallowing of the seeds.

Six efficient cocoa frugivores were identified in the Amazon basin: for monkeys (spider, woolly, capuchin and saki), the kinkajou and the coati. These are also associated with eight other fleshy fruit families, including *Annonaceae* (*e.g*. Soursop, Custard Apple and Annona) and *Mimoseae* (*e.g*. Ínga). In La Convención, Carlos Rodriguez identified five *T. cacao* frugivores (spider and squirrel monkeys, coatis, nocturnal rodents and squirrels) three of which are different from the Amazon frugivores.

Olfactory cues for ripe fruit identification have been demonstrated in several primate species (Nevo et al., 2015). Spider monkeys inspect fruits by sniffing or biting (Van Roosmalen, 2008) and were able to discriminate odors from wild fruits of *Coumama crocarpa* and of *Leonia symosa* which are part of the *T. cacao* frugivory syndrome in the Amazon (Nevo et al., 2015). Laska et al. (2006) demonstrated an unexpectedly high olfactory sensitivity of the squirrel monkey, equaling that of the dog. No information was found on the role of fresh fruit flavors in establishing efficient seed dissemination by frugivores in general.

The Matsigenka domesticators must have disseminated Chuncho seeds since historical times in La Convención which is related to their cocoa pulp and bean consumption traditions (Missioneros Dominicos, 2009). While they don’t have names for fellow human beings they have names for cocoa and three cocoa products demonstrating the importance of cocoa in Matsigengas’ lifes. They must have selected Chuncho trees for their pulp sensory traits and planted such trees in their traditional “*home gardens*”.

13.3. Methods

Because of the fact that the Chuncho basic flavors are generally uniform and very mild among trees (Table 14.3), our sensory trait survey aimed mainly at identification of the large variation for cocoa fresh fruit fine flavors and aromas.

The ***Chuncho pulp sensory trait survey***, performed by two experienced cocoa scientists, included 100 trees from a 50 km long central stretch of the La Convención valley. The main criteria for tree selection were preference by the farmers for pulp juice consumption, typical Chuncho traits (morphological and sensory) and age of the trees. Confirmation of the Chuncho trees' genetic identity was obtained in 2014 with SNP markers (Zhang 2014). The assessment consisted of identification of aromas perceived upon pod opening and of fruity flavors during tasting of pulp of two equally ripe pods per tree.

For the ***Chuncho raw bean survey*** wet beans were collected in early 2015 and fermented during 2-4 days followed by sun-drying (2-3 hrs per day). The bean survey included 126 Chuncho trees scattered over the 200 km long La Convención valley. The criteria for Chuncho tree selection were the same as for the pulp assessments. Evaluation was done in April 2015 by three cocoa quality specialists. Two Peruvian fine-chocolate manufacturers Alain Schneider (Chocomuseo) and Pablo Morales (Amaz Food) participated afterwards in 50% of the assessments that confirmed identified traits. Bitterness, acidity, astringency, flavor and aroma intensities and general preference was scored on 0-5 point scales after deliberation and consensus of the panel members. Any observed flavor and aroma identities from known fruit, flower or spice species were recorded also by consensus. The logics behind flavor and aroma identification studies are presented in the Discussion. Associations encountered between flavor and aroma traits with basic flavor traits were analyzed with the Kruskall/Wallis test. Repeatability of trait identifications was assessed by blind re-evaluation of pulp and bean sensory traits from 20 different genotypes during the 2016/17 harvest.

13.4. Results

13.4.1. Chuncho sensory traits

Pulp flavors and aromas of 100 Chuncho trees were evaluated in 2012. Ninety seven of the 100 trees showed qualitative expressions

of pulp flavors and/or aroma, representing 30 distinct pulp sensory profiles. *These involve 17 fruit flavors and nine aromas or spices, totaling 26 different flavors and aromas*. The most frequently encountered sensory profiles are *Soursop/Jasmine*, *Floral* and *Citrus/Jasmine* found in at least 13 trees.
In April 2015 the sensory panel identified and evaluated intensities of sensory traits and assigned preferences to 126 slightly fermented raw bean samples. The four most frequently encountered raw bean sensory profiles were *Mandarin/Jasmine*, *Soursop/Floral*, *Cranberry* and *Malt* found each in 6 or more trees.

Table 13.4.1. shows the total of 40 sensory traits identified in the 30 pulp and 92 bean samples together. Table 13.4.2. shows the total of 64 sensory profiles identified in the 30 pulp and 92 bean samples together.

Table 13.4.1. Sensory traits identified in pulp and beans of 226 old Chuncho trees.

28 Fine Flavors:
Citrus; Mandarin; Tangelo; Jackfruit; Annona; Guanabana; Custard Apple; 5 Bananas; Grape; Green Aple; Dried Apple; Rose Apple; Guava; Cranberry; Mango; Inga; Peach; Plum; Honey; Raisin; Red Mature Fruit; Fresh Red Fruit; Fresh Yellow Fruit; Fruity

12 Fine Aromas
Rose; Jasmine; Lily; Violet; Floral; Heavy Floral : Spicy; Cinnamon; Vanilla; Mint; Yeast; Basil; Malt

Table 13.4.2. Unique pulp and raw bean sensory profiles found 226 farmers' preferred Chuncho trees in La Convención Province, Cusco, Peru.

Soursop/Floral; Floral; Citrus/Jasmine; Mandarin/Jasmine; Jasmine; Grape/Jasmine ; Tangelo/Jasmine ; Fruity ; Banana/Floral ; Soursop ; Lily ; Annona ; Grape : Guava/Heavy Floral; Rose apple/Floral; Banana (*var* "Cavendish"); Banana (*var*. Manzana); Banana (*var*. "Chinito"); Green Apple/Floral; Soursop/Rose; Rose/Vanilla; Mint/Rose; Mango; Custard Apple; Inga; Inga/Floral; Citrus/Yeast; Citrus/Banana (*var*. Isla); Citrus/Rose/Jasmine; Basil; Cranberry; Malt; Mint/Floral; Malt/Jasmine; Cranberry/Rose; Mint/Jasmine; Nuts; Mint/Nuts/Lily; Peach/Jackfruit; Dried Apple; Peach; Ripe Red Fruit; Nuts/Raisin; Nuts/Rose; Peach/Nuts/Rose; Ripe Plum/Raisin/Rose; Peach/Nuts; Peach/Raisin; Peach/Raisin/Rose; Malt/Lily; Rose/ Lily/ Rose/Lily; Fresh Red Fruit; Ripe Red Fruit/Rose; Ripe Yellow Fruit/Lily; Nuts/Lily; Nuts/Honey/Cinnamon; Raisin/Jasmine; Soursop/Lily; Jackfruit/Floral; Mint/Nuts; Custard Apple; Mango/Spices; and Malt/Nuts/Rose.

13.5. Analysis of sensory traits

Out of the 64 sensory profiles, 25 (39%) are made up by only one flavor or one aroma trait. ***The remaining 39 profiles (60%) are based on combinations of two or more sensory traits.***

Thirty-three (52%) contain exclusively fruit flavor and/or flower or spice aroma combinations. Six profiles (9%) are made up of three flavor and/or aroma combinations.

Out of the 40 sensory traits ***29 (73%) are mimicking those of known fruit, flower and spice species***. Chuncho mimics not only flavors of fruit species but also of varieties within species, such as observed for the five mimicked banana varieties (Tables 13.1). It also mimics flavors of related species within the citrus genus

(Citrus, Mandarin and Tangelo) all combined with the aroma of the citrus flower aroma (Jasmine) (Tables13.2).

The nine and two occurrences of nutty and raisin traits, respectively, were only found in the bean samples. On the other hand, the Soursop flavor trait occurred 19 times (21%) in the assessment of pulp traits but only twice (5%) in the bean assessments. Furthermore, the malt trait was not found in the pulp survey while it was identified 12 times in the bean assessments. *This suggests that Soursop pulp flavor may be transformed during fermentation into malt raw bean flavor.*

13.6. Discussion about Cocoa Sensory Diversity

13.6.1. Volatile Organic Compounds (VOCs) in cocoa pulp and in beans

Pino et al. (2010) were the first to identify VOCs in fresh cocoa pulp from a farm in Colombia in 2010. The relevant compounds among 66 VOCs were esters (2-heptyl acetate and 2-pentyl acetate) and linalool that are related to the known fresh fruit flavor (esters) and floral (linalool) aroma from Trinitario and Nacional, respectively.

Kadow *et al*. (2013) reported on relative concentrations of VOCs in fresh fruit pulp and beans of three genotypes (EET62, SCA6 and CCN51) that were chosen for their contrasting well-known pulp and chocolate sensory qualities (Tables 5.1 and 7.2 of Chapters 5 and 7). VOC concentrations were very low in the low-flavor CCN51 clone and high in the fine-flavor SCA6 and EET62 clones. The VOCs in SCA6 and EET62 derived from two different metabolic pathways: methyl ketones, secondary alcohols and esters in EET62 and monoterpenes in SCA6.

Table 13.3. Examples of 20 unique sensory profiles of 2-4 days fermented Chuncho cocoa beans evaluated on a 0 to 5 point scale in 2015 by a panel of three judges

Bitter-ness	Aci-dity	Astrin-gency	Frui-ty	Flo-ral	Flavor type	Aroma type	Prefe-rence
3	0	1	4	5	Mandarin	Jasmine	5
2	4	1	4	0	Cítrus	-	4
2	3	1	4	4	Cranberry	Rose	5
2	1	2	0	4	-	Rose	5
2	2	1	2	2	Peach	Rose	4
3	2	3	3	2	Peach/Raisin	Rose	3
0	1	1	4	2	Mint	Jasmine	5
2	1	0	3	0	Mint/Nutty	-	4
2	2	1	4	0	Nuts	-	5
2	1	2	4	0	Peach	-	5
1	1	1	3	0	Peach/Nuts	-	5
1	1	1	3	0	Peach, Banana and Jackfruit	-	4
2	2	3	5	0	Cherimoya	-	5
2	0	2	0	3	-	Lily	4
2	2	1	0	5	-	Lily/Rose	5
2	1	1	3	2	Ripe Yellow Fruit	Lily	4
0	0	1	2	2	Malt	Lily	3
3	2	4	4	0	Fresh Red Fruit	-	3
3	1	3	3	2	Raisin	Jasmine	3
0	2	2	3	4	Nuts	Lily	4

VOC concentrations were substantially higher in the pulp tissue than in the beans, confirming empirical observations that sensory compounds are primarily metabolized in the pulp. Migration to the cotyledons appeared to start only upon fruit ripening and is likely to be completed during fermentation (Kadow et al., 2013).

The authors confirmed that pulp sensory traits are the most important sources for fine-flavor cocoa sensory trait variations in beans and in chocolates and that VOC profiles and concentrations

are in full agreement with the assessments of contrasting pulp sensorial traits in these genotypes (Tables 6.1 and 6.2 in Chapters 6 and 8).

Based on the study of Kadow *et al.* (2013), Hegmann (2015) analyzed the volatile profiles of the fruit pulp of five genotypes selected at CATIE, Costa Rica. Relative quantities of aroma-active substances differed strongly with genotypes, season and fruit ripeness. The VOC profiles were quite different from the SCA6 and EET62 control genotypes suggesting that large diversity exists among cocoa genotypes for pulp flavors and aromas.

13.6.2. Genetic determination of fleshy fruit sensory traits

Barry (2009) considers that *aromas imparted by ripening fleshy fruits represent the most complex and species-specific aspect of ripening and one of the key attractants for frugivores*. Species and varieties all have unique sensory profiles consisting of up to hundreds of individual compounds classified as alcohols, aldehydes, ketones, esters, terpenes, furans, phenolics and Sulphur-containing compounds (Barry, 2009).

However, apparently only a fraction of the VOCs is most odor-active (*e.g*. Pino and Bent, 2013). The content and composition of VOCs show both genotypic variation and phenotypic plasticity (El Hadi et al., 2013). The number of flavor and aroma genes in fruits is generally large.

Although transgenes altering many volatiles simultaneously are already available, fruits with improved flavor will likely still require coordinated regulation of multiple biosynthetic pathways (Klee, 2010). ***Cocoa has apparently solved this problem long ago (see results).***

13.6.2. Chunchos' vs. *other cocoa varieties' sensory traits*

Fine-flavor cocoa varieties

Traditional fine-flavor cocoa varieties present *six flavor or aroma traits* (Table 5.1, Chapter 5) that are very similar to six of the 40 Chuncho pulp and bean sensory traits (Tables 13.1 and 13.2). This indicates that *34 of the Chuncho sensory traits are completely new* with regard to the traditional fine-flavor varieties. However, two trees identified in old Trinitario plantations in Trinidad expressed Banana and Soursop pulp flavors (Table 9.1, Chapter 9). This suggests that more Chuncho-like flavors and/or aromas might be found within Trinitario and likely also within other cocoa varieties.

Other cocoa varieties

Between 2007 and 2017 twelve different fruit flavors and aromas that are part of the Chuncho trait diversity were detected in pulp of widely different varieties and locations (Table 10.1, Chapter 10). These observations confirm that Chuncho-like flavors and aromas can also be found in different places inside and outside Peru and in different *T. cacao* varieties. It is likely that with systematic single-tree pulp assessments many of the known Chuncho flavors and aromas, and possibly others, will be detected in varieties that are not currently recognized for their fine flavor. An example is the Jasmine trait identified in 2017 in the Brazilian Amelonado variety (Table 10.1, Chapter 10) hitherto considered as a typical bulk cocoa variety.

Chuncho vs T. cacao *sensory trait specificity*

When adding the sensory traits in the traditional fine-flavor cocoa varieties (Table 14.1) to the traits found in other varieties outside La Convención (Chapter 10) we arrive at a total of 14 different sensory traits detected so far outside La Convención that are all included in the 40 Chuncho sensory traits panoply (Tables 14.1 and 14.2). ***This suggests that all sensory traits identified should be considered as T. cacao traits rather than as individual cocoa***

variety traits. It seems likely that many more Chuncho-like sensory traits can be found in other cocoa varieties that might increase the market value of such cocoa varieties. However, Chuncho has the great advantage of presenting very mild basic flavor traits (Table 14.3). This reduces the need for harsh post-harvest and processing procedures required for *most cocoa varieties worldwide to reduce acidity, bitterness and astringency but that at the same time reduce flavor and aroma intensities.*

13.6.3. Chuncho vs other fleshy fruit genetic sensory trait diversity

The Chuncho variety mimicking of 21 flavors and seven aromas from known fleshy fruit species is ***unique when compared to reported variations in sensory trait mimicking in other fleshy fruit species*.**

For example, among 52 descriptors used to analyze diversity of ***16 apple varieties*** (Ulrich et al., 2009), reportedly being the species displaying the "greatest" sensory diversity among commercial fruit species (Baietto and Wilson, 2015), ***only two refer to related other species' flavors (pears and almonds).*** Furthermore, the descriptor lists used for sensory evaluation of nine mango varieties (Vasquez-Calcedo, 2002) only contained non-specific flavors and aromas such as "sweet" or "acid" and "sweet", "sour", "juiciness" and "mango impact", respectively, a type of generic sensory variations that is commonly found also for many other fruit species.

Presence of great diversity for ***fruity flavors and flower aromas in "primary wine aromas"*** is well-documented (*e.g.* Marais, 1983; Ulrich and Fischer, 2007). ***However, these are mainly generated by specific combinations of varietal precursors during the fermentation process, comparable to the precursors of the chocolate flavor***. Diversity for pre-existing grape varietal aromas, which can be compared to fresh cocoa pulp flavors and aromas, is apparently restricted to a few exceptionally aromatic grape varieties like Muscat and Shiraz. Grape juices from different grape

varieties reportedly show little sensory variation (Ulrich and Fischer, 2007).

These comparisons seem to exalt the Chuncho sensory capacity to mimic flavors and aromas from 29 known fruit and flower or spice species apparently with high precision.

Chemical and more sensory studies will be needed to analyze how perfect the mimicked traits of cocoa are.

The unique and apparently very precise mimics of 28 flavor and aroma from other plants transforms *T. cacao* into a ***Phenomenal plant entity.***

13.6.4. Frugivore and human pulp preferences vs *Chuncho flavor and aroma diversification*

T. cacao ***depended exclusively on frugivores that effectively disseminated its seeds during evolution***. Five legitimate frugivore animal families or genus are associated with *T. cacao* in La Convención as observed by Carlos Rodriguez. The large sensory diversity of Chuncho suggests that evolutionary conditions must have been favorable for intensive and specialized frugivore x *T. cacao* interactions in La Convención.

Besides animal associations, the Matsigenkas have been directly associated with Chuncho cocoa even before the Inca Empire (Johnson and Johnson, 1996) and reportedly always consumed cocoa as fresh fruit pulp (Missioneros Dominicos, 2009) and as slightly roasted beans something that is currently still the case.

Color, smell and texture are reportedly the most important traits of fruit species to attract frugivores (*e.g.* Dominy et al., 2001 ; Rodriguez et al., 2013 and Van Roosmalen, 2008). ***However, the role of sensory compounds that accumulate inside ripening fleshy fruits in the interactions with legitimate vertebrate dispersers is still badly understood*** (Rodríguez et al., 2013). It has been suggested that once a frugivore identifies the pulp of a fruit as sweet and nutritious, that would be enough to ensure pulp eating and seed dissemination (*e.g.* Van Roosmalen, 2008). Chuncho pulp flavor

traits are present in 53 (83%) out of the 64 analyzed sensory profiles while only 36 pulp aroma traits (56%) were identified in the same 64 profiles. Thirty-three sensory profiles (52%) are made up of specific combinations of one flavor trait (taste) with one aroma or spice trait, which is unlikely to be just a result of chance. ***It is therefore inferred that ripening* T. cacao *fruits firstly offer an aroma to attract frugivores from a certain distance and then a flavorful pulp to stimulate consumption and effective seed dispersal***. However, it is also possible that during domestication the Matsigenkas as well as nowadays the Chuncho growers may have selected trees more for their pulp flavors in juices than for odors.

Chuncho pulps and beans mimic sensory traits associated with four fruit species that are sympatric with *T. cacao* in South American tropical forests: three *Annonaceae* species (Soursop, Annona and Custard Apple) and the Inga species (Tables 14.1 and 14.2). Frugivores of *T. cacao* are equally associated with the *Annonaceae* and Inga species (Van Roosmalen, 2008). It is understandable that these frugivores prefer, and therefore select, *T. cacao* fruit pulp that mimics sensory traits from familiar fruits to which they are also associated as frugivores.

An apparently more difficult question to explain is why *T. cacao* mimics as many as 24 flavors and aromas from allopatric fruit and flower or spice species. The *T. cacao* frugivores might have imposed extremely high evolutionary selection pressures on *T. cacao* for it to be able to metabolize cocktails of volatile compounds that mimic the unique sensory identity of allopatric fleshy fruit and flower species listed in Tables 13.1 and 13.2. Once again, *T.cacao* appears to be the only fleshy fruit species worldwide that mimics so many far away flavors and aromas. ***This reinforces again the hypothesis that* T. cacao *is a Phenomenal species.***

13.6.4. Genetic determination of Chuncho sensory profiles

The intensity of the Chuncho ***Lily aroma*** varied largely in our raw beans' evaluations (scores of 1 to 4 in Table 13.3) as well as in pulps observed in different trees in the field in La Convención. This appears to suggest quantitative expression and ***polygenic inheritance of this trait***. However, other evidence points to generalized qualitative simple inheritance of Chuncho sensory traits.

The hundred Chuncho trees evaluated in the pulp sensory trait survey showed to belong to the Chuncho molecular genetic diversity cloud (Zhang, 2014) with very little duplication of genotypes. Trees with similar flavor and/or aroma traits were often different molecular genotypes, ***suggesting that similar sensory phenotypes can be found in different Chuncho genotypes***. In other words, sensory phenotypes are not necessarily associated with genotypes. This can only be explained by assuming qualitative simple inheritance of fresh fruit sensory traits. This is quite different from the situation with other fleshy fruit species where sensory traits are complex, highly polygenic and associated to the genetic background.

Several Chuncho hybrid trees, identified as such by molecular markers (Zhang, 2014), have shown high expression of Chuncho pulp sensory traits. The same is known from breeding trials including hybrids of SCA6 and EET62 with unrelated cocoa genotypes. The above is suggestive of ***dominant gene action*** of *T. cacao* pulp sensory profiles. ***Such would simplify enormously selection for fine flavor traits in any cocoa variety worldwide.***

The Chuncho multi-trait sensory profiles that were found in more than one tree (Tables 13.1 and 13.2) are expressed as stable qualitative traits with rather similar intensities among trees and locations that were found mainly at very distant locations. One example is the Mandarin/Jasmine sensory profile from distant places that always displays strong Mandarin fruit flavor and medium to strong Jasmine odor combined with higher than average

bean bitterness. The Soursop flavor occurring alone or with other traits is always associated with a translucent pulp (see above). Other identified stable multi-trait sensory profiles are the Soursop/Jasmine, Citrus/Jasmine, Mint/Floral, Cranberry/Rose, Mint/Jasmine, Nuts/Rose and Peach/Nuts/Rose associations. These stable multiple trait associations, including in hybrid genotypes, are ***suggestive of pleiotropic dominant gene action*** *(=one gene expressing two or more traits simultaneously).* This resembles Gregor Mendels' identification in peas of trait number "three" (Mendel, 1866) responsible for simultaneous expression of "brown seed coat", "violet flowers" and "axial spots".

The molecular age proved that single genes can produce multiple products with pervasive effects on the phenotype (Stearns, 2010), including for mutants affecting ripening (Kovacs et al., 2009). *T. cacao* may have benefitted from pleiotropy as an evolutionary favorable mechanism associating several attractive traits for frugivores simultaneously. ***Genetic correlations*** between flavor and aroma traits may have exemplified *T. cacao* pleiotropy (Stearns, 2010). ***Such is contrasting with the commonly found quantitative and polygenic expression of sensory traits in other fleshy fruit species*** (*e.g.* Klee, 2010).

The possible common dominant pleiotropic inheritance of flavors and aromas in sensory profiles of *T. cacao* ***would simplify largely the selection and breeding for specific qualitative sensory traits in cocoa.*** The above inferences on the genetic determination of flavors and aromas in cocoa would merit confirmation by carrying out more formal genetic studies.

13.7. Unique Chuncho sensory profiles vs the fine-flavor cocoa market

The commercial value of a fine-flavor cocoa variety is dependent on the full spectrum of flavor and aroma traits including basic flavor traits. Chuncho has the advantage of combining a multitude

of very interesting sensory traits with favorable basic flavor traits (Table 14.3). While commercial fine cocoas usually have a narrow sensory profile, Chuncho offers a remarkable choice of 64 interesting flavor and/or aroma combinations. Thirty-three (52%) of the 64 unique sensory profiles are made up by fruity flavor x floral or spice aroma combinations. Six profiles (9%) are made up of a combination of three flavors and/or aromas. The 25 Chuncho profiles with just one sensory trait mimic 16 known flavors and aromas: ***Cranberry, Basil, Dried Apple, Peach, Rose, Jasmine, Lily, Inga, Mango, three Banana Varieties, Soursop, Grape, Annona and Custard Apple***. Fifteen of these traits are attractive already just because they are completely new to the current fine-flavor cocoa market.

Complex Chuncho sensory profiles might be even more attractive commercially as seems to be the case for the complex multiple sensory trait combinations in TSH varieties selected in Trinidad. A few examples of apparently interesting complex Chuncho sensory profiles (Tables 14.1 and 14.2) are: ***Mandarin/Jasmine, Soursop/Jasmine, Rose/Vanilla, Mint/Jasmine, Citrus/Jasmine, Tangelo/Jasmine, Cranberry/Rose, Nuts/Raisin, Peach/Nuts, Peach/Rose, Lily/Rose, Mint/Nuts/Lily, Ripe Plum/Raisin/Rose and Nuts/Honey /Cinnamon***. The expected commercial use of such unique varieties could lead to a significantly refined diversification and enlargement of the fine-flavor cocoa market.

13.8. Selection of fine-flavor genotypes in Chuncho and in other varieties

As shown by our results, selection for fine-flavor cocoa genotypes can be done ***simply, rapidly and efficiently*** by fresh fruit sensory evaluation for fine-flavor traits. We expect that, besides Chuncho, fresh fruit sensory trait selection and breeding can be successful also in ***other cultivated and native cocoa populations or in landraces in Peru and elsewhere.*** Populations that are genetically

narrowly related to Chuncho *eg* from Madre de Dios and Beni deserve possibly extra attention.

Farmer associations and research institutes could promote large scale competitions for farmers to identify trees, within any diverse cocoa variety, with the most delicious pulp combined with non-bitter beans that should thereafter be characterized for flavor and aroma identity and intensity, following the logics of or approach in Chuncho. Once trees with favorable pulp and bean traits have been identified and which have also interesting yield components then the ***next step is multiplication and/or breeding***. Firstly, individually selected trees need to be multiplied as clones for conservation purposes. Secondly, if the selected tree has also interesting yield components and is self-compatible it could be used directly for commercial mono-clonal multiplication.
Breeding should aim at high yield, resistance and fine-flavor quality. An interesting option is the creation of hybrid varieties by crossing Chuncho selections with parental genotypes (eg PA121 and PA169, that are available in La Convención and elsewhere) that are known to produce high yielding and resistant hybrids and which neutral pulp does not interfere with the fine-flavor Chuncho quality expected to dominate in the hybrids.

Thirdly, the establishment of small-scale commercial plantations can be achieved by using open-pollinated seed from selected Chuncho trees which, even if self-incompatible, as expected from the pleiotropic dominant gene action should reproduce largely the sensory traits of the parental trees. Such seed progenies could be selected within 3-5 years for flavor/aroma traits and for yield components. The then selected trees should provide enough budwood to ensure establishment of larger commercial polyclonal plantations with uniform sensory traits. Finally, the definite answer to the need of rapid commercial multiplication of Chuncho trees with high quality and average or high yield potential is probably best provided by large-scale somatic embryogenesis.

13.9. Potential for Chuncho fresh juice and roasted whole bean consumption markets

Matsigenkas and Chuncho growers consume selected cocoa pulps and juices as well as slightly roasted whole beans. These two ways of Chuncho consumption may potentially become two new segments in the fine cocoa market. The fresh juices produced from selected Chuncho trees would be as diverse as the 64 unique sensory profiles, ***e.g. Soursop", Cranberry", Mango/Rose", Peach/Jasmine and Tangelo/Jasmine****".*

Our sensory trait assessments have convinced us that eating the Chuncho dry raw bean from selected genotypes is a superior tasting experience. The flavors and aromas are fully expressed in raw Chuncho beans while several Chuncho sensory traits are modified or become weaker in chocolates (Table 9.1). Basic flavors of Chuncho beans are very mild (Table 13.3) favoring direct consumption of slightly roasted de-hulled beans or nibs.

Such a new market might favor cocoa producers who would possibly receive ***a higher percentage of the final selling price*** of the cocoa beans that do need only minimally processing and no transformation of the Chuncho cocoa beans. Last but not least, consumption of de-hulled slightly roasted cocoa beans is expected to bring along ***health benefits through higher polyphenol*** concentrations than in chocolates combined with high tasting pleasure benefits.

13.10. Cocoa's sensory identity and evolutionary survival

Any fruit or flower species has built up its own unique sensory identity over millions of years during evolution and domestication (Barry, 2009). This sensory identity is very unique and precious to the fruit and flower species as it serves as the main recognition factor for frugivores and human beings to be efficient seed dispersers, thus guaranteeing survival during evolution and domestication.

Each of such sensory identities is based on a very delicate quantitative and qualitative balance among large numbers of VOCs (Barry, 2009; El Hadi et al., 2013; Klee, 2010). With Chuncho possibly being a type of the "mother" of all *T. cacao* flavor and aroma traits we might consider the possibility that it is also should be the "mother" of a ***unique cocoa sensory identity.***

With our findings that Chuncho expresses 64 unique savory fresh fruit sensory profiles based on 40 sensory traits, 29 of which mimic other fruit, flower and spice species, one might wonder ***why* T. cacao *has built up a very diversified fresh fruit sensory trait panoply rather than building its own specific fresh fruit sensory identity as all other fleshy fruits including Cupuaçu, a close cousin of* T. cacao*, have done?***

We hypothesize that the likely scientific reason for this can be that "Cocoa Loves Human Beings"!

Or if not: Cocoa is Certainly a Phenomenal Being!

14. The Identity of Cocoa

All Fruit Species on Earth

Have Their Unique Aromatic Identities

Well-Defined,

Like Apple, Pear, Grape, Cupuaçu and Plum

Conquered with Hardship During Evolution

In Order to be Recognized and Eaten

By Frugivorous Animals

That Disseminated the Seeds

In the Garden of Eden

The Incredible Cocoa

Is not like that

Cocoa Developed

More than 60 Aromatic Unique Identities

That are Flavors and Aromas

Combined and Recombined

For Example:

Mandarin and Jasmine

Mango and Rose

Soursop and Lily

Rose and Lily

Peach and Almond

Mint and Jasmine

Cranberry and Rose

These Unique Identities are Based

On 43 Flavors and Aromas

Borrowed Mainly from Other Plants

Fruit Species, Flowers and Herbs

But Our Detailed Study

Was not able to Discover

A Proper Identity of the Cocoa Species

No Unique Cocoa Flavor

No Unique Cocoa Aroma

In Her Fresh Fruit

Or Task Force Came Together

To Discuss this very Unusual Finding

We Then Decided that the Best Symbol for Cocoa

Is the Chameleon

Imitating the Colors of the Rainbow
Up in the Sky

Just as Cocoa imitates Flavors and Aromas

From Far Away Locations

The Rainbow

Symbol of the Incas

Symbol of Peace

Cocoa is like the Incas

Which Symbol are the Rainbow Colors

They Ate Savory Beans of Chuncho Cocoa

Two Entities that are Naturally Phenomenal

Married in History

That Deserves to be Re-Written

Cocoa Cured two Chronical Diseases of Mine in Cusco

By Providing me so Much Happiness

She Still has Much + Much More
Happiness and Health to Give

To All Human Beings

***Theobroma cacao* and the *Efecadepatos* Chameleon are both able to mimic faraway attractive features**

15. Brazilian Pulp Flavors and Aromas

Limited Brazilian Cocoa Pulp Sensory Profile Survey by Bertus Eskes and David Pujol

2017/18

33 clones were evaluated in commercial varieties in farmers' fields

Results

- **Unique Fresh Fruit Flavors**
- **Unique Fresh Fruit Aromas**
- **Unique Sensory Profiles for Brazil**

Amelonado	***Fruity, Jasmine***
Salobrinho 3	***Soursop , Lily***
Cepec 2008	***Soursop, Rose***
TSH1188	***Soursop, Lily***
TSH565	***Muscat Grape, Lily***
CCN10	***Soursop, Lily***
EET397	***Mango, Rose***
Cantagalo 3	***Violet***
PH15	***Citrus, Floral***

SJ02	***Cranberry, Rose***
CEPEC 2002	***Peach, Rose***
CP49	***Green Apple***
PS1319	***Green Apple, Jasmine***
BN34	***White Grape, Rose***
TSA 654	***Inga, Lily/Jasmine***
C2001	***Fruity, Floral***
TSH516	***Fruity, Lily***
CCN51	***Citrus, Jasmine***
RB 42 e 46	**Mangosteen**

2019

15 clones evaluated in the "*Garden of Eden" of Emir de Macedo, Espírito Santo*

Chiquita 11	***Citrus***
FA13	***Green Apple***
Dr Ron	***Soursop, Herbal***
LP06	***Soursop***
Cepec 2004	***White Grape***
CA71	***Peach, Jasmine***
EQX107	***Basil (Herbal)***
PS2006	***Sweet Apple, Floral***
FC902	***Sweet Apple***
PAIN 9324	**Licorice,** ***floral***

SM06	***Peach, Jasmine***
SCS20	***Citrus, Lily***
CCN16	***Jasmine***
BJ11	***Green Apple, Floral***
Joventina 37	***Soursop***

Thirty-four (80%) of the 48 Brazilian varieties are fine varieties!

Average Sensory Diversity is 53% of that of Chuncho

- **Flavors** **16 (57%)**
- **Aromas** **7 (58%)**
- **Unique Sensory Profiles** **28 (44%)**
- **No Flavor nor Aroma** **14 (20%)**

Some Fine Brazilian Cocoa varieties

Conclusions

- ***Incredible*! Twenty-eight commercial clones have unique sensory profiles identified so far, which is 44% of the total unique sensory profiles (64) identified in Chuncho, Peru.**
- **For the unique flavors and aromas, the relative richness in Brazil as compared to Chuncho is 46% and 58% respectively.**
- **The potential of Brazilian fresh fruit flavors and aromas is expectedly much higher than identified so far in a very limited sample of just 48 commercial clones.**
- **This limited survey identified three flavors and aromas that were not identified in Peru: *Mangosteen, Violet and Licorice.***
- ***The richness in Brazil for unique commercial fine-flavor sensory profiles warrants a great potential to develop a large Brazilian fine flavor cocoa market.***
- **However, Brazil is not yet known to possess so many commercial fine-flavor varieties which may related to still inefficient post-harvest methodologies.**
- ***Brazil will need to adopt a new fermentation method that is able to express these interesting fine flavors (see Anima further down)***
- **The large variation for fine fresh fruit sensory traits is difficult to explain by traditional fruit quality-related genetics. The inheritance of the**

fresh fruit sensory traits deserves to be studied in detail such as in diallel mating designs.

- **The sensory survey in Brazil needs to be expanded to at least to 1000 clones in order to assess the total variation for fresh fruit sensory traits in the country.**
- ***As shown for Brazil, many other cocoa producing countries can be expected to harbor large variation for fine fresh fruit flavor and aroma traits and should have the same potential as Brazil and Peru to produce fine cocoa products.***

16. Sentences Unlike Sentences 3

My Logical Nature
Contains
Illogical Parts
To be Able to Live Better
In a Logical World

Logics
Happens to
Love Il-Logics

Chaos Is the Origin of Life
Chaos Gives Birth to Love
Chaos Gives Birth to
Existence
And also to Non-Existence

Behind a Big Lie
Is Hiding a Big Truth
Behind a Big Truth
Is Hiding a Big Lie

"God is Whom Helps to
Understand What Cannot be Understood" (Raul Seixas)
In Other Words
"God Explains Things
That We Cannot Understand"

While the Devil Explains
Only Things
That We Wish to Understand
Can You Understand?

The Devil does not Understand The Good
Because the Devil Is not The Good
Only God Understands
The Good and the Evil
God is the Good and the Evil!

The Good Does not Understand the Evil
The Good Does not Need to Understand the Evil
The Evil Exists Thanks to the Good
But the Good can Exist
On Its Own

A Lonely Person Usually Feels Bad
A Lonely Person Usually is Bad

Good Persons act Alone
Bad Persons
Use to Act in Groups

Time Passes
More Rapidly When Persons
Are Not Alone

But, Time of a Lonely Persons Arrives More Quickly
Than that of Non-Lonely Persons

Better
Give Time
To Time

Only God and the Poor Have Grace, Thanks to God!

God is the Inspiration of the Poor,
And God is also Inspired by the Poor!

There are Jokes that Cannot be Told, and
There are Tales that Are not Funny

Good Jokes Use to Hide True Tales or Stories
But the Majority of the Tales and Stories
Are not Funny

Only Absurd or Mad Stories are Funny
Absurd or Mad Stories Can be True

Normal Persons Do Not Tell Absurd Nor Mad Stories

Only Special Persons Know How to Tell Such Stories

The Poor are Richer
Spiritually than the Rich

17. Fine Cocoa Magical Mystery Tour

Bertus Eskes, Cocoa Magical Mystery Tour Leader

Presentation of additional mysterious features of the cocoa sensory trait panoply

17.1. Fresh Fruit Sensory Trait Diversity

STOP 1. Cusco, World

17.1.1. Chuncho Sensory Diversity Revisited

(Eskes and Rodriquez et al., Agrotropica 30 : 157. 2018. On line.

The fine-flavor cocoa industry explores mainly ***four fine flavor sensory profiles*** from the four traditional fine cocoa (*Theobroma cacao* L.) varieties: Criollo, Trinitario, Nacional and SCA6 progenies (TSH varieties). This sensory diversity that has been explored over centuries ***is minimal when compared to the 64 sensory profiles discovered in the Chuncho variety.***

Growers of the native Chuncho variety from Cusco, Peru, which is the cocoa that the Incas consumed, make pulp juices from preferred trees (genotypes). Evaluations of 226 such preferred trees evidenced ***presence of 64 unique mostly multi-trait sensory profiles***. ***Twenty nine of the 40 flavors and aromas identified mimic those of other known fruit and flower or spice species. Such large sensory diversity and mimicry is completely unknown in other commercial fleshy fruit species.***

The 28 pulp flavors that Chuncho revealed to us are:
Soursop, Citrus, Mandarin, Grape, Fruity, Common Banana, Banana "Cavendish", Banana "Manzana", Banana "Isla", Annona, Guava, Rose Apple, Green Apple, Mango, Custard Apple, Inga, Cranberry, Nuts, Peach, Jackfruit, Dried Apple, Ripe Red Fruit, Raisin, Ripe Plum, Fresh Red Fruit, Ripe Yellow Fruit, Honey and Tangelo.

The 12 aromas that Chuncho revealed to us are:
Floral, Jasmine, Lily, Heavy Floral, Rose, Vanilla, Yeast, Basil, Mint, Cinnamon, Spices and Malt.

Fresh fruit sensory traits are ***strongly genotype dependent*** and correlated to human preference. Stable expression of multi-trait Chuncho sensory profiles strongly suggests ***pleiotropic dominant inheritance***, favoring ***simple selection*** for sensory trait combinations, which is ***contrasting with the complex sensory trait determination in other fleshy fruit species***.

It may be inferred that the large sensory diversity of Chuncho cocoa might be primordially explained by highly specialized sensory trait selection pressure exerted by frugivores, during evolution, and later by the indigenous "Matsigenkas", during domestication. ***However, many other fruit species, including the related* T. grandiflorum *species, are likely to have received similar selection pressure and do not show the same variability for flavor and aroma traits***. ***There is therefore currently no scientific explanation for such large sensory variation in T. cacao.***

Chuncho beans become more and more processed as a source of extra-fine cocoa. The valorization of the numerous T. cacao *sensory profiles in chocolates, raw beans and juices should substantially diversify and boost the fine-flavor cocoa imarkets, this time based on the Matsigenka/Inca and not anymore on the Maya cocoa traditions.*

Carlos Rodriguez: Magical Mystery Tour Driver

STOP 2. Cusco

17.1.2. Chuncho Unique Sensory Profiles Revisited

We probably all love Cocoa because of it being a ***mysterious*** plant but often ***we do not really know why Cocoa is mysterious***. I am very happy to have helped to unveil, together with my good friend Carlos Rodriguez from Quillabamba (photo with old Chuncho tree), many cocoa flavor and aroma secrets. We worked only ***with the Cocoa that the Incas used to consume,*** *ie*. old trees of the native Chuncho ("From the Forest") variety from Cusco.

Yes, the Incas consumed cocoa, according to some historic literature, although there do not seem to be historical Spanish references linking Incas with Cocoa.

The traditional Chuncho farmers typically selected individual trees for making pulp juices, a habit unknown to exist elsewhere. Then the beans were slightly fermented and dried. This means that these trees were selected because they had special flavors and/or aromas. Carlos directed our sensory survey to the trees that farmers had selected. ***This largely helped us to unveil the enormous fresh fruit flavor and aroma treasury within*** **T. cacao.**

Herewith we copy again the 64 sensory profiles unveiled in Chuncho, 30 of which were detected in fresh Chuncho fruits:

Soursop and Floral , Floral, Citrus and Jasmine, Mandarin and Jasmine, Jasmine, Grape and Jasmine, Tangelo and Jasmine, Fruity, Banana and Floral, Lily, Anona, Grape, Guava and Heavy Floral, Rose Apple and Floral, Banana (var "Cavendish"), Banana (var. "Manzano"), Green Apple and Floral, Soursop and Rose, Rose and Vanilla, Mint and Rose, Mango, Custard Apple, Inga, Inga and Floral, Citrus and Yeast, Citrus and Banana (var. "Isla"), Citrus Rose and Jasmine, Basil, Banana (var. "Chinito")

And 34 unique sensory profiles were detected in slightly fermented and dried beans:

Cranberry, Malt, Mint and Floral, Malt and Jasmine, Cranberry and Rose, Mint and Jasmine, Nuts, Mint, Nuts and Lily, Peach and Jackfruit, Dried Apple, Ripe Red Fruit, Nuts and Raisin, Nuts and Rose, Peach, Ripe Plum, Raisin and Rose, Peach and Nuts, Peach and Raisin, Peach Raisin and Rose, Peach and Rose, Malt and Lily, Rose, Lily and Rose, Ripe Red Fruit and Rose, Ripe Yellow Fruit and Lily, Nuts and Lily, Nuts Honey and Cinnamon, Raisin and Jasmine, Soursop and Lily, Jackfruit and Floral, Mint and Nuts, Custard Apple (Cherimoya), Mango and Spices, and Malt Nuts and Rose.

Interestingly, only 5 sensory profiles were in common between the fresh fruit and raw beans profiles but many flavors and aromas were the same. This could be explained because the fresh fruit survey area was largely different from the raw bean survey area. In

this case it may well be possible that more unique sensory profiles can be found with further searching.

STOP 3. *Brazil*

17.1.3. Brazilian T. cacao *Sensory Traits Revisited*

After the Chuncho project in Peru we started looking for fine-flavor traits in Bahia, Brazil in 2017/19.

The first big surprise was that the oldest variety planted in Brazil, Amelonado, always considered as a typical "bulk" variety expresses a fruity pulp flavor and a strong Jasmine aroma. Brazilians questioned by me if they were aware of the Jasmine Amelonado aroma reckoned that the Amelonado aroma was simply the "cocoa fresh fruit aroma".

The Jasmine aroma is one of the outstanding features of the fine-flavor profile of the Nacional variety! The fact that Amelonado was and still is mainly a bulk variety may have to do with the inefficient traditional fermentation method (see further down fine-flavor Amelonado sensory profiles obtained by the innovative ***Anima fermentation method***).

The limited Brazilian pulp flavor and aroma survey has included so far only 48 clonal varieties and Amelonado (genotypes). The number of fruity flavors and aromas unveiled was 16 and 7, respectively, totaling 23.

These 23 traits are expressed in ***28 different unique sensory profiles that can be used for making differentiated fine-chocolates.*** Chocolates made with the ***Mango/Rose*** *(EET397) and with the* ***Cranberry/Rose*** *(SJ02) profiles* have already shown recognizable and very remarkably interesting sensory traits.

Nineteen (83%) of the 23 flavors and aromas are the same as detected by us in Chuncho. This shows large overlapping of sensory traits with the Chuncho panoply.

This large sensory diversity should therefore be considered as belonging to* T. cacao *rather than to individual varieties of* T. cacao. *Such diversity might therefore be found in any cocoa growing country in the many cocoa varieties planted globally.

The "new" pulp flavors and aromas detected in Brazil were ***Mangosteen*** (fantastic taste!), ***Liquorice*** (exquisite!) and ***Violet*** (persistant).

Twenty (71%) of the ***34 (71%) sensory profiles*** identified are the same as found in Chuncho. The eight (29%) "new" unique sensory profiles in Brazil are:

Muscat Grape and Lily (SCA6 origin), Violet, Citrus and Floral, Inga Lily and Jasmine, Mangosteen, Soursop and Herbal, Sweet Apple and Floral, and Liquorice.

This finding increases the total amount of unique fresh fruit sensory profiles identified in* T. cacao *from 64 to 72! *It is very likely that more can be found with further surveys in Brazil and in other countries.*

The big advantage of Brazil in exploring this large sensory diversity is that the diverse nice sensory profiles will result in very diversified fine cocoas that can be explored immediately at commercial scale because of the already available fine flavor commercial clones.

In our recent studies with the ***innovative Anima fermentation technologies*** (see later on) *we observed that expression of fruity flavors and floral aromas in chocolates is generally enhanced with regard to the traditional fermentation method.* ***For example, Amelonado and CCN51 chocolates made with Anima-fermented beans showed very low basic flavors, high caramel and nutty flavors, and expressive balanced fruity/aromatic sensory profiles.***

The sensory traits identified in commercial varieties in Brazil, combined with innovative fermentation technologies, warrant great potential for the country to become a major producer of fine-flavor cocoas.

STOP 4. *World*

17.1.4. Cocoa Fresh Fruits Have no Proper Sensory Identity

Fleshy fruit species developed during 20-30 million years of evolution *unique sensory profiles* which are fundamental tools to be recognized by species-specific frugivores and/or insects needed to perpetuate the plant species. As such, the sensory profile of a peach is unique for the Peach species and that of a Mandarin for the Mandarin species. Be aware, *Theobroma cacao* is very different!

Recently, 226 Chuncho trees from Cusco revealed 64 sensory profiles based on combinations of 28 fruity flavors and/or 13 floral/spicy aromas. First Magic: *These profiles were developed in only 10 million of years of Cocoa evolution!* Second Magic: *Twenty-nine of the Cocoa flavors and aromas mimic those of other plant species.* Third Magic: *We were unable to detect a cocoa-specific sensory identity.* Cocoa's sensory condition is completely different from that of other fleshy fruit species.

Attempting to explain Cocoa's unbelievable sensory nature we had to choose a symbol resembling Cocoa. Our choice fell easily on the ***Chameleon*** because this animal displays ***faraway colors*** of the rainbow just like cocoa displays flavors and aromas from ***faraway aromatic plant species*.**

The rainbow is the symbol for PEACE and also for the INCAS that used to consume Chuncho cocoa beans.

Is the Chameleon the living being resembling* T. cacao *most with regard to its capacity to mimic far away features perfectly and by not having its own proper identity?

17.2. Fine Cocoa Evolution and Domestication

STOP 5. *Cusco*

17.2.1. Frugivore Origin of Fine Flavor Cocoa Traits?

Cocoa is an indehiscent species, ie. *it does not drop its fruits on the ground*. In order to survive during evolution, cocoa developed very specialized interactions with frugivore animal species, such as the seven frugivores identified by Carlos Rodriquez in Cusco (see

photos): ***big parrot, capuchin monkey, howler monkey, coati, kinkajou, big squirrel and spider monkey.***

The frugivores typically climb into the cocoa trees, smell to see if the pods are ripe, then open the pods, suck the savory pulp and swallow the entire seeds that are disseminated when defecating. This might tentatively explain how Chuncho Cocoa has suffered diversified selection pressures to develop 28 fruity pulp flavors and 13 aromas. *However, it does not explain why other fleshy fruit species that have interacted similarly with frugivores only developed one species-specific sensory profile.*

Primates, as human beings, possess a low olfactory capacity. Cocoa frugivores need a high olfactory capacity to be able to smell the aromas produced inside the cocoa pods. Interestingly, a study with the black *Spider Monkey* (see photo) revealed that its olfactory capacity was even higher than that of the dog! One of the two *parrots,* identified by Carlos Rodriquez in Cusco, that feed on cocoa pods opens the ripe pod, has the peculiar habit to feed on the pulp and to throw the intact seeds on the ground.

The large squirrel feeds on cocoa seeds destroying them while also burying some seeds as a food reserve. However, the squirrel also happens to forget where he buried the seeds and that allows the buried seeds to germinate and grow.

T. cacao *frugivores identified in La Convención, Peru, by Carlos Rodriquez*

Large diversity among frugivores and their particular food preferences may not have been enough for cocoa to have generated the enormous diversity in fine-flavor cocoa traits unveiled in the Chuncho variety.

STOP 6. *Cusco*

17.2.2. Domestication and Use of the INCA Cocoa

Historical Peruvian reports point out that the native ***Matsigengas*** ("***Human Beings***") always lived in close relationship with the native Chuncho ("*From the Forest*") Cocoa. Carlos Rodriguez informs that the *Matsigengas* do not give personal names other than "*Matsigenka*" to family members but that they have very specific names for cocoa ("***Sariguemineki****"*) and for three cocoa products, demonstrating the great importance of cocoa in the *Matsigenka* society.

Matsigenkas typically consume the savory Chuncho cocoa pulp from selected trees and then only slightly ferment and roast the sweet Chuncho beans that are eaten as a snack. It is likely that the Matsigenka Cocoa traditions allowed for a further diversification and concentration of flavors and aromas than that the Chuncho *Sariguemineki* variety had already developed during evolution. The discovery of 64 sensory profiles in Chuncho opens the way for a boost and further diversification of fine-flavor cocoa consumption and consumption patterns.

Matsigenga Chiefs still have the habit to ***eat the Chuncho beans together with coca leaves.*** We experienced that the sweet Chuncho beans dominate the bitterness of the coca leaves. It is documented that the *Matsigenkas* sold Chuncho beans to the "*highlanders*" including during the *INCA* Empire. ***It can be postulated that the Incas adopted the Matsigenga traditions on how to eat sweet raw Chuncho beans together with coca leaves.***

Coca leaf and cocoa bean consumption by Matsigenka and Inca chiefs

HISTORY MIGHT NEED TO BE REWRITTEN AS THERE DOES NOT SEEM TO BE ANY SPANISH TREATIZE ON THE USE OF COCOA BEANS BY THE INCAS.

STOP 7. *Peru and Central America*

17.2.3. Domestication of Criollo and Chuncho for Low Bitterness

Nearly all cocoa varieties have very bitter and astringent seeds with a very high polyphenol content of ca. 20% on a dry bean basis. Such can be expected to be related to their natural defense mechanism (see Chapter 18). However, rare cocoa genotypes can be found in segregating populations that show low or no bitterness nor astringency in their fresh beans (Personal Observation in Brazil).

As postulated here, it is very likely that the unique ancient Criollo and Chuncho varieties have been consciously selected by their domesticators for beans with low bitterness and astringency,

favoring consumption of dry beans (Chuncho) and of cocoa drinks (Criollo).

The Chuncho domesticators are known as the Matsigenka tribe in Cusco, Peru. Until today they consume slightly fermented and slightly roasted dry beans that do not have any bitterness.

Criollo and Chuncho seeds with low bitterness appear to have reduced fresh seed and plant defense mechanisms (Chapter 18) and should thereby possess a serious disadvantage in survival of the fittest during evolution.

It is well known that the ancient Criollo variety is very susceptible to diseases and pests. Frugivores might well consume pulp and fresh seeds at the same time if the seeds are not bitter and therewith reduce the dissemination efficiency of the non-bitter cocoa genotype. Therefore, cocoa varieties with low bitterness and astringency are likely to have been counter selected in nature.

This suggests that Criollo and Chuncho are exceptions that were consciously selected by human beings that consumed their non-bitter beans.

17.3. Pulp Sensory Trait Significance

STOP 8. *Cusco, Brazil*

17.3.1. Pulp vs *Fine Chocolate Traits*

Travelling to 12 cocoa producing countries annually made it ***impossible for me not to conclude in 2007 that pulp flavors and aromas are at the basis of many of the fine flavor traits in chocolates.*** Fine-flavor chocolate producing countries also grow

varieties with fine-flavor pulps (*e.g*. Peru, Ecuador, Venezuela and Trinidad). *A special example is Trinidad* with its famous TSH clones that produce one of the nicest pulp and chocolates in the world (*red/yellow fruit, floral, nutty, raisins*). The price paid for beans of varieties with such nice pulp included in 2008 a bonus of *ca*. 200%. ***This suggests that nice pulp may pay off high cocoa prices!***

The relationship between pulp and chocolate sensory traits is evident for the traditional fine-flavor varieties Criollo, Trinitario, Nacional and Scavina hybrids. The association of the following pulp *vs.* chocolate traits is, respectively, as follows: ***very sweet*** **vs.** ***honey/caramel, citrus/lemon*** **vs** ***fresh fruit, jasmine (orange blossom)*** **vs** ***floral and muscat grape/lily*** **vs** ***raisin/heavy floral.*** This apparent relationship has guided our approach to discovering new sensory traits in cocoa varieties.

STOP 9. *Brazil, World*

17.3.2. Pulp Sensory Traits Migrate into Beans and Chocolates

When discussing our suspected pulp *vs.* chocolate fine-flavor trait relationship my French Cirad technology colleagues were sceptic: "***Chocolate sensory traits are born from precursors formed in the fermentation process, as is the case with wine***".

We (Dario Ahnert and me) tested our hypothesis of *pulp vs. chocolate sensory traits* by fermenting cocoa beans with Cupuaçu (*Theobroma grandiflorum*) and Soursop (*Annona muricata*) pulp on our cocoa farm in Bahia. The fermentation took 12 days but the beans were not spoiled. Chocolates made by Ed Seguine in 2007 eliminated any doubt: *they displayed very strong Cupuaçu and Soursop flavors*. My many French friends loved the chocolates. ***This demonstrates clearly that the sensory fresh fruit environment migrates into the beans and is expressed also in the chocolates.*** *Therefore, the 72 fresh fruit sensory profiles (Stop 3)*

detected so far in cocoa could be expressed in chocolates when adequate fermentation and chocolate processing methods are adopted.

This led us to file an EU patent (WO/2009/103137A2) in 2009 on modification of cocoa sensory traits by addition of aromatic substances during fermentation ("***TropMix****"*). However, we abandoned the patent in 2013 when we realized that traditional fermentation methods rendered the TropMix cocoa more bitter and astringent than we liked. Since 2015 we put all or energy in developing an ***accelerated fermentation method*** that warrants effective transfer of any foreign aromatic substances into the cotyledons within 3-5 days that at the same time displayed ***very low bitterness and astringency.***

ValRhona used the TropMix method to produce two chocolates by fermentation with passion fruit and orange in 2016. They continue claiming that they invented, in a 10-year period, the "Double Fermentation" method that is part of the patented TropMix variants. They never acknowledged the real inventors of this method.

At least they showed the commercial viability of TropMix.

STOP 10. *Peru*

17.3.3. Pulp Sensory Trait Opportunities

The pulp *vs* chocolate sensory trait relationship that we discovered opened two great opportunities:

1. ***Modification of the pulp environment by adding foreign substances*** (see STOP 8), and

2. ***Rapid selection of new fine-flavor cocoa varieties based on pulp sensory evaluation*** **(STOP 1-3).**

The potential fine-flavor characteristics of existing and new varieties can best be assessed by judicious sensory pulp evaluation.

Pulp characteristics of nine genetically different Cocoa clones from the collection of UNAS, Tingo Maria, Peru, were evaluated in 2008. Variables observed were ***aroma (odor), fruity flavor, sweetness, acidity, astringency, fresh bean bitterness/astringency and overall preference.*** A panel of six cocoa scientists evaluated pulp from two ripe pods of each clone. Great variation among varieties for all pulp traits was observed. ***Overall preference was positively correlated with aroma, flavor and sweetness***. Highest preference was obtained for EET62, a Nacional clone (***sweet pulp, strong flavor and aroma***). The third most preferred clone was ICS1 (Trinitario) with a *strong citrus/lemon flavor*. The least preferred clone was CCN51 (***acid and astringent pulp, bitter beans, no perceivable flavor***).
Sensory trait attributes of EET62 and CNN51 represented opposite extremes among the nine clones. These results demonstrate that ***pulp preference*** is directly related with recognized variation for fine-flavor cocoa varieties.
Pulp preference on its own will therefore be already a very useful trait for quick selection of the fine-flavor potential of commercial or new cocoa varieties.

17.4. Discovering Fresh Fruit Sensory Traits

STOP 11. *Trinidad*

17.4.1. Banana Cocoa Discovery

So, we saw that cocoa pulp sensory traits become integrated into fine chocolates. A striking example is the discovery in 2010 of a

cocoa banana tree in Trinidad standing amidst traditional Trinitario trees. The pulp of these Trinitario trees varied for acidity, sweetness and bitterness of the seed.

The pulp of the banana cocoa tree was very sweet and had a ***very typical fresh banana flavor*.** The seeds were not bitter. Ten fruits yielded chocolates made by Ed Seguine.

My good Trinidad friend Kamaldeo Maharaj assessed the chocolate as being "***very fruity with a distinct banana flavor***". My assessment was that of an "***intense persistent banana jam flavor***".

After this very savory experience I stopped buying any common fine chocolates.

Conclusion: savory pulps can yield very interesting chocolates!

STOP 12. *Cusco*

17.4.2. Mandarin Cocoa Discovery

Rolando Herrera, ex-president of APPCACAO, gave me 200 dry Chuncho beans in France in 2011. All beans were sweet and nice. Surprise: one bean out of 10 appeared to have a Mandarin flavor, something I had never met with before in cocoa.

Arriving the same year in La Convención, Cusco for the onset of a "Chuncho Competitivity" Project, I asked my Peruvian colleagues to help me find a Mandarin Chuncho tree. Each of us tasted pulp of all trees in one row. Arriving at tree number 20, I was very happy to be the one to meet with a "Mr Mandarin Chuncho" tree! The pulp was sweet/acidulous, slightly bitter and with a well-defined Mandarin flavor. Not just that of the Mandarin flesh but much more like the Mandarin flesh and peel together. Furthermore, we could not fail to discover a strong "Jasmine" aroma, just as the aroma of the flowers of real Mandarin trees! ***Big mysteries***: how cocoa knew that in nature Mandarin fruits go together with Jasmine flowers? And how cocoa is able to mimic so perfectly a fruit that has its

origin in far-away South East Asia??? Only if cocoa is ***Phenomenal!***

STOP 13. *Lima, Pichari*

17.4.3. Tangelo Cocoa Discovery

It was in July 2016 at the "Salon de Cacao y Chocolate" de Lima that I met with the Laura cocoa producing family from the town of Pichari, 300 km north of Quillabamba. It had not been concerned by our Chuncho flavor and aroma survey so far but it still belongs to the La Convención Province. The family had brought several fresh fruits from their farm including from a native cocoa variety. I asked the farmer to open some fruits from her stand. Big surprise: the odor was that of Jasmine and the flavor of an unknown Citrus fruit, possibly a tangerine, sweet and aromatic. We had not met before with this flavor x odor combination in the survey.

At night in the hotel I searched with Google to find a possible *Citrus* spp. candidate for the pleasant Pichari cocoa fruit pulp mimic. A likely candidate, unknown to me, was that of "Tangelo", a hybrid between Mandarin and Pomelo. According to Wikipedia its varieties have a very sweet juice flavor as the Pichari cocoa pulp. Trying out my chances in the morning I went to the nearest supermarket in Lima and, surprise, there were Tangelo fruits on the shelves. Beautifully yellow/orange colored (see photos). Back to the stand of Mrs. Laura we compared the flavors of Tangelo with that of the pulp of the Pichari native cocoa fruits and yes, ***they were the same*** but only if we mixed the sweet Tangelo juice with a bit of the more aromatic peel of the Tangelo. The native cocoa from Pichari mimics therefore perfectly the Tangelo juice taste and the Tangelo peel taste in its pulp at the same time. On later occasions Carlos Rodriquez confirmed presence of "Tangelo" cocoa pulps in other places in La Convención. This Chuncho cocoa pulp mimic was therefore included into our survey results.

Tangelo cocoa pulp mimic in native Pichari cocoa fruits

17.5. Magic Sensory Trait Associations

STOP 15. *Cusco*

17.5.1. Three Curious Associations

CITRUS X JASMINE ASSOCIATION.

Chuncho Cocoa mimics flavors of three *Citrus* species: Mandarin, Lemon and Tangelo. Interestingly, all Chuncho trees with *Citrus* pulp flavors also display the Jasmine aroma. How did Cocoa develop the genetic association of *Citrus*-like pulp flavors with the flower aroma of all true *Citrus* varieties, *ie* Jasmine? Considering that Chuncho displays Jasmine in 11 out of its 64 sensory profiles, the probability that this association was created during evolution purely by ***random events*** would be only 0.001 (11/64x11/64x11/64). This is a value far below the widely adopted statistical significance threshold of 0.05. Therefore, the ***Citrus x***

Jasmine associations might have resulted from ***some type of mysterious directed Selection***.

MANDARIN FLAVOR VS PULP AND BEAN BITTERNESS. Chuncho pulp and raw beans are all very sweet and display ***no bitterness***. However, one exception is that all trees with the ***Mandarin containing sensory profiles display always statistically increased pulp and bean bitterness*** (score 2.9) ***(P=0.003) in relation to other profiles*** (score 2.0).

Carlos Rodríguez discovered that the bitterness is produced in the endocarp tissue of the cocoa pod wall as is the case with true Mandarin fruits. ***Could frugivore animals have preferred bittersweet rather than just sweet mandarin pulp?***

CITRUS FLAVOR VS. BEAN ACIDITY

Bean samples with citrus/jasmine flavor showed significantly *higher (P=0.01)* ***than average acidity scores*** (2.3) than that of the control samples (1.3).

RED FRUIT ASTRINGENCY

The average astringency score (3.3) for three red fruit flavored bean samples was ***significantly higher*** *(P=0.007)* than that for the control samples (1.3).

SOURSOP COCOA FLAVOR VS SOURSOP PULP TRANSPARENCY. Another intriguing Chuncho sensory trait association is that of ***Sour Sop flavor and Sour Sop pulp transparency*** observed in all Chuncho trees with Sour Sop pulp flavor. This association has also been detected in several Cocoa varieties elsewhere, showing the genuine genetic nature of this association. ***Could this association have been selected by simultaneous frugivore preferences for flavor and appearance, both part of "taste"?***

Watery appearances of Soursop pulp and of Soursop flavored cocoa pulp compared to the dryer normal cocoa pulp in the center.

STOP 16. *Cusco, World*

17.5.2. Three Other Curious Associations

INGA PULP FLAVOR *VS* PULP TEXTURE.

Cocoa genotypes that display Inga pulp flavor also display Inga pulp appearance as found in Peru and in Brazil (see photo). **Again, could this association have been selected by simultaneous frugivore preferences for flavor and texture, both part of "taste"?**

Inga cocoa pulp flavor mimics Inga beans appearance

ROSE PULP AROMA *VS* RED RAW BEAN COLOR.

Cocoa genotypes that display Rose aroma have always dark-reddish bean testa and cotyledon colors as found in Peru and in Brazil. ***A real mystery as this does not seem to be related to any effective evolutionary selection pressure!***

The EET 397 variety with fresh fruit rose aroma has dark reddish testa and cotyledon colors

YELLOW PEACH FLAVOR *VS* YELLOW PULP.

Chuncho trees that display yellow peach pulp flavor always display also yellowish pulp color (see photo). ***Another Real Mystery as, again, there is no apparent evolutionary advantage in cocoa having yellow pulp associated with yellow peach pulp flavor! Phenomenal Cocoa persists in being mysterious!***

Cocoa pulp with yellow peach flavor has always yellow pulp color!

17.6. Determination of Pulp Sensory Traits

STOP 14. *World*

17.6.1. Environmental Determination Hypothesis

In a recent video featuring a famous French fine chocolate maker he expressed happiness to see fruit trees and flowering plants inside a cocoa plantation in Peru because "*Cocoa will capture traits from those aromatic neighboring plants".* When I communicated on social media about the "Banana" and "Mandarin" cocoa pulps the most frequent question was if there were Bananas or Mandarins growing nearby the cocoa trees that displayed these flavors and

aromas. ***This shows how common the perception is that cocoa sensory traits are born from the environment.***

However, our discovery of multiple *40 qualitative pulp and bean flavors and aromas* in the Chuncho Cocoa variety in Cusco was completely independent from any neighboring aromatic fruit trees or flowers. *This can only be explained by the inference that Cocoa fine-flavor sensory traits are mainly based on* ***simply inherited genetic traits***. Progeny trees from "Banana" Chuncho trees all showed banana flavors in their pulps (Comm. Carlos Rodriguez). ***This suggest that fine-flavor traits in Cocoa are genetically dominant.***

This does however not exclude an environmental or *"terroir*" effect (climate, pod ripeness, sun exposure, *etc*.) on the intensity of basic and fine-flavors of cocoa. Furthermore, Cocoa may absorb environmental aromas if wet beans come into contact with aromatic plants, as witnessed by me with Coriander plants growing in cocoa fields in Ecuador. And: *the effect of aromatic substances added during fermentation, known as* "TropMix" *fermentations invented by us in 2007, allows of course for* ***controlled environmental modifications*** *of cocoa bean sensory traits*.

17.6.2. Genetic Determination of Pulp Sensory Traits

The fine-flavor sensory trait survey carried out in the Chuncho Cocoa variety in Cusco in 2015/16 demonstrated clearly that the 40 flavor and aroma identities discovered are of genetic nature. For example, the 13 individual trees found in the bean survey with the Mandarin/Jasmine combination came from widely different cocoa fields of up to 200km apart. The qualitative expression of the Mandarin pulp flavor and of the Jasmine aroma association was always strong and stable. ***This can only be explained by genetics***. The fixed association of the Mandarin flavor and Jasmine aroma suggests *that this combination is based on one dominant pleiotropic gene (=one gene expressing two or more traits simultaneously)*. ***This suggests that the production of several tens***

of volatiles (VOCs) that must be behind each of the two sensory traits is determined by one Phenomenal Cocoa gene!

The same picture of flavor and/or aroma combinations was observed with many other Chuncho sensory trait profiles. Cocoa may have benefited from the fact that pleiotropic gene expression transmits fixed flavor/aroma combinations that attract frugivores simultaneously for pulp aroma and flavor.

The above findings contrast strongly with the predominantly polygenic expression of sensory traits with other fleshy fruit species, e.g. *the* ca. *100 minor genes (QTL's) found for sensory quality in tomato.* ***High-tech genetic research over decades in tomato has still not succeeded to create effective pleiotropic genes for color and flavor associations.***

How* Phenomenal Cocoa*, with its long generation cycle and relatively short evolutionary path, was able to do its genetic engineering millions of years ago resulting in such efficient gene action for so many fine-flavor sensory traits?

17.7. More curious fresh fruit sensory trait modifications

STOP 21 *Brazil*

17.7.1. Cocoa Rose Perfume Disappears at Night!

In Brazil I visited the orchid collection in the Botanical Garden of Rio de Janeiro in 2019. The Guide explained that some orchids produce aromas in the morning, others in the evening and still others at night. This periodicity in aroma production of orchids is known to be related to attract pollinating insects that are active at different times of the day. *This made me think of verifying the periodicity of fresh fruit aroma production for two cocoa perfumes: Rose and Jasmine, on the farm of my good friend David Pujol in Bahia.*

We started with observing Jasmine production by two clones: CCN51 (Citrus/Jasmine) and PS1319 (Green Apple/Jasmine) *Both produced their aroma the entire day and the entire night!*

However, the cocoa Rose aroma behaved different in two clones: BN34 (Grape/Rose) and Cepec 2002 (Peach/Rose). Both clones behave the same by producing their aroma in the day ***but there is no aroma in the night.***

Curiously the fresh fruits are full of Rose aroma at 17:00 but at 18:00 there is no more aroma at all! ***This can only be explained by active destruction of the Rose aroma in the closed fruit and by simultaneous stopping of aroma production***. If it was a passive process the aroma would continue to be present in the husk for many hours!

Interestingly, the Rose aroma is part in two different flavor/aroma genotypes but behaves the same with regard to periodicity of aroma presence. ***Therefore, the similar behavior can only be due to a***

pleiotropic gene that regulates Rose aroma production and destruction!

If the similarity with the orchid aroma periodicity holds, the ***Rose cocoa clones may be trying to avoid to be eaten by nocturne frugivore animals*** such as the kinkajou?

This is another very fascinating feature of Phenomenal Cocoa!

STOP 22. *Brazil*

17.7.2. The Lily Aroma Becomes Violet Aroma by Pod Storage

We have been carrying out repeatedly Anima fermentations in Bahia, Brazil using often the Amelonado and Scavina 6 hybrid varieties simultaneously. Cocoa pods were stored for 0, 4 and 7 days before opening and initiation of fermentation. We followed any modifications in the fresh fruit flavors and aromas in the time span of 7 days. Amelonado seeds became less bitter while the Scavina 6 hybrid seeds tended to become more bitter. There was no change in the fruity pulp flavors during the time of pod storage.

The Amelonado Jasmine aroma intensity increased considerably but did not modify its nature.

However, the Lily aroma of the Scavina 6 hybrids underwent a complete transformation. With the 4- and 7-days pod storage treatments the normal Lily aroma (present at o-days storage) was completely modified into a Violet aroma.

This represents another very mysterious capacity of cocoa in transforming a specific full aroma, based supposedly on many VOCs, into a totally different and also complex aroma just by storage of its pods by 4-7 days.

The Scavina 6 hybrid fresh fruit Lily aroma is transformed into a Violet aroma after 4-7 days of pod storage

STOP 23. *World*

17.8. Wine vs. Fine Cocoa Sensory Expressions

Wine flavors and aromas are mainly unrelated to the grape origin (Ulrich and Fischer**,** 2007.), except for some very distinct and aromatic grape varieties like Muscat and Shiraz. The wine flavors and aromas are mainly born from precursor combinations and microorganism metabolites during the fermentation process. This might be comparable with the precursors that combine to form the typical cocoa flavor during the cocoa roasting process but is completely different from the action of pre-existing full flavors and aromas in cocoa fresh fruits.

This is already a major difference from cocoa fresh fruit flavors and aromas that are present in the beans and in chocolates made from those beans. A very expressive example is given in Chapter 12 on the chocolates made from the Banana pulp flavored cocoa tree identified in Trinidad in 2008. Other strong examples are the chocolates made with the cranberry/rose and mango/rose pulp sensory profiles in the SJ02 and EET397 varieties, respectively, that have yielded very expressive flavors and aromas in their chocolates that remembered the original fruit flavors and aromas present in the pulps of those varieties (personal observations).

Wine flavors and aromas are very nuanced and rarely mimic full fruit flavors or flower aromas.

Primary wine flavors and aromas come with the grape variety and with the "terroir". They represent generally fresh fruit, citric and tropical, white flowers and herbal flavors and aromas (Wikipedia). There is no identification possible of a full flavor or aroma.

Secondary wine flavors and aromas are formed by precursors and micro-organisms during fermentation. Flavors may remember butter, roasted bread, yoghurt and cheese sensations. So, the secondary flavors do not contain full fruit flavors or aromas as is the case with cocoa.

Tertiary wine flavors and aromas develop over time during ripening of the wines in bottles or in barrels. They use to be more complex. Fruity and floral notes that develop with ripening include, among others, floral and fruity notes, basil, cocoa, tobacco, vanilla, cinnamon, caramel, honey, coffee and fungi (Wikipedia).

Genetic components in wine aromatic compounds' composition is based on enzymes that produce aroma compounds or their precursors (Lin *et al*. 2019). One example is that of linalool production by specific grape genes such as Muscat. Linalool is a volatile compound that has a flowery aroma connotation (Kadow *et al*. 2013).

With cocoa, the linalool presence has been evidenced for example in the pulp of the Scavina 6 variety by Kadow *et al*. (2013). We have identified the full "Muscat" grape flavor and lily aroma in the same Scavina 6 variety (personal observations). It is tempting to conclude that the linalool of the Scavina 6 variety is just a component of the full flavor and aroma of the Scavina 6 fresh fruit sensory profile whereas the linalool in the Muscat grape variety is representing a volatile component related to a flowery aroma but that it does not represent on its own a full flavor or aroma as is the case in cocoa.

This comparative overview shows that with cocoa the pre-existing full fruity flavors and floral aromas can play a more important and direct role in the full fine-flavor and aroma traits encountered in chocolates than that with the role of pre-existing flavors and aromas in wines.

Besides, the cocoa fresh fruit flavors and aroma profiles appear to be based on simple inheritance whereas the grape aroma genetics appears complex and polygenic, with many precursors and QTLs having been identified (Lin et al. 2019) for individual aroma compounds.

The phenomenal achievement of cocoa is its capacity to produce many metabolites, based on relatively simple genetics (our Chuncho survey), that together represent apparently perfect mimics of full fruit flavors and floral aromas that are produced by totally different plant species.

18. Cocoa Fresh Seed Stress Reactions

Seed stresses increase bitterness and astringency, thought to be a mechanism of defense against natural enemies

18.1. Reaction to biting fresh seeds *twice*

Fresh cocoa seeds contain up to 20% of polyphenols on a dry weight basis that are related to the bitter and astringent flavors of cocoa seeds, beans and chocolates. This % is extremely high as compared to other fleshy fruits. ***One explanation for such a high polyphenol content in cocoa is that polyphenols may be related to a biological stress reaction capable of preventing damages caused by predators to fresh cocoa seeds.***

The following describes discoveries about the speed and intensity of cocoa seed stress reactions as expressed in bitterness and astringency.

This study started with ***biting fresh cocoa seeds*** to see if the cotyledons of different varieties are more or less bitter/astringent. We considered that this could be an important trait related to the facility with which ***classical fermentation can be applied successfully on different varieties***. Fine-flavor varieties tend to have lower fresh seed bitterness, like Criollo, Trinitario x Criollo and Chuncho genotypes. Bulk varieties tend to have medium to high fresh seed bitterness and astringency (personal observations).

Dario Ahnert and I then found out that *the fresh cocoa seeds have two levels of bitterness/astringency*. With Amelonado, the first bite results in an average or low bitterness/astringency level of 3 while *the immediate second bite results in high bitterness/astringency level of about 6-7.*

With other varieties, like CCN51, the first bite results already in high bitterness/astringency while the second bite results in very high bitterness and astringency.

We concluded that the fresh seeds defend themselves within less than five seconds against a bite aggression. We interpret this as an evolutionary defense of cocoa against organisms that attack the fresh seeds after having been disseminated in the forest by defecating frugivore animals.

18.2. Amelonado Seed Stresses

We then decided to expose fresh *Amelonado* seeds to seven different stress conditions during 5, 15 and 30 minutes.

1. *Control: intact seed pulp exposed to the air*
2. *Seeds without pulp exposed to the air*
3. *Seeds with pulp in drinking water*
4. *Seeds with pulp in vinegar (5-8% acetic acid)*
5. *Seeds with pulp in 54% alcohol*
6. *Seeds with pulp in a refrigerator at 6-10 °C*

	5	min	15	min	30	min
Treatment	**B**	**A**	**B**	**A**	**B**	**A**
1 air	**3**	**2**	**3**	**2**	**3**	**2**
2 no pulp	***7***	***4***	***8***	***5***	***8***	***5***
3 water	***8***	***5***	***7***	***4***	***8***	***5***
4 vinegar	***7***	***5***	***7***	***4***	***6***	***5***
5 alcohol	***7***	***5***	***7***	***4***	***6***	***5***
6 frig	***3***	***2***	***6***	***4***	***8***	***6***

Table 18.1. Stress Reactions of Fresh Amelonado cocoa seeds (B = Bitterness and A = Astringency)

Under all conditions Amelonado seeds show higher bitterness than astringency intensity. Interestingly, treatment 1 with fresh seeds in the air does apparently not induce any stress reaction. The treatments 2 to 6 resulted in very quick and intense stress reactions, with 2-3 times higher bitterness and astringency intensities as compared to the control treatment 1.

The stress induced by de-pulping of the fresh seeds (treatment 2) suggests that any seed exposed to the air including after having been eaten by a frugivore will develop a stress reaction. The stress reaction induced by placing fresh seeds and pulp in water (3) is very surprising. It may partly explain why fresh cocoa from the first day of placing it in traditional fermentation boxes is already developing a stress reaction with high bitterness and astringency.

The rapid stress induced by treatments 4 (vinegar) and 5 (alcohol) would suggest that Amelonado cocoa seeds will get more bitter and more astringent during both the alcoholic and acetic acid fermentation phases as compared to the fresh seed bitterness and astringency intensities.

18.3. CCN51 Seed Stresses

The same stress treatments as applied to Amelonado in Brazil were applied to CCN51 in Peru by *Carlos Rodriquez*.

The control treatment 1 of CCN51 presented a much higher bitterness and astringency intensity (5) than that of Amelonado in Brazil (2.5), *suggesting that the basic level of defense in CCN51 is higher than that of Amelonado*. Bitterness and astringency of CCN51 were overall high and

of similar intensities. *The exception is the vinegar treatment that evolved rapidly from a high intensity of 5-6 to a very high intensity of 8-9.*

	5 min		15 min		30 min	
Treatment	**B**	**A**	**B**	**A**	**B**	**A**
1 air	*5*	*4*	*5*	*5*	*5*	*5*
2 no pulp	*5*	*5*	*5*	*5*	*6*	*7*
3 water	*5*	*5*	*5*	*5*	*6*	*6*
4 vinegar	*6*	*5*	*7*	*8*	*8*	*9*
5 alcohol	*5*	*5*	*5*	*6*	*7*	*7*
6 frig	*5*	*5*	*5*	*5*	*6*	*6*

Table 18.2. Stress Reaction Intensities of fresh CCN51 cocoa seeds (B = Bitterness and A = Astringency)

18.4. Chuncho Seed Stresses

The same stresses were applied also to the fine flavor variety Chuncho in Peru by *Carlos Rodriquez.* Pure Chuncho fresh seeds do not express any bitterness nor astringency upon first nor second biting.

Accordingly, the control treatment 1 (air) showed nearly complete absence of bitterness and astringency, with intensities being much lower (1-2) than for Amelonado (2-3) and for CCN51 (5).

The Chuncho seeds reacted however to the other treatments with bitterness and astringency intensities increasing from 1-2 to 4-5-6 after 30 minutes. This certainly demonstrates the capacity of Chuncho to also react rapidly to stresses,

even with its low base intensity levels of bitterness and astringency.

The strongest Chuncho stress reaction was with vinegar, reaching after 15 minutes bitterness and astringency intensities of 7-8, *ie*. nearly as high as that for CCN51 (8-9) for the same treatment. This confirms the extreme sensibility of cocoa seeds to vinegar, even for the fine flavor Chuncho variety.

	5 min		15 min		30 min	
Treatment	**B**	**A**	**B**	**A**	**B**	**A**
1 air	*1*	*1*	*2*	*1*	*2*	*2*
2 no pulp	*2*	*1*	*3*	*3*	*4*	*5*
3 water	*2*	*1*	*2*	*3*	*5*	*4*
4 vinegar	*4*	*1*	*7*	*8*	*7*	*8*
5 alcohol	*3*	*1*	*5*	*3*	*6*	*5*
6 frig	*3*	*1*	*3*	*1*	*5*	*3*

Table 18.3. Stress Reaction Intensities of Fresh Chuncho cocoa seeds (B = Bitterness and A = Astringency)

18.5. Conclusions

Fresh cocoa seeds in general show a very strong and rapid reaction to several types of stress conditions. This might tentatively be explained by the conditions of evolutionary dissemination of fresh seeds in the wild that need to defend themselves strongly after having been consumed by frugivore animals and after falling on the ground.

Firstly, we showed a strong stress reaction after de-pulping of the seeds that is a condition when frugivores eat the pulp.

Secondly, the most striking stress reaction we found with regard to vinegar which activity might imitate that of the

stomach acidity in primate frugivore animals. *Such double stressed seeds during consumption and digestion of fresh cocoa seeds might then have become much less attractive to natural enemies after falling on the ground when defecated by the frugivore animals and after initiation of the germination process.*

The base bitterness and astringency levels varied largely with the genotypes. Chuncho had no or very little (1-2), Amelonado moderate (3) and CCN51 high levels (5) of bitterness and astringency. *This might be related to the relative difficulty with which bitterness and astringency can be eliminated during fermentation of these varieties by traditional methods.*

The varieties tested showed important relative differences in reactivity to stresses. The Amelonado variety was most reactive to *water, to de-pulping and to low temperatures* whereas the CCN51 and Chuncho seeds were most reactive to *vinegar.*

The above shows that all varieties react strongly to multiple stress factors existing in nature or in fermentation boxes such as ***water, alcohol and acetic acid***. This is in agreement with our observations on Amelonado fresh seeds that increase in bitterness and astringency intensity from 3 to 5-6 rapidly at the onset of the fermentation process.

The bases of the observed cocoa fresh seed stress reactions are *mysterious.* What is the signal that is produced by the stress conditions that incites the cocoa seeds to produce such strong and quick increases in bitterness and astringency intensities? For example, what type of signal is produced by drinking water or by cold? The stress reactions that may have evolutionary sense as well as consequences

for fermentation efficiency would deserve to be studied scientifically.

19. Sentences Unlike Sentences 4

A Lovely Person
Is Often Alone
But a Lonely Person
Is Often not Lovely

Only Love
Can Break Barriers
Including Love Barriers

All that is Good
Should be Simple (Cocoa wisdom)
But not all that is Simple
Is Good

All that is Good
Should also be Beautiful
Even Food

My Caipirinha is a
Diluted Fruit Juice

In Love
One plus One
Can be One (Fusional)
Or more than Two (Complementary)

Knowledge is not Wisdom
Wisdom is Uniting
Knowledge
With Ourselves

Wisdom is the
Daughter of Experience

(Leonardo da Vinci)

Being on My Own
Is not Being Alone
I am Stronger on My Own
Then Accompanied
On My Own, I Break the Rules
Accompanied, the Rules Break Me

Our Future Depends
On our Capacity
To Walk on Our Own

If Life is not Playing Games with You
You Better Play Games with Life

We can only Choose in Life
How we Want to Die

Always There Has to be
A First Time
Even in Love!

A Wisdom Can Be
A Great Banality

Being Brilliant
Can be a Banality

Unhappiness Increases
The Capacity to be Happy
The Capacity to be Happy
Is the Same as to be Unhappy

It's Better to Joke
Than to Cry

All that comes from God
Is a Blessing, Grace to God
But, the Grace of the Devil Is no Blessing

A Disgrace is More Expensive
Than a Grace

20. The “Whole Fruit” CacaoNut Discovery

20.1. CacaoNuts (BR1020180074954) Description

"CacaoNuts" is a Very Tasty and Healthy Natural “Whole Fruit” Cocoa Product that was Discovered in 2018 in Brazil

Finalized CacaoNuts covered with natural dark cocoa powder

CacaoNuts (see photo) is a 100% cocoa product but has nevertheless no bitterness nor astringency. The taste sequence is ***mild cocoa, strong almond and a balanced sweet/acidulous/fruity flavor*** that comes from the pulp. The finish-off is that of a strong floral aroma such as jasmine, lily, rose or violet. The nutty/fruity flavors persist longtime in the mouth (see sensory evaluation below).

CacaoNuts can easily be ***flavored*** with fruit juices or with spices diversifying sensory traits.

Dark chocolates ground with CacaoNuts ***("CacaoNutLates")*** provides a very balanced and nice composite product.

Chemical analysis showed that CacaoNuts contain ***twice as much polyphenols (35 mg/g)*** than in craft natural chocolates (15-20 mg/g). It further contains ca. ***15-19% healthy natural soft fibers***.

CacaoNuts are relatively ***easy to produce on-farm*** with a method that is far simpler than that of chocolate processing. They can be sold directly to consumer companies allowing to obtain a very competitive tasty and healthy product for the consumers.

Once the Market for CacaoNuts will have been developed farmers will be able to obtain much more (minimum of 5 times more) than any fair price currently paid for fermented and dried cocoa beans. Such will favor long term sustainability of cocoa farming.

The product should appeal to healthy natural snack consumers and, in general, to all the dark chocolate consumers.

20.2. Craft Method for CacaoNut Production

"All that is Good Shall be Simple"

(Citation of *Theobroma cacao*, 2018)

20.2.1. Selection of Cocoa Variety

CacaoNuts are best obtained from cocoa varieties with medium to small beans. Very importantly the ripe fruits should best have perceivable aromas when opened, like *jasmine, violet, rose, lily*, or present mixed aromas. The pulp should also best have expressive fruity flavors, like *fresh fruit, citrus, lemon, cranberry, soursop, peach, grape* or have a mixture of fruity flavors.
If no expressive aromas and/or fruity flavors are present in the pulp of the available varieties than still very interesting CacaoNuts can be made by *flavoring* of the seeds during drying in the oven (see later on).
Varieties will normally have very bitter and astringent seeds. Incredibly, these unwanted flavours disappear during the 2-3 hours cooking of the seeds. This, in itself, was one of the main discoveries during the CacaoNut invention, that started with using seeds without any bitterness nor astringency.

20.2.2. Harvesting of Fruits and Seeds

Ripe fruits are harvested as for normal cocoa processing. The fruits are opened and seeds with well-ripe white/rose colored pulps are placed in an inox tray with a height of 3-6 cocoa seeds. Trays having a black protective layer against sticking of the pulp during cooking/drying of the cocoa seeds may also

be used. Aluminum trays will cause more sticking of pulp of the cocoa seeds.

20.2.3. Cooking and Drying of CacaoNuts

Before starting to cook and dry the CacaoNuts it is important to add water to the seeds in the tray until half a cm from the top of the upper layer of the seeds and pulp.

There are different temperature regimes that may produce good CacaoNut cooking and drying.

My preferred method starts with the kitchen oven at 220 ^{0}C and with turning the seeds and pulp every twenty minutes. Once the water has evaporated and the color of the pulp/seeds starts changing into a rose/reddish color the temperature should be decreased to 180^{0}C while turning the seeds at 15 min interval. Once the color becomes more reddish/pink and the seeds more sticky the temperature should be reduced to 150^{0}C with mixing also every 15 min. Once the CacaoNuts become individualized and less sticky the drying should start by opening the door of the oven at 1/3 of total opening. Turning of the CacaoNuts should continue at every 15 minutes until the seeds become nearly dry. Normally the surface of the CacaoNuts will still be somewhat sticky once the drying is finished. The whole process takes about three hours.

20.2.4. Flavor and Aroma of Dried CacaoNuts

The flavor and aroma of dried CacaoNuts is based on the fruity flavor and floral aroma of the pulp of the cocoa variety (or variety mix) used. It is important to realize that despite the

high temperature the fruity flavor and floral aroma do not evaporate during the cooking and drying process. Another important aspect is that the shell of the CacaoNuts becomes soft and can be easily eaten and digested with the rest of the CacaoNut.

20.2.5. Flavoring of CacaoNuts

If the cocoa variety (or variety mix) does not have a very expressive flavor and/or aroma it is very well possible to carry out a flavoring process of the CacaoNuts in the middle of the oven drying process. Typically, one can use 30-60 ml of fresh fruit juice (*e.g.* Passion Fruit, Soursop, Mandarin or any other tasty locally available fruit) per one liter of CacaoNuts. The juice will then dry together with the CacaoNuts and incorporate interesting flavors to the CacaoNuts.

20.2.6. Covering the CacaoNuts with cocoa powder

In order to improve the look and also the taste of the CacaoNuts it is recommendable to cover the sticky outside of the CacaoNuts with 100% cacao powder. Thorough mixing with the powder will produce dry CacaoNuts with a slight taste of cocoa.

20.2.7. Sensory evaluation of CacaoNuts and of "CacaoNutlates"

Table 20.1 shows sensorial analysis of the kernel of the CacaoNut (cotyledons), of the entire CacaoNuts (covered with cocoa powder), of 70% chocolate and of "CacaoNutLates" (mixture of CacaoNuts and 70% chocolate).

Highest overall preference was obtained by CacaoNuts and CacaoNutLates (9 and 10, respectively). The 70% chocolate used received relative low preference as compared to CacaoNuts and CacaoNutLates.

The general conclusion is that very high sensory and health services can be delivered by CacaoNuts and CacaoNutLates.

Table 20.1. Sensory Comparison of CacaoNuts, Chocolate 70% and "CacaoNutlates" (Mix of CacaoNuts and 70% Chocolate)

Treat-ments	Acidity	Bitterness	Astringency	Cocoa	Nutty	Sweet	Fresh Fruit	Brown Fruit	Aroma	Aftertaste	Preference	Obser-vations
Nut of CacaoNut	0	2	0	0	8	3	0	0	0	8	8	Strong nutty
Entire CacaoNut	4	2	0	2	6	3	8	3	6	9	9	Eaten as a dried fruit
Chocolate 70%	0	3	2	7	3	4	0	4	0	7	7	Little fruit and no aroma
Cacao-Nutlates (85%)	3	2	0	4	4	4	7	4	5	10	10	Very well balanced!

20.3. Photos of the Cooking and Drying Process of CacaoNut Production

Photo 20.1. Cooking and Drying of Two Cocoa Varieties in a Kitchen Oven

Photo 20.2. Flavoring of CacaoNuts Followed by Further Drying in the Oven

Photo 20.3. CacaoNuts with Natural Cranberry/Rose Flavor and Aroma
(SJ02 variety from Brazil; the red color of the CacaoNuts is related to the cranberry flavor in the SJ02 pulp)

Albertus Eskes, Dario Ahnert and Chico Durão

CacaoNut Discoverers

Brazil

21. CocoaPerfume

"CocoaPerfume" is a very Original Natural Fragrance from Cocoa Discovered two Years Ago in Brazil.

21.1. CocoaPerfume Description (BR1020190094877)

Another new cocoa product invented by a uni-national in Brazil in 2018, CocoaPerfume comes as a fragrance with aromas such as rose, jasmine, lily, violet and mixed flowers. *Persistence on the skin is for 12+ hours as good as that of Channel 5 perfume.*

Excellent product to put on the shelf together with B2B chocolates or in perfume shops.

Again, the main winner of this product once commercialized is the farmer as the base product can only be made on-farm. A rapid calculation shows that one laborer can extract one liter of CocoaPerfume in two hrs. That may mean with value of at least 100+ USD, not bad for a two hours' laborers job.

21.2. Craft Method of CocoaPerfume Production

"Everything That Is Good Shall be Simple"

(citation of *Theobroma cacao*, 2018)

21.2.1. Introduction

Cocoa is known to produce 28 different fruity flavours and 12 different aromas in its fresh ripe fruits (*Eskes* et al., *Agrotropica 30:157, 2018, On line*). These flavors and aromas are found in most ripe cocoa pods of *most commercial and native cocoa varieties.*

The evolutionary explanation for the existence of combined flavor and aroma presence in cocoa genotypes is that cocoa seed dissemination depends on frugivore animals that climb into the tree to first smell the odor of the pod to make sure it is ripe and then eat the pulp and swallow the seeds that are later defecated in the Garden of Eden.

The fruity flavors seem to be produced inside the pulp. They persist long time in the pulp that is outside the pod.

The aroma is strongest when opening the pods but decreases in intensity after 10-20 seconds. I am not sure if the aroma is produced in the white endocarp of the fresh ripe fruit or in the pulp. The fact is that once the pulp is taken out of the pod, the inside of the empty pod still harbors a strong aroma.

Twenty eight of the 40 cocoa flavors and aromas mimic flavors and aromas of other fruit or flower plants, such as *soursop, mandarin, grape, cranberry* and *mango* flavors and *rose, violet, lily, jasmine, floral, heavy floral, mint, vanilla, spicy, cinnamon, herbal* and *basil* aromas.

The most common floral aromas encountered in Peru and in Brazil are ***rose, lily, jasmine, violet and floral***.

21.2.2. Craft Method of CocoaPerfume Production

The idea of trying to capture the cocoa aromas was born in Bahia, Brazil in 2018. All trees of the Amelonado variety produce strong jasmine aroma on opening the pod. The author bought 100% ethanol and tried to capture the aroma in empty pod husks after having extracted the pulp from ripe pods. The surprise was very big in that the ethanol captures perfectly the cocoa pod aromas. After maturation of the "CocoaPerfume" for 3-6 months in presence of a perfume fixator the obtained craft "Cologne" had much less alcohol intensity and appeared ready to be used. Typically, the CocoaPerfume would persist on the skin for 8-12 hours which is as much as the Channel 5 perfume.

Details of *CocoaPerfume* Production

1. **Pod harvesting and opening**
   Ripe pods are harvested as for normal cocoa harvesting. Diseased or wounded pods should be eliminated. Pods are opened and pulp plus seeds are completely removed from the pod husk.

2. **Collecting of empty pod husk aromas**
   The same person that opens the pods and removes the beans smells the interior of the empty pod husks to verify presence of aroma. If aroma is present, he then passes the husk onto

the person that will capture the aroma by pouring 100% (minimum 93%) ethanol into the empty husk shaking gently the ethanol for 10 seconds before pouring the ethanol into a second empty husk repeating the shaking and further pouring into more husks. Once the amount of ethanol decreases to *ca.* 50% from the original amount poured into the 8first pod (*this happens usually after capturing aromas from some 15-20 pod husks*) the liquid is stored into a dark container, like a thermo bottle, hence in the absence of light.

3. **Fixating of the CocoaPerfume**
   The most important ingredient to fixate the CocoaPerfume is Galaxolide at 3%. This product helps to reduce ethanol smelling and feeling on the skin, to also increase intensity of the aroma and to increase persistence of the CocoaPerfume on the skin to 8-12+ hours.
   Other ingredients exist to refine the aroma even more but are not considered fundamental in producing a craft product.

4. **Maturation and bottling of CocoaPerfume**
   Maturation of the raw CocoaPerfume plus fixator needs to be done for 4-6 months until the aroma becomes stronger and the ethanol smell and feeling less strong. It can then be sieved and bottled for commercialization.

22. « Anima » Fermentation Technology (2019)

"Everything That Is Good Shall be Simple"
(Theobroma cacao, *2018)*

22.1. Anima "Child"

"Anima" = "*Soul*"

"Anima" = "*Spirit of the Forest*"

The Chameleon is the best *Symbol for Cocoa*

The Chameleon Mimics the Colors of the Far Away Rainbow

Which is the *Symbol of Peace*

And also the *Symbol of the Incas*

That Consumed Chuncho ("From the Forest") Sweet Beans

That Mimic 28 Flavors and 12 Aromas

From Far Away in its Fresh Fruits

Like, *Mandarin, Sor Sop, Mango, Banana,*
***Cranberry, Rose, Lily, Jasmine, Vanilla, Mint, etc*.**

(*Eskes, Rodriquez et al. Agrotropica 30 : 157, 2018*)

So many Flavors and Aromas in Cocoa Fresh Fruits

That are not Expressed with Traditional Fermentations

That Were the Reason for Creating the

New Fermentation Method

"Anima"

Based on 250 Experimental Fermentations

Between 2015 and 2019 in *Brazil*

Anima "Child" (2015-2017)

50 Fermentations in Polystyrene Boxes

(Steps: Bean Spreading, Air and Inoculum)

22.2. Anima "Child" Sensory Examples

Additional Sensory Global Preference Points for Anima Child with Regard to the Control (Table 21.1)

Air (+2), Bean Spreading (+1), and Inoculation (+1)

Days Ferm.	Treat-ment	Acidity citr.	Bitterness	Astring.	Fr. Fruit	Br. Fruit	Floral	Preference	Obser-vation
6	Control	0	3	4	0	2	0	5	
6	+ Inoculum	0	3	2	0	2	0	6	
5	+ Aire	0	3	3	0	0	2	7	Floral
5	+ Bean Spreading	0	2	3	0	1	0	6	
4	+ All 3 Steps	0	0	0	2	3	0	9	Nutty
Other Full Anima Child Treatments									
4	Amelonado	0	2	1	0	2	7	8	Jasmine
3	Salobrinho 3	0	1	1	0	5	5	10	Soursop/ Lily
3	EET397	0	2	1	0	5	6	10	Mango/ Rose

Table 22.1. Sensory Evaluation of Raw Beans Fermented According to Anima Childhood Steps

► *Very Good Anima Child Sensorial Results: Strong Fruity and Floral Traits*

► *The combination of the three innovative steps makes the difference!*

► *Anima Child is an Accelerated Method (3-4 days)*

2017: Distinction obtained for Anima Child Chocolates at the "Cocoa of Excellence Competition" in Paris

Discussion on Anima Childhood:

"Bean Spreading and the Way Air is Introduced into Small Boxes are *non-Adapted* Steps for Large Scale Cocoa Fermentations"

22.3. Anima "Adult" (2017-2019)

250 Fermentations and More Innovations:

1. *Modified Aeration System*
(More Air = 2-3 + Preference Points)

2. *Modified Inoculation System*
(= 1 Preference Point)

3. *End of Fermentation by Tasting*
(= More Constant Quality Results)

22.4. Anima *vs.* Traditional Fermentations

One of the main features of traditional fermentation is the strict separation between the alcoholic and acetic acid fermentation processes. The alcoholic phase of 36-48 hours is considered to *profit from anaerobic conditions* as much as possible because the yeast fungi should prefer to grow in absence of oxygen. Our method demonstrates that the yeasts develop as well under anaerobic as under aerobic conditions, thereby inviting the acetic acid bacteria to enter the fermentation game earlier on and therewith creating superposition of the alcoholic and acetic acid fermentation phases.

Our tentative explanation on the Anima aerobic alcoholic phase is that with increased air in the system the yeasts perform partially a *fermentation process* (alcohol and CO_2 production) and partially a *respiration process* (H_2O and Co_2 production). The latter process is producing high energy output, accelerating the temperature increase in the system. The combined fermentation and respiration processes are expected to be responsible for the observed lower alcohol and acetic acid production in comparison to traditional fermentations, and probably thereby helping to reduce the total fermentation duration to 4-5 days.

In Anima fermentations *acetic acid disappears largely from the fermentation boxes just before the end of the fermentation process* while with traditional fermentations the acetic acid intensities continue very high until the very end of the 6-7 days fermentations. It is therefore anticipated that Anima cocoa beans have zero acetic acid contents after fermentation and drying, even when using rapid drying methods. The traditional beans need slow drying to eliminate the high acetic acid intensities which is often not achieved.

A further important difference with the traditional method is in the way the Anima fermentations are ended. This is done based on *bean bitterness and astringency evaluations* once the acetic acid intensity has decreased significantly after 3-5 days. If the bitterness is reduced to 0-2 points on a 0 to 10-point scale the fermentation should be finalized and the beans placed out to dry. With traditional fermentations the verification of the right time to finalize fermentations is done mainly by colometry using the cut-test and more recently by Ph measurements.

22.5. Anima Fermentation Temperatures

Variety and Inoculum Dosis	Days, A = Afternoon, M = Morning												Dura-tion Ferm. (days)
	2	2	3	3	4	4	5	5	6	6	7	7	
	A	M	A	M	A	M	A	M	A	M	A	M	
Control, 0	27	27	27	40	44	35	40	36	41	39	41	X	6,5
Amelonado, 1	28	34	49	43	39	37	X						4,0
" , 2	32	42	38	37	X								3,0
Maranhão, 1	29	31	32	40	40	37	36	X					4,5
" , 2	28	30	32	44	39	41	35	X					4,5
CCN51, 3	29	30	33	44	45	44	42	35	X				5.0
SJ03, 1,5	29	31	34	34	45	45	46	X					4,5
CEPEC 2000, 1	30	32	34	38	48	41	46	X					4,5
FM 31, 1	31	33	36	36	40	37	41	37	37	X			5,5
FM31, 2	33	35	37	36	42	36	X						4,0
Mix box, 2	43	41	42	46	48	X							3,5
Mix box, 0	43	40	42	41	45	42	37	X					4,5

Table 22.1. Temperatures of Adult Anima Fermentations from Second Day Onward (X = End of Fermentation)

Analysis of Table 22.1.

► *Effect of Inoculum % on Fermentation Duration*

► *Fermentation Duration of Anima Adult is Accelerated (3-5.5 Days) in comparison to the Control Fermentation During 6,5 Days*

22.6. Anima Bean and Chocolate Sensory Profiles

22.6.1. Anima Raw Bean Qualities

Anima sensory bean qualities have ***Global Preferences*** of 8 to 10 (Table 22.2). This is usually 3-5 points above the beans obtained by traditional control fermentations.

Days Ferm.	Days pod storage	Variety	Inoc. Dose	Acidity citr.	Bitterness	Astring.	Sweet	Nut	Fr. Fruit	Br. Fruit	Floral	After taste	Preference
4	0	Mix white	1,5	4	1	0	4	5	6	3	3	9	10
4	4	PS40.7	2	0	2	1	4	6	0	6	6	8	9
4	4	FA13	3	1	0	0	3	4	0	4	3	8	9
3	4	FM31	2	0	1	0	6	4	0	6	5	9	9
5	3	Amelonado	2	1	2	1	3	4	3	3	4	8	9
5	3	CCN51	3	4	0	0	4	6	5	3	6	9	10
4,5	3	CCN51	3	2	2	1	4	4	3	5	5	8	8
4,5	3	BN34	2	0	3	2	3	5	0	8	7	8	8
3,5	5	IPI+Salob	3	0	1	2	5	6	2	8	6	10	10
6	0	Control	0	2	4	3	0	0	0	4	0	4	5

Table 22.2. Sensory Profiles of Anima Beans Compared to Traditionally Fermented Beans

► *Anima = Very Complex and Harmonious Sensory Profiles*

► *Anima Transforms Bulk into Fine Cocoa (e.g. Amelonado and CCN51)*

► *Anima = Three to Five Preference Points Above the Control*

22.6.2. Anima Chocolate Sensory Profiles

Anima chocolate sensory bean qualities have ***Global Preferences*** of 9-10 as compared to 6 for the Amelonado control (Table 22.3).

Variety	Acidity	Bitterness	Astringency	Sweet	Nutty	Fresh Fruit	Brown Fruit	Floral	Aftertaste	Preference
Amelonado	2	1	1	5	6	4	4	3	9	9
Maranhão	0	0	1	5	6	5	3	3	10	10
Trinitario Hybrid	4	1	2	4	5	6	2	3	10	10+
Green Cambodia	2	0	0	6	8	0	8	5	9	10
Mix Cambodia	2	0	0	6	8	4	4	4	9	10
Durian TropMix	4	0	1	6	6	10	3	4	10	10++
Amelonado Control	2	3	2	2	2	0	3	2	6	6

Table 22.3. Sensory Profiles of Anima Beans Compared to Traditionally Fermented Beans

All Anima chocolate sensory profiles are complex and balanced, even if based on the 3 single-variety origins depicted in Table 22.3.

All Anima chocolates show low or zero bitterness and astringency, high caramel and almond flavors (yes, as in pure Criollo!), varietal fresh/mature fruit and aroma and a long nice aftertaste.

The Amelonado control fermentation yielded medium/high bitterness and astringency, with low intensities of the axillary flavors and aromas, and an unpleasant short aftertaste. This contrasts strongly with the Amelonado Anima chocolate which has low basic flavors and strong xylary flavors and aromas.

The ***Maranhão and Trinitario*** chocolates were quite astringent after making. However, after 4 months maturation these undesirable features disappeared totally.

Maranhão is a sub-variety of Amelonado It has however a more pronounced fresh fruit flavor remembering that of the Anima Trinitario chocolate.

The ***Trinitario*** hybrid has surprising fresh fruit sensory features that seem to become liquid, like a red wine, while tasting goes on. The preference score of 10+ goes beyond the 10-point scale.

The following Anima chocolates were made from beans produced at the innovative CFARM cocoa farm in West Cambodia. The "**Green"** variety mix is made up of 6 clonal varieties originally introduced from Vietnam and Malaysia. These can be considered in their majority as Forastero genotypes. Despite this, I identified a rich arsenal of fresh fruit flavors: Grape, Soursop, Yellow Peach, Herbal, Muscat Grape and Lemon. The aromas identified were Jasmine and Herbal. This shows the profound fine cocoa bases present in these cocoas.

The **Green** Anima chocolate is very delicate with very strong caramel and almond flavors. Mature fruit is extra strong which can be explained by the presence of the four fresh fruit flavors in the variety mix that became likely transformed into mature fruit by the roasting process. The most astonishing is the herbal aroma trait that is well expressed in the Green chocolate despite originating from only one out of six clones. *It certainly suggests the strong persistence of this trait during fermentation and processing. And the astonishing capacity of Anima fermentations to express subtle fresh fruit flavors and aromas.*

The Cambodia Anima **Mix** chocolate is based on 8 clonal varieties, 6 having green pods (as the Green variety above) and two have red pods. The red-podded TD3 and TD10 varieties have pulp remembering that of Trinitario with Lemon flavor and Jasmine aroma. The Mix Anima chocolates express exactly this genetic makeup. The Mix expressed a very nice balanced fresh and mature fruit harmony as compared to only mature fruit expression in the Green chocolate

The **Durian TropMix** chocolate contains a mix of all eight CFARM varieties. The TropMix treatment consisted of adding blended Durian fruit pulp to the fermenting cocoa mass. This did not alter the temperature (36-46 ^{0}C) nor the fermentation duration (3.5 days).

The Durian TropMix is the most astonishing chocolate I ever ate in my life. It expresses citric acidity and strong caramel/almond flavors. The prevailing fresh fruit flavor is very savory and comes with a liquid consistency of a Porto wine! Overall preference cannot be less than 10+++.

*The above shows the interest in **marrying the TropMix technology with the Anima technology** in order to produce unlimited new flavor and aroma combinations in chocolates. Unfortunately, international and national cocoa and chocolate competitions tend to forbid participation of samples that have undergone TropMix treatments. This is the more striking as chocolate makers are allowed to make any inclusion in their competing chocolates.*

23. Potential of Anima in Creating Fine and More Healthy Cocoa Market Segments

23.1. Mass Production of Anima Beans

Anima fermentations have the potential to be applied at large scale even by smallholders. The method is relatively ***simple*** and can be applied with ***adapted protocols for small and large farmers' existing fermentation facilities***. Furthermore, the method is ***cheap*** as there is no need for any entrant from outside the farm.

These above conditions warrant the feasibility of successful application of the Anima technology at large scale, allowing to create potentially a ***large segment of fine-flavor cocoa on the international cocoa market***.

23.2. Non-Dutched Anima Chocolate Health Services' Potential

Further considerations are related to the combined ***enhanced quality and health services*** provided by future Anima-based fine cocoa market segments.

The high sensory quality of Anima beans would allow for suppression of the commonly applied ***industrial alkalization process (Dutching)*** that eliminates negative features of commodity cocoa beans (*acidity, bitterness and astringency*) but also its positive features (*fresh fruit flavors and aromas and anti-oxidants*) (Hurst *et al*. 2011).

The negative effects of the Dutch process on the flavanol quantities in cocoa powders is depicted in Figure 23.1. The remaining percentages of flavanol in light, medium and heavily Dutched cocoa powders are 39%, 21% and 10%, respectively, with an average of *ca*. 23%. (Miller *et al*., 2008).

In other words, Anima cocoa products that do not need Dutching would expect to ***increase its polyphenol content with 156%, 376% and 900%, respectively for light, medium and high Dutching intensities.*** In average this means an increase of about 330% of antioxidants in comparison to the average Dutched cocoa products that currently dominate the cocoa markets.

Therefore, large scale production of Anima cocoas has the realistic potential to increase significantly the quality of cocoa products as well as their health services in comparison to currently predominating industrial cocoa products.

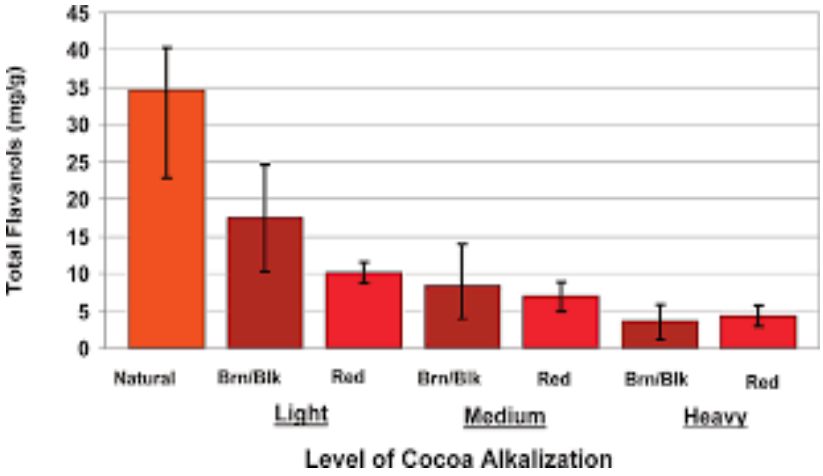


Figure 23.1. Effect of Dutching levels on flavanol concentrations in cocoa powder (Miller* et al., *2008))

The above deductions should warrant increasing interest from small and large cocoa industries as well as from cocoa consumers for Anima cocoas. This might boost producer and consumer market segments based on Anima fermentation technology.

All this together should be able to enhance farm gate prices and thus cocoa sustainability in the medium and long term.

Anima Publicity Made by my Granddaughter Flora of Seven Years Old. She Loves Dark Anima Chocolates Because they are not Bitter.

"Who Owns the Childhood of Cocoa Preferences Owns the Future of Cocoa Preferences"

24. Transformation of African Cocoa into “Fine” Cocoa

24.1. Anima African Variety Transformation

As shown in Brazil in 2017-2019, ***the innovative Anima fermentation technology*** can transform “bulk” varieties, such as CCN51, into varieties with expressive fine-flavor traits (sweet, nutty and fruity) and aroma (Jasmine).

An ***Anima fermentation*** study was carried out with fresh beans from:

- **Amelonado** from a farmers field, and
- **15 Forastero Amazon** clones (IMC and PA mixture).

The latter were obtained from the germplasm collection of CEPLAC in Itabuna, Brazil. Together with Amelonado, the IMC and PA Forastero germplasm has been employed widely in African cocoa introduction and breeding programs such as in Ivory Coast, Ghana and Nigeria.

Fresh fruits of the IMC and PA pulps displayed fine fruity and aroma traits in 50% of their fruits, which was unexpected for these pure Forastero varieties.

The following expressions of sensory traits on a 0-10 point scale for the IMC/PA raw beans were observed as a result of Anima fermentations of beans from 4-day pod storage (Table 24.1): ***0 acidity, 2 bitterness, 1 astringency, 3 sweet, 2 nutty, 5 fruity, 3 floral and 9 for overall preference.***

For the Amelonado Anima fermentations of beans with 4 days pod storage the raw bean sensory trait expression was very similar to the Amazon clones: ***0 acidity, 2 bitterness, 0 astringency, 3 sweet, 2 nutty, 5 fruity, 6 floral and 8 for overall preference***.

The Amelonado fermentation with pod storage of 7 days resulted in a ***maximum score of 10 for general preference (Table 24.1)***. The raw beans were sweeter and had more nutty taste than the beans fermented with pod storage of 1 and 4 days.

For the Amelonado control beans, *obtained by traditional fermentation*, the sensory trait expression revealed inferior quality: ***4 acidity, 4 bitterness, 4 astringency, 0 sweet, 0 nutty, 0 fruity, 2 floral and 5 for overall preference***, such as expected from bulk cocoas.

Treatments	Pod Storage	Acidity	Bitterness	Astringency	Honey	Almond	Fresh Fruit	Brown Fruit	Floral	Preference
Amelonado	7	0	0	0	4	3	0	5	4	10
Amelonado	4	0	2	1	2	2	0	3	5	8
Amelonado Control	1	4	4	4	0	0	0	2	0	6
Amazon IMC, PA	4	0	2	1	3	2	0	5	3	9
Modified Heap Fermentation	4	0	2	1	2	2	3	4	5	8
Traditional Heap Fermentation	4	0	5	3	0	0	0	2	0	5

Table 24.1. Anima Bean Sensory Profiles of African Cocoa Varieties and Heap Fermentations

The genetic similarity of the Amelonado/IMC/PA varieties used in our study with that of African cocoa varieties suggests strongly that African bulk cocoa can be transformed into fine cocoa by applying Anima fermentation technology that exalts the fine-flavor traits existing in these varieties.

24.2. Modified Anima Heap Fermentation

Ghana is known for its relatively good bulk cocoa quality thanks to the general application of the traditional heap fermentations using banana leaf coverage. In Brazil we compared the traditional heap fermentation method with an innovative heap fermentation method using wet beans of a mixture of Brazilian varieties.

For the ***Control*** heap fermentation, the sensory trait expression for the raw beans was (Table 24.1):

0 acidity, 4 bitterness, 3 astringency, 0 sweet, 0 nutty, 3 fruity, 0 floral and only 5 for overall preference.

For the ***Anima modified*** heap fermentation method, the following sensory trait expression for raw beans was obtained:

0 acidity, 2 bitterness, 1 astringency, 2 sweet, 2 nutty, 6 fruity, 5 floral and 8 for overall preference!

Scores for negative traits were 4 points lower and for positive traits 15 points higher with the innovative Anima fermentation method as compared to that of the traditional heap fermentation method.

This suggests that heap-fermented African bulk cocoas can be transformed into fine cocoas

24.3. Conclusions

The Table 24.1 shows that African type of Forastero varieties can be transformed into fine cocoa varieties with expression of complex attractive sensory profiles with overall preference scores of 8-10. A preference score of 8 was obtained by the modified Anima heap fermentation method. These “African” Anima preference scores compare with scores of 5-6 for the two control treatments. Therefore, the Anima method can be expected to transform African cocoas and the African heap fermentation method into raw beans of high qualities.

25. Sensory Evaluation of Raw Anima Beans and of Anima Chocolates

25.1. Traditional Raw Bean Quality Evaluations

Cocoa raw bean qualities have been mainly assessed by the colors of the ***cotyledons with the cut-tests***. The higher % of brown and brown-violet indicates a higher percentage of well-fermented beans. Generally, 70% of well-fermented beans is considered as characteristic for a well-fermented bean batch. More recently, a relatively high Ph value has become an additional parameter for assessing fermentation efficiency.

However, the relationship of colorimetric and Ph evaluations with favorable bean sensory traits has never become clearly established. A certain relationship of fermentation index with basic flavors is apparent. A high fermentation index is expected to indicate a less bitter and astringent cacao batch but could also be related to a flatter sensory profile and/or overfermentation. On the other hand, lower fermentation indices may hide a more interesting sensory profile, including presence of fruity flavors, albeit likely being slightly more bitter and astringent. A high Ph is likely to indicate less acetic acid intensity.

However, the cut test as well as the Ph value do not provide any information on the fine cocoa sensory bean profile characteristics.

25.2. International Proposal for a Raw Bean Sensory Evaluation Standard

Unfortunately, cocoa sensory specialists have not proposed yet a suitable method for raw bean sensory quality evaluations to be carried out on farms. *This is an enormous gap within the fine cocoa production chain as the farmer is disoriented on which path to follow to obtain higher quality beans.*

Mid 2020 a protocol of the *Fine Cacao and Chocolate Institute* (FCCI) for raw bean quality evaluations was circulated by the *International Standards for the Assessment of Cocoa Quality and Flavour* (ISCQF). It includes sensory evaluation of ground raw bean nibs of 0.5 mm in diameter obtained from 30-50 beans per batch treated by a popcorn popper or by a nutcracker. The nibs' powder is to be placed on the tongue and the sensory traits evaluated as they evolve in the mouth.

I tried the nutcracker version of the method and found great discrepancies with my own method. Acidity becomes strongly overestimated, bitterness and astringency are assessed more or less correctly but all fine flavor and aroma traits are largely underestimated. ***Therefore, I conclude that the proposed method is not suited for fine cocoa bean evaluations.*** I recorded my findings and presented my concern to the coordinators of this proposal. *To my surprise the proposal was officially adopted early 2021 as a new international standard method to evaluate sensory traits of raw cocoa beans.*

25.3. My Raw Bean Sensory Evaluation Method

From the onset of the development of an improved cocoa fermentation method we created ***a functional raw bean sensory evaluation method***. The development of the Anima

fermentation method would have been impossible without a reliable raw bean sensory quality evaluation method. The method has allowed us for ***comparisons*** between different Anima treatments as well with the control treatment. Most importantly, it also permitted to monitor the Anima bean ***maturation process*** after fermentation and drying. Such enabled us to decide on when the beans become suitable to make Anima quality grade chocolates.

Raw cocoa beans allow for evaluation of sensory traits that can also be observed in chocolates. It is therefore considered possible to train technicians in evaluating such traits also in raw beans.

The number of beans used for sensory evaluation of ***Anima raw beans*** can be limited to 3-5. This is because all Anima beans within the same fermentation batch tend to have the same taste, even if the batch contains a mixture of different varieties. Nibs of 0.1-0.2 cm diameter of the 3-5 Anima raw beans are prepared by using a small knife. The nibs from different beans are mixed and ca. 6-10 small nib pieces are tasted while thoroughly chewing. Sensory traits are recorded according to the sequence that they are perceived in the mouth and nose (see Table 25.1). If necessary, water is taken between two assessments to clean the sensory sensations in the mouth.

For ***traditional fermentation*** batches it is necessary to prepare nibs of at least 10 raw beans to represent the average sensory qualities of the beans.

My raw bean sensory assessment method is based on 10 years of experience in evaluating distinct raw bean sensory traits. I distinguish the following raw bean sensory traits that follow more or less the sequence with which these are perceived in the mouth and nose:

1. ***Citric Acidity***
2. ***Bitterness***
3. ***Astringency***
4. ***Sweet/Honey***
5. ***Almond/Nut***
6. ***Fresh Fruit***
7. ***Brown Fruit***
8. ***Spicy***
9. ***Floral/Herbal***
10. ***Spicy***
11. ***Aftertaste***
12. ***Global Preference***
13. ***Observations (special positive or negative traits)***

The scale used for these assessments runs from 0 to 10.

As Anima beans rarely express off-flavors, therefore such are just annotated in the Observations column. Some other negative traits that may be annotated in the Observations column are: “Acetic Acid”, “Woody”, “Over-fermented” and “Flat”. Some positive traits that could be mentioned could be “Aromatic”, “Complex” and “Harmonious”.

25.4. Anima Bean vs. *Anima Chocolate Evaluations*

Table 25.1 shows four comparisons of sensory profiles of Anima raw beans and chocolates. Chocolates with 70% cocoa were made in the CIC laboratory in Ilheus, Brazil, using roasting at 120^0C for 25 minutes.

In general, the chocolate profiles resemble strongly that of the Anima raw bean sensory profiles.

Acetic acidity was present only in the control beans. Some *citric acidity* was found in the CCN51 chocolate that appeared related to the fresh fruit trait of this clone.

Bitterness and astringency intensity were low in the beans and completely absent in the chocolates, suggesting that the chocolate processing has eliminated these traits. This was most evident for the CCN51 clone.

The *cocoa* flavor was strongest in CCN51 and in the Scavina 6 Hybrid. This trait is born during roasting and is therefore rarely observed in raw beans.

Caramel and almond flavors tend to appear with similar strength in beans and in chocolates. The slight bitterness of the Amelonado beans seem to have hidden these traits in the Amelondo beans while this variety showed strong caramel and almond traits in its chocolate. The high bitterness in the control beans did not allow these traits to appear in the sensory evaluation. The most likely explanation is that these traits are not expressed in traditional fermentations.

Fresh and brown fruit expressions were strong in Anima beans and in the chocolates of all varieties. Curiously there were shifts from more brown fruit in beans towards more fresh fruit intensities in chocolates. The extreme case was EET397 that switched completely from brown to fresh fruit in the chocolates. I ascribe this to the effect of sugar in the chocolates that helps to reveal the fresh fruity character, as fresh fruit in nature is always associated with sugar. So, apparently, fresh fruit intensity in beans is more difficult to assess than brown fruit.

The *spicy* trait was not observed in these bean and chocolate samples. This trait is relatively rare in cocoa.

The *floral* trait was present in high intensities in the raw beans of all four varieties. Amelonado and the Scavina 6 hybrid showed significantly lower chocolate floral aromas than in their beans. This

is attributable to the roasting at 120^0C. *My experiences with roasting have shown loss of all types of aromas at temperatures above 110^0C.*

However, the intensity of the Rose aroma in EET397 was still very strong in the chocolates. I ascribe this to the strong persistence character of this aroma that is partly herbal as compared to other more delicate cocoa aromas. Aroma intensity of the control beans was, as expected, very low. This is ascribed by me to the long fermentation time at high temperatures which would cause evaporation of the aroma.

The *aftertaste* is a trait that is unfortunately rarely evaluated in chocolate sensory assessments worldwide. *However, I consider it to be the most important trait as it summarizes the persistence of the more or less favorable sensory traits after consumption of the bean or chocolate.* Anima beans and chocolates have a very long and savory aftertaste that lasts 20-30 minutes in the mouth. Chocolates with bitterness and astringency, even when not very strong, usually have a short and less nice aftertaste. Table 25.1. shows that the raw bean scores for aftertaste resemble strongly those of the chocolate aftertaste.

25.5. Simplified Bean Sensory Trait Evaluation

These above results suggest that two sensory traits may have a valid predictive value for the entire sensory profile of raw cocoa beans:

- Bitterness, and
- Aftertaste.

*Table 25.1. shows that bean samples with higher **bitterness intensity** scores had lower overall preference scores*. The extreme case is the control bean sample that had the highest bitterness score of 5 and also the lowest preference score of 6. On the other hand, the two samples of the Scavina 6 hybrid and of EET397 that had the lowest bitterness scores of 1 and 2, respectively, obtained the

highest preference score of 10. The Amelonado beans, also with score 2 for bitterness, obtained also a high score of 9 for preference. The CCN51 beans, with score 3 for bitterness, had the lowest preference score of 8 among the Anima raw beans.

The above identified negative relationship between bitterness intensity and preference scores suggests that bitterness alone is a valid criterion that may simplify and speed up sensory quality assessments of Anima and other raw beans for certain purposes, as compared to a full assessment of all proposed sensory traits mentioned in Table 25.1.

The second criterion that appeared to have a valid predictive value of the overall sensory preference of raw bean samples is the **aftertaste**. Table 25.1 shows that the aftertaste scores are very closely related to the preference scores. The lowest aftertaste of 5 was obtained by the control beans that had the lowest preference. An intermediate aftertaste of 7 and preference score of 8 was obtained by the CCN51 beans. The highest aftertaste scores of 8-10 were obtained for the highest preference score bean samples (9-10). *This strong relationship can be explained by the integrated expression of all important sensory traits and by its duration in the combined sensory sensation that is experienced in the mouth at the end of the raw bean tasting.*

In summary, the above justifies us to propose the use of *simplified and more elaborated raw bean sensory trait evaluations* as follows, each for the following specific purposes:

- ***Bean bitterness intensity***
  Assessment:
  0 = zero, 1 = low, 2 = average, 3 = high and 4 = very high
  Purposes:
  a. Assessment of fresh bean bitterness.
  b. Assessment of fermenting and drying raw beans, and

c. Routine evaluations of individual stored fermentation batches

- ***Aftertaste quality***

  Assessment:

  0 = bad, 1 = low, 2 = average, 3 = high and 4 = very high

  Purposes:

  a. Assessment of sensory quality of fermented and dried raw beans
  b. Monitoring of maturation during storage of fermented and dried bean batches

- ***Full sensory raw bean evaluation***

  Always whenever feasible, this is the preferred method for assessment of all sensory traits indicated in Section 25.3. and, most importantly, for comparison of overall preferences of individual batches of fermented and dried beans.

Table 25.1. Sensorial Traits of Anima Raw Beans Compared to Chocolate Traits (scale 0-10)

Va-riety	Acidity	Bitterness	Astringency	Cocoa	Caramelo	Almond	FreshFruit	Brown Fruit	Spicy	Floral	Aftertaste	Preference	Obser-vations
Amelonado													
Chocolate	0	0	0	4	5	5	2	4	0	2	9	10	*Harmonious Multiple Fruity*
Raw Beans	0	2	0	-	3	2	0	5	0	6	8	9	*Floral*
CCN51													
Chocolate	2	0	0	6	3	3	4	4	0	4	9	9	*Cocoa/Fruity*
Raw Beans	0	3	2	-	3	3	0	3	0	4	7	8	*Bitter*
Scavina 6 Hybrid													
Chocolate	0	0	0	5	5	3	2	6	0	2	10	10	*Raisin Very Fruity*
Raw Beans	0	1	0	-	4	3	0	7	0	6	10	10	*Very Floral*
EET397													
Chocolate	0	0	0	4	3	2	7	0	0	8	10	10	*Mango/Rose Fruity/Floral*
Raw Beans	0	2	1	-	3	2	0	6	0	10	9	10	*Fruity/Floral*
Control Fermentation													
Raw Beans	3	5	3	-	0	0	0	2	0	2	5	6	*Acid/Bitter*

26. The End of the Glacial Cocoa Era

Warm Cocoa Stimulated the Mayas
By Drinking its Hot Chocolates
Aromatic Cocoa Pulps and Beans
Were Savored by the "Matsigengas" in Cusco
Female Cocoa Beans Dominated
The Male Coca Leaves
Consumed together by the Incas
These are Warm, Savory and Love Traditions

It was the Spanish that initiated the Path
Of Chilling Down Cocoa
Mixing it with Milk
Mixing it with Sugar
Destroying its Original Spirit

They Started to Produce Cocoa Beans
In Dead Boxes without Air
Suffocating Her
Killing Her Soul

With so much Suffering
She became Glacial, Bitter and Astringent
Treated with Lack of Love
For Five Centuries

Until Today
The Genocide of Cocoa Beans Continues
Suffocating Her Massively
Inside and Outside
Concentration Boxes

And then Treated by the "Dutching" Process
By a Dutch Invention
To Eliminate the Consequences of
Cocoa Sufferings
To Eliminate also all Her Beauties
Including Antioxidants
Creating a Chemical "Frankenstein" Product
That Nothing has in Common
With Her True Nature
Gracious, Docile, Savory, Aromatic
And Healthy

Finally,
Another Dutch Invention
Respecting Her True Nature
Is now Illuminating the
Light at the End of the Tunnel
Of Her Massacre in the
Concentration Boxes

Allowing Her to Respire
Allowing Her to Stay Alive
Caressing Her with Love
Of Passionate Human Beings
Revitalizing Her "Anima"
The "Soul of the Woman"
The "Spirit of the Forest"

She is Reviving
Performing Her Path Back
From the Past to the Future
From the Traditions
Of the Matsigenkas,
Of the Incas and

Of the Mayas

That were the First

To Worship the Cocoa Goddess

Docile, Savory and Aromatic

A "*SuperNatural*" Being

That Cures Many Diseases

And Feeds the "Anima" of the Human Being

The Most Perfect Being in the World!

27. SuperNatural Cocoa Features Challenge Science

Everybody will agree that Cocoa has Phenomenal features. Not everybody will agree that Cocoa might have SuperNatural features.

The Oxford Dictionary provides the following definition:

"A SuperNatural Manifestation or Event is Attributed to Some Force Beyond Scientific Understanding or the Laws of Nature"

The British Dictionary adds the following:

"Exceeding the Ordinary, Abnormal"

According to these accepted definitions I can see many features of Cocoa that go beyond ***Phenomenal*** and can be described as SuperNatural, *i.e.*

"Beyond Scientific Understanding, Abnormal and Extraordinary"

Here goes a list of Cocoa manifestations or events quoted from the beginning of this book that accordingly can be described as ***SuperNatural.***

- Cocoa expresses ***43 distinct genetic fresh fruit fine flavors and aromas***, 31 of which are apparently full mimics of other plant species' flavors and aromas. These are combined in 72 fresh fruit sensory profiles (13.4.7). This unique feature is the opposite with regard to all other fleshy fruit species that express only one proper elaborated fruit flavor and/or aroma profile (a Peach is always a Peach). *There is no scientific explanation for the abundant and diverse full flavor and aroma expressions in fresh cocoa fruits.*
- While the cocoa fresh fruit expresses so many flavors and aromas it *does not have its own unique sensory profile* (17.1.4), which again is very distinct from other fleshy fruit species.
- The empirical evidence (13.4.6) showed that the cocoa fresh fruit flavor and aroma expressions are ***qualitative and based on simple inheritance***. This is completely different from the quantitative polygenic expressions of sensory qualities in other fleshy fruit species (*e.g*. tomatoes).
- The simultaneous expressions of a flavor and an aroma trait in 50% of the sensory profiles (13.4.6) of cocoa strongly suggests the action of ***pleiotropic genes*** that are rare or non-existent in other fleshy fruit species.
- Out of the eleven Chuncho sensory profiles that present Jasmine aromas (Tables 13.1 and 13.2), all three of the Citrus

fruit profiles (Citrus, Mandarin and Tangelo) show the same association with the Citrus flower aroma (that is Jasmine). ***The chance that this could be due to evolutionary random events would be 0.001 (11/64x11/64x11/64)*** which is much lower than the statistical 0.05 acceptance level. *How cocoa knows that citrus fruit flavors go together with citrus flower aromas?*

- Cocoa fresh fruit sensory traits showed the following associations (17.5) that are difficult to explain by scientific reasoning: ***Mandarin flavor x bitterness, Soursop flavor x Soursop texture, Inga flavor and wooly pulp texture, Rose aroma and reddish raw beans, and yellow Peach flavor vs. yellow pulp.***
- Two cocoa varieties in Brazil showed that the Cocoa fresh fruit ***Rose aroma disappears mysteriously between 5 and 6 pm*** (17.7.1). The only explanation for the aroma to disappear inside a closed fruit within less than one hour is that ***cocoa destroys its own aroma.*** This is suggestive of the gene being responsible for aroma production is also responsible for aroma destruction.
- The Scavina 6 genotype expresses a strong lily aroma in its fresh fruits. Twice we observed that this ***Lily aroma is transformed into a Violet aroma after 4 days of pod storage*** (17.7.2). How to explain such an epigenetic modification that is expected to involve numerous volatile organic compounds?
- Cocoa bean reactions to stresses are "*Abnormal and Extraordinary"* (Chapter 18). The fresh cocoa bean increases bitterness immediately after receiving a first bite. How cocoa transfers so quickly a signal to the rest of the bean for the entire bean to become stressed? The same applies to the quick and strong stress reactions when placing fresh seeds plus pulp in water, in vinegar, in alcohol or in the cold?

The above "abnormal" features of cocoa sensory expressions merit to be studied in detail and might be considered as ***SuperNatural*** *until a scientific explanation can be found.*

28. Epilogue

The subtitle of the book refers to "***Infinite Cocoa and Chocolate Qualities***". The content of the book has justified this statement as follows:

- Firstly, by the 72 fresh fruit sensory profiles identified so far in *T. cacao* in Peru and Brazil. ***Similar and possibly new sensory profiles might be found in other countries, even in the so-called bulk cocoa producing countries.***
- These sensory profiles can be found in *different genetic cocoa flavor backgrounds, ie*. multiplying the sensory trait combinations that can be found in chocolates. This alone may explain a large part of the ***innumerous flavor and aroma combinations found currently in chocolates.***
- The TropMix fermentation technology provides further scope for creating ***infinite combinations*** of sensory traits present in fresh cocoa fruits with that of added aromatic substances.
- The *Anima fermentation technology* provides a potent tool to express the many fine fresh fruit

flavor and aroma traits in chocolates that may be less expressed when using traditional fermentation technology. ***So more and better expression of the infinite fresh fruit flavors and aromas is possible.***

As stated before, ***all main discoveries tend to be empirical, not scientific.***

And, ***all new sciences start naturally with empirical observations.*** This is the main context and significance of this book.

Cocoa quality studies have focused mainly on the bases of the typical chocolate flavor in finished products. The findings reported in this book should form the basis for a ***new cocoa quality science based on cocoa fresh fruit sensory trait studies: their metabolic, chemical and genetic bases***.

Furthermore, the ***Anima fermentation technology contradictions with classical fermentation technologies*** merit to receive innumerous scientific studies aiming at explanation of the biological phenomena that lead to the typical Anima qualities that are no bitterness and astringency, strong caramel and almond flavors and varietal fruity flavors and aromas. These studies need to take into account the presence of full known fruity flavors and floral aromas in the fresh cocoa fruits that migrate into the beans and are expressed in chocolates.

This book cannot be just a technical overview of what cocoa unveiled to me on my quest to discover her sensory

beauties. ***Cocoa incites an integrated technical x intuitive approach***. Without emotion the empirical reality of cocoa would not have become unveiled to me.

I hope to have convinced the readers that the sensory features and diversity of *Theobroma cacao* cannot be explained just by science, hence her ***SuperNatural*** nature *(by definition:* ***exceeding the ordinary, abnormal, unexplainable by natural law****)* cannot be excluded until the many mysteries described in this treatise become unraveled by science.

Then we have to thank cocoa also for the magnificent opportunity provided to valorize its many fresh fruit flavors and aromas in three unusual discoveries*:* ***CacaoNuts, CocoaPerfume and in the Anima fermentation method***. Without these flavors and aromas, the sensory diversity and richness present in these products would have been impossible to achieve.

Among these, Anima is the most important discovery as it represents potentially the future of cocoa fermentations worldwide. It transforms commodity bulk cocoas into very fine cocoas. Anima eliminates the differences between bulk and fine cocoas as all cocoas become fine cocoas with Anima fermentations. On one hand, this allows Anima to enlarge the currently limited fine-flavor cocoa market. On the other hand, Anima allows for creating a much more significant industrial fine cocoa segment in the world cocoa market. This segment potentially creates a large proportion of fine and 400% more healthy cocoa products than currently available.

28. My Identity

"I am Not from Here nor from Beyond"

(By Fagundo Cabral, interpreted by Chavela Vargas)

I like the Sea and the Weeping Woman
The Swallows and the Dirty Mistresses
Jumping over Balconies and Open Windows
And the Girls in April

I like the Wine as much as the Flowers
And the Lovers, but not the Misters
It is my Delight Being Friends with the Robbers
And to Listen to French Songs

I am not from Here nor from Beyond
I have no Age, no Future
And Being Happy is the Color
Of my Identity

I Like to Squander Around in the Arena
And to Chase Manuela on a Bicycle
And Take all the Time to Contemplate the Stars
And be with Maria in the Cornfield

I am not from Here nor from Beyond
I Have no Age, no Future
And Being Happy is the Color
Of my Identity

***"The Superb Voice of* Chavela Vargas**

Dominated my Happiness and Sadness.

She Directed my Quest

in Discovering the Magic Cocoa Identity

Linking Existence with Non-Existence

Ying with Yang, as

Phenomenal Cocoa

Became Unveiled to Me"

29. Literature

Ahnert D. and A.B. Eskes. *2018. Developments in cacao breeding programs in Africa and the Americas*. *In:* Umaharan, P. (ed.), Achieving Sustainable Cultivation of Cocoa, Burleigh Dodds Science Publishing, Cambridge, UK, 2018.

APARICIO VEGA M. J. 1999. De Vilcabamba a Camisa : Histografia de la Provincia de la Convención. Universidad Nacional de San Antonio Abad del Cusco. Cusco, Peru.

APARICIO VEGA, M. J. 2000. Perspectivas y observaciones de los valles de Santa Ana por José Teodosio Rozas, Cusco Noviembre de 1861. Instituto Americano de Arte y Monografías Históricas del Cusco Nº 2. Cusco, Peru.

BAIETTO, M,; WILSON, A. D. 2015. Electronic-Nose Applications for Fruit Identification, Ripeness and Quality Grading. Sensors 15:899-931; doi:10.3390/s150100899.

BARRY, C.S. 2009. The discovery of aroma and flavor genes in fruit. *In* Ostergaard L. Ed. Fruit development and seed dispersal. Annual Plant Reviews 38**.** Wiley-Blackwell. Pp 307-289.

CAIN, W. S. 1979. To know with the nose: Keys to odor identification, Science 203: 467–470.

CASTRO-ALAYO, E. et al. 2019. Formation of aromatic compounds precursors during fermentation of Criollo and Forastero cocoa. Heliyon 5: e01157.

CÉSPEDES-DEL POZO W. H. et al. 2017. Assessing genetic diversity of the native Chuncho cacao (*Theobroma cacao L.*) in La Convención, Cusco, Perú. International Symposium on Cocoa Research (ISCR), Lima, Peru, 13-17 November 2017. ICCO.

CHESNIK, I. et al. 2018. Investigation on the aroma of cocoa pulp (*Theobroma cacao* L.) and its influence on the odor of fermented cocoa beans. J. of Agr. And Food Chemistry14:2467-2472.

CONDORI CRUZ, D. 2015. Optimización del manejo pos cosecha del cacao proveniente de La Convención (Cusco) para el mejoramiento de su calidad organoléptica y del contenido de fitoquímicos benéficos para la salud. MSC thesis, UPCH, Lima.

DESOR, J. A.; BEAUCHAMP, G. K. 1974. The human capacity to transmit olfactory information. Percep Psychophys 16: 551–556.

DOMINY, N. J. et al. 2001. Role of smell. The sensory ecology of primate food perception. Evol Anthropol 10:171-186.

EL HADI, M. A. et al. 2013. Advances in Fruit Aroma Volatile Research. Molecules 18:8200-8229.

ENCINAS, M. A. 2009. Historia de la Provincia de la Convención, Tomo I, Siglos XVI al XIX, Centro Cultural José Pio Aza, Lima, Perú

ESKES A.B., D. GUARDA S., L. GARCÍA C. AND P. GARCIA R. 2007. ***Is Genetic Variation for Sensory Traits of Cocoa Pulp Related to Fine Flavor Cocoa Traits? INGENIC Newsletter 11:22-29.***

ESKES A.B., D. AHNERT, L. GARCÍA CARRION, E. SEGUINE, S. ASSEMAT, D. GUARDA AND P. GARCIA R. 2012. Evidence on the Effect of the Cocoa Pulp Flavor Environment during Fermentation on the Flavor Profile of Chocolates. Int. Cocoa Res. Conf. (COPAL) 17. Yaounde, Cameroon. October 2012.

ESKES A.B., C.A.C. RODRIGUEZ, D. AHNERT, D. CONDORI, A. PARIZEL , F. DE PAULA DURÃO C., , Matsigenkas and Chuncho growers in Peru. 2017. Advances on Genetical and Naturally Induced Variations for Fine Flavors and Aromas in Theobroma cacao. International Symposium on Cocoa Research (ISCR), Lima, Peru, 13-17 November 2017

ESKES A.B., C. A.C. RODRIGUEZ, D., CONDORI, E., SEGUINE, L. F., GARCIA CARRION, P. LACHENAUD, Matsigenkas and Chuncho growers in Peru. 2018. Large Genetic Diversity for Fine-Flavor Traits Unveiled in Cacao (*Theobroma cacao* L.) with Special Attention to the Native Chuncho Variety from Cusco, Peru. Agrotropica 30: 157. 2018. Google on line.

GADE, D. W. 1975. Plants man and the land in the Vilcanota valley. Biogeographica vol 6, Dr. W. Junk B.V. Publishers, The Hague.

HEGMANN, E. C. 2015. Qualitatsbedingende eigenschaften neuer kakao-genotypen und deren verhalten im nachernteverfahren – eine analyse neuer kakao-selektionen aus Costa Rica, Dissertation, Fakultat fur Mathematik, Informatik und Naturwissenschaften der Universitat von Hamburg. ICCO 2016. Fine or Flavor Cocoa.

HURST, W.J. *et al*. 2011. Impact of fermentation, drying, roasting and Dutch processing on flavan-3-ol stereochemistry in cacao beans and cocoa ingredients. Chemistry Central Journal Volume 5, Article number 53

JOHNSON, O.; JOHNSON, A. 1996. Matsigenka. Encyclopedia of World Cultures. Encyclopedia.com.

KADOW, D. et al. 2013. Identification of main fine or flavor components in two genotypes of the cocoa tree (*Theobroma cacao* L.). J. Appl. Bot. Food. Qual. 86: 89 – 98.

KLEE, H. J. 2010. Improving the flavor of fresh fruits: genomics, biochemistry and biotechnology. New Phytol 187:44–56.

KOVACS, K. et al. 2009. Effect of tomato pleiotropic ripening mutations on flavor volatile biosynthesis. Phytochemistry 70: 1003-1008.

KULMAR, T. 2016. Supernatural power in the religion of the Incas: Huaca or Callpa. Usualeaduslik Ajakiri 70:137-146

LIN J., MASSONNET M. and D. CANTU. 2019. The genetic basis of grape and wine aroma. Horticultural Research 6: article 81.

LASKA, M. et al. 2006. Olfactory Sensitivity for Aliphatic Alcohols and Aldehydes in Spider Monkeys (*Ateles geoffroyi*). Am J Phys Anthropol 129:112–120.

LOCKWOOD, G. AND ESKES A. B. 1995. Relationship between cocoa variety and quality. Seminar Proceedings, Cocoa Meetings "The Various Aspects of Quality"; 1995 AFCC. CIRAD, June 30, 1995, Montpellier, France, pp 159-167.

MARAIS, J. 1983. Terpenes in the aroma of grapes and wine: a review. S. Afr. J. Enol. Vitic. 4: 49-58.

MENDEL, J. G. 1866. Experiments in plant hybridization. Verhandlungen des Naturforschenden Vereines in Brunn 4: 3-47.

MILLER, K. B. *et al*. 2008. Impact of Alkalization on the Antioxidant and Flavanol Content of Commercial Cocoa Powders. J. Food Chemistry 56: 8527 – 8533.

MISIONEROS DOMINICOS, 2009. La Vida del Pueblo Matsiguenga, Aporte etnográfico de los misioneros dominicos al estudio de la cultura Matsiguenga (1923-1978) Centro Cultural Jose Pio Aza, Lima, Perú.

NEVO, O. et al. 2015. Chemical recognition of fruit ripeness in spider monkeys. Sci Rep 5:14895.

PINO, J. A. et al. 2010. Headspace volatiles of *Theobroma cacao* L. pulp from Colombia. JEOR 22: 113-115.

PINO, J. A.; BENT, L. 2013. Odor-active compounds in guava (*Psidium guajava* L. cv. Red Suprema), J Sci Food Agric 3114–3120.

PIPITONE, L. 2016. *Global Situation and Prospects of the Cocoa and Chocolate Markets - Current Challenges and Opportunities,* 2nd Cocoa Revolution, Ho Chi Minh City, 09-11 March 2016.

RODRÍGUEZ, A. et al. 2013. Fruit aromas in mature fleshy fruits as signals of readiness for predation and seed dispersal. New Phytol 197:37–48.

STEARNS, F. W. 2010. One hundred years of pleiotropy: Retrospective. Genetics 186(3):767-773.

SUKHA DA AND BUTLER DR. 2005. The CFC/ICCO/INIAP Cocoa Flavor Project-Investigating the Spectum of Fine Flavor within Genotypes and between Origins. Ingenic Newsletter 10:22-25

SUKHA, D. A. AND BUTLER, D. R. 2005. The CFC/ICCO/INIAP Cocoa Flavor Project-Investigating the Spectrum of Fine Flavor within Genotypes and between Origins. INGENIC Newsletter 10:22-25.

THAMKE, T., K. DURRSCHMID AND H. ROHM. Sensory description of dark chocolates by consumers. 2009. Food Science and Technology 42: 534-539.

ULRICH, U.; FISCHER, C. 2007. Wine aroma. In Flavors and Fragrances, Chemistry, Bioprocessing and Sustainability, Ed. R.G. Berger, Springer, Chapter 11

ULRICH, U. et al. 2009. Diversity and dynamic of sensory related traits in different apple cultivars. J. Appl. Bot. Food Qual. 83:70-75.

VAN ROOSMALEN, M. G. M. 2008. Blootvoets door de Amazone: De Evolutie op het Spoor. Bert Bakker, Amsterdam.

VÁSQUEZ-CAICEDO, A. et al. 2002. Physical chemical and sensory properties of nine Thai mango cultivars and evaluation of their technological and nutritional potential. *In* International Symposium on Sustainable Food Security and Managing Natural Resources in Southeast Asia Challenges for the 22st Century, January 8-11, 2002, Chiang Mai, Thailand.

ZHANG D. 2014. Personal Communication. Genetic diversity of Chuncho genotypes evaluated with SNP markers. Cocoa geneticist, USDA/ARS, Beltsville, USA.