Modelling Cacao and Chocolate Flavour Through Human Sensory Tasting

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Flavour: Past, Present, Future

Current Flavour Systems
Text Descriptions: Qualitative
Flavour Wheels: Infographic
Spider Diagrams: Ad-hoc

The Science of Flavour
The Chemistry of Chocolate Flavour
Flavour Relations and Networks
How Does the Brain Do It?

Modelling Chocolate Flavour
A Neural Model For Flavour Perception
A Map for Chocolate Flavour
Real-World Tasting Experiments

Future Work
Expanding the Map
Towards Field Cacao Profiling
But Does the Chocolate Taste Good?
Text Descriptions: Qualitative

Based on Listing of Attributes
Uses descriptors with an unquantified, but defined meaning

Resists Spurious Oversystematisation
Does not attempt to apply systems that may naively oversimplify the complexity of flavour

But: Usually Requires Expertise
Knowing what the attribute descriptors mean generally requires some years of tasting experience

Cannot Indicate Precise Character
Since attributes are unquantified, the balance of each - and hence the overall profile, cannot be described.


<table>
<thead>
<tr>
<th>Perception</th>
<th>Sensory attribute</th>
<th>Volatile compound (IK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floral</td>
<td>Floral</td>
<td>1.426, 1.450, 1.578, 1.609, 1.688, 1.695, 1.696, 1.712, 1.750, 1.752, 1.773, 1.825, 1.832, 1.862, 1.894, 1.930, 2.254, 2.830</td>
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<tr>
<td></td>
<td>Jasmine</td>
<td>1.696, 1.748</td>
</tr>
<tr>
<td></td>
<td>Rose</td>
<td>1.743, 1.773, 1.832, 1.862, 2.382</td>
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<tr>
<td></td>
<td>Lavender</td>
<td>1.743</td>
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<tr>
<td></td>
<td>Honey</td>
<td>1.748, 1.773, 1.775, 1.862, 2.125, 2.254, 2.830</td>
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<td></td>
<td>Balsam</td>
<td>1.475, 1.895, 2.020, 2.125</td>
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<td></td>
<td>Refreshing</td>
<td>1.450</td>
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<td></td>
<td>Faint balsamic</td>
<td>2.310</td>
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<td>Essences</td>
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<td>Fragrant</td>
<td>1.445, 1.733, 1.862</td>
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<td></td>
<td>Heavy floral</td>
<td>1.762</td>
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<td></td>
<td>Wax flowers</td>
<td>2.496</td>
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<tr>
<td></td>
<td>Herbaceous</td>
<td>1.195, 1.320, 1.688, 1.762</td>
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<tr>
<td></td>
<td>Green</td>
<td>1.195, 1.304, 1.320, 1.695</td>
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<tr>
<td></td>
<td>Mild green</td>
<td>1.100, 2.226</td>
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<tr>
<td></td>
<td>Woody</td>
<td>1.445, 1.815, 2.031</td>
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<tr>
<td></td>
<td>Spicy</td>
<td>1.578, 1.663</td>
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<tr>
<td></td>
<td>Cereal</td>
<td>1.431</td>
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<tr>
<td></td>
<td>Raw potato</td>
<td>1.373</td>
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<tr>
<td></td>
<td>Sweet chocolate</td>
<td>1.251, 1.297, 1.318, 1.377, 1.438, 1.475, 1.932, 1.968</td>
</tr>
<tr>
<td></td>
<td>Cocoa</td>
<td>1.163, 1.251, 1.438, 2.594</td>
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<tr>
<td></td>
<td>Chocolate</td>
<td>1.163, 1.251, 1.438, 2.594</td>
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<tr>
<td></td>
<td>Vanilla</td>
<td>2.594</td>
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<tr>
<td></td>
<td>Sweet</td>
<td>1.129, 1.420, 1.445, 1.460, 1.475, 1.540, 1.609, 1.727, 1.743, 1.748, 1.762, 1.775, 1.832, 1.894, 1.932, 2.022, 2.254, 2.382, 2.594</td>
</tr>
<tr>
<td></td>
<td>Sweet candy</td>
<td>1.005</td>
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</tbody>
</table>
Flavour Wheels: Infographic

An Attempt to Group Flavours
Tries to put similar flavours close together on the wheel

Can Be Hierarchical
Inner wheel segments can represent supergroups

But: Implies a Cyclic Relationship
Does flavour link 'end-to-end'? There is always going to be a discontinuity somewhere.

Categories May Be Arbitrary
Without very careful research establishing what flavours are 'similar' can be very ambiguous

Only Says What You Might Get, Not What You Have
No way to represent relative strengths or similarities, or compare chocolates.

Spider Plots: Ad-Hoc

Add A Quantitative Dimension
Spider plots can indicate relative strength of different factors.

Multivariate
Can depict several factors simultaneously.

But: Axes Are Defined Ad-Hoc
Arbitrary choice of variables, which may not be orthogonal. No standard exists.

What is Being Quantified?
Since variables are qualitative, it is unclear exactly what feature they describe.

No Clear Link to Flavour
It is not easy to predict what a cacao will tastes like from a spider plot.
The Chemistry of Chocolate Flavour

General Method: GC-MS Analysis

Fractionates compounds and then identifies chemical signatures

Flavour 'Heroes'
- 4-Hydroxy-2,5-dimethyl-3-furanone
- Linaool Oxide
- 2-Phenyacetaldehyde

Flavour 'Villains'
- 3-Methybutanoic acid
- Dimethyl di- and trisulphide

May Not Correspond to the Flavour Experience

Different chemicals taste different in different contexts, and the human sensory system does not taste chemicals separately.

Flavour Relations and Networks

Flavour Network from Ahn, et al.  
*Scientific Reports.* 1:196 [4]
How Does the Brain Do It?

**Sensory Neurons: Input**
Basic sensing of chemicals

**Olfactory Bulb: Sorting**
Chemicals are sorted into different pathways

**Piriform Cortex: Patterning**
Chemical signatures are matched against stored archetypes

**Orbitofrontal Cortex: Flavour**
Archetypes are combined to represent an entire complex flavour

**Amygdala: Emotion**
Chemicals are classified according to degree of 'like' rather than type
A Neural Model Of Flavour Perception

Neural Networks: Models of the Brain
A (hardware) computer-based simulation of a brain circuit (like the olfactory system)

3-Layer Model
Models Olfactory Bulb, Piriform Cortex, and Orbitofrontal Cortex

Simplified Chemical Model
Uses data from Bonvehí, 'Investigation of Aromatic Compounds in Roasted Cocoa Powder'

Convolutional Network Model
Internal neurons match to a template and respond according to degree of match
A Map of Chocolate Flavour

Uses an PCA of Composition to Flavour Profile

Principal Component Analysis: extracts the most important (in this case 2) variables affecting flavour.

Mapped Hidden-Layer Neurons

Each hidden layer neuron in the model represents one archetypal point in the space

Names Assigned Subjectively

Point names themselves are only for reference, can be changed and applied in different cultural contexts

Somewhat Synthetic

The model equally distributes archetypes in the space, in the real brain these might be nonuniform.
Real-World Tasting Experiments

Real Tasters, Real Chocolates

44 different chocolates, up to 38 Tasters/Session

Tasters Used Profiling Map

Expanded map as seen at right used for profiling, matched to neural data

Results Aggregated

Archetype score for each point added to give global total per point

Clear and Consistent Results

Live profiles closely match predictions

Orange Bowties: Akessons Madagascar 75%

Yellow Left-Arrows: Michel Cluizel Los Ancones

Green Triangles: Green & Black's 70%
Expanding the Map

Character defects:
- Excessive bitterness
- Excessive astringency
- Excessive acidity

Process Defects:
- Variety
- Under fermentation
- Over fermentation
- Mould
- Cacao contamination
- Over roast
- Over processed
- Chocolate contamination
- Temper/bloom

The University of Manchester

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A Simple Field-Deployable Profiling System

Distributed on an electronic form that requires minimal prior expertise.

**Hierarchical**

Asks for easily-assessed characteristics first, with the ability to dig deeper but stop when unsure.

**First Level: Basic Like/Dislike**

The ultimate 'acid test': simple preference.

**Second Level: Simple Attributes**

Asks the profiler to describe why they like or dislike.

**Third Level: Specific Qualities**

Asks the profiler to detail positive and negative characteristics.
Pleasure is What Matters in the End
The quality of a chocolate or cacao is ultimately decided by how much you like it.

Quantifying Flavour is Only a Tool
Models and systems of chocolate flavour can tell us what we have in a chocolate but do not decide whether it is good.

With Relevant Quantitative Systems We Can Reliably Establish Value
Uninformative systems will lead to unreliable quality assessment. Systems need to quantify the human experience of taste to give an accurate value to a given cacao.

With Relevant Ways to Describe Flavour We Will Gain Consumers
Clarifying the bewildering choice between equal-looking bars on a shelf removes the biggest barrier to consumer adoption.
References

[1] Bonvehi, J. S. 'Investigation of aromatic compounds in roasted cocoa powder', *European Food Research Technology* 221, pp. 19-29, March 2005


Questions?
Comments?