The real Oompa-Loompas: Microbes that make chocolate

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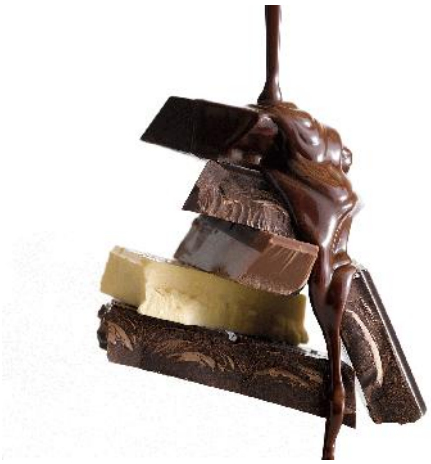
Fungi, bacteria and yeasts are the unsung heroes of chocolate production. Managing these little helpers better could keep the future for chocoholics sweet.



IN THE fictional chocolate factory of Willy Wonka, small cheery folk called Oompa-Loompas do the hard labour of making chocolate, and are paid in cocoa beans. In real life, the chocolate workers are much, much smaller. Before cocoa beans can be dried, roasted and made into the good stuff, they must be fermented – and this job falls to a host of microbes.

The surprise is that it is largely left to chance which microscopic minions participate. Whereas fermentation in other foods tends to be controlled by adding just the right mix of microbes, in chocolate the process is still usually spontaneous. But leaving everything up to nature is risky. As global demand for chocolate grows, and supply is imperilled by diseases affecting cocoa trees, microbiologists and chocolatiers have embarked on a quest to give cocoa bean fermentation a helping hand. That is great news for chocoholics everywhere, as it promises to keep the chocolate river flowing. It should improve the quality of our favourite confectionery, too.

The journey from ripe cocoa pod to chocolate is complex. Fermentation is the critical first step. "Cocoa beans have to be fermented and dried before they can be used as the raw material for chocolate production," says Luc De Vuyst at the Free University in Brussels, Belgium. Each pod contains 30 to 50 beans, embedded in the slimy pulp of the fruit. At harvest time, pods are plucked from the trees, opened with a knife, and the contents scooped into a giant heap on banana leaves or in a wooden box. Microbes in the air, soil and leaves – and on the knives and hands of farmers – inoculate the pulp, and the transformation begins.

Handle with care: cocoa beans get their flavour in part from microbes on hands and knives *(Image: Pascal Aimar/Tendance Floue)*

The pulpy mass is packed so tightly that oxygen cannot penetrate, and it starts to ferment. Wild yeasts initiate the process, converting the sugars glucose, fructose and sucrose into ethanol, just like in the production of beer or wine. Alongside yeasts are ethanol-tolerant lactic acid bacteria that convert sugars and citric acid into lactic acids, similar to the process that occurs in yoghurt and cheese. As the yeasts do their work, they also produce enzymes that attack the viscous pectin in the pulp, turning it into a sweaty liquid, which slowly oozes away.

Ethanol production requires a low-oxygen environment and, as air enters the heap and liquid departs, this process slows down. Airflow allows a boom in a third class of microbes: acetic acid bacteria. These oxidise the ethanol into acetic acid in a reaction that heats up the whole pulpy mass to between 45 ⅼC and 50 ⅼC. Unable to stand the heat, the yeasts, lactic acid and acetic acid bacteria all die. Some 72 hours after the process begins, all the microbes are dead and fermentation stops. Meanwhile, the

volatile acetic acid penetrates the beans, killing the embryonic seedlings and starting chemical reactions that generate the precursors of the rich colour, flavour and aroma released when the beans are roasted. From start to finish, the process may take up to 10 days.

Left to the vagaries of nature, there is huge variation in the outcome of this so-called spontaneous fermentation. "Many of these fermentations do not run as they should," says Christoph Wittmann at Saarland University in Saarbrücken, Germany. Properly fermented, the beige beans should turn a rich dark brown. Some do not ferment, leaving them purple. Others over-ferment, turning almost black. With about one-third of the beans unusable, that's bad news for farmers who are paid on quality. Around 90 per cent of cocoa plantations are small family businesses, so "this is something we need to improve", says Wittmann. There are also regional differences in the flavours that fermented beans acquire, depending on things like soil quality as well as the exact mix of microbes that inoculate the bean from the local environment. Typically, chocolate producers blend beans of mixed quality and geographic origins to average out the variation. What they would really like is a reliable supply of high-quality beans – and that means taking control of fermentation.

So researchers have been finding out exactly which microbes are involved. At the Leão De Ouro (Golden Lion) plantation in Brazil, De Vuyst and his colleagues took a sample 30 hours into spontaneous box fermentation, when all of the major microbial players in the process are well established. They then employed metagenomics, sequencing the DNA of the entire community in one go, to work out the different species present.

Earlier research had indicated striking differences in the microbial community from region to region, but the advanced methods revealed a surprising degree of similarity in the species present. Hanseniaspora uvarum was the most common fungus, along with 16 other species. Of the 28 bacterial species they identified, the lactic acid bacteria family Lactobacillaceae was the most abundant (especially Lactobacillus, the genus used in the production of yogurt and cheese).

Meanwhile, Wittmann and his colleagues have been looking at the metabolism of Acetobacter. They discovered that for optimum performance, these acetic acid microbes need a mix of ethanol and lactate, supplied by both yeasts and lactic acid bacteria. "We now understand who is doing what and why," says Christoph Bolten at the Nestlé Research Center in Lausanne, Switzerland. What's important, says Wittmann, is a balanced population structure. So developing a "starter cocktail" of the right mixtures in the right proportions "may strongly improve the quality of the fermentation process".

Consistent flavours

Vuyst's team is already on to it. Working with Nicholas Camu from the Belgian chocolate maker Barry Callebaut, they have been testing starter cultures containing various combinations of naturally derived microbes. They found that pulp inoculated with these cocktails fermented in four days – less than half the time it can take with spontaneous fermentation. The beans also gave more consistent flavours. Controlled fermentation is now being used at farms in Ivory Coast, Cameroon and West Java, Indonesia, with early indications that it substantially improves both yield and quality. Barry Callebaut is already marketing chocolate from the beans (see "Box of delights?").

Of course, chocolate manufacturers are keenly aware that this approach will only be successful if we, the chocolate consuming masses, continue to enjoy their products. Taste is paramount. At the University of Copenhagen in Denmark, researchers funded in part by Danish firm Toms Confectionery Group compared chocolate produced from spontaneously fermented beans with chocolate made from beans inoculated with their own starter culture. An expert tasting panel described the former as "sweet with cocoa and caramel flavours" and the latter as "fruity, acid and bitter with berry, yoghurt and balsamic flavours". Untrained tasters had no preference. The differences were "too small to significantly change consumer perception", the researchers concluded. Outside the lab, only time will tell.

Developing and testing recipes for starter cultures is an ongoing global project. Some of the research is happening behind closed doors. For example, Nina Keller, a spokeswoman for Lindt & Sprüngli, declined my request for an interview with their researchers, saying "we do not disclose our production secrets and insights with the general public due to competitive concerns". Perhaps it's more surprising that research funded by the likes of Nestlé, Barry Callebaut, Masterfoods Australia and Toms Confectionery Group is being shared at conferences and published in peer-reviewed journals, allowing all chocolate companies and researchers to benefit from the emerging knowledge.

Purists may be uneasy about these developments. It's too early to say whether a move towards controlled fermentation will spark a niche market for traditional, spontaneously fermented chocolate. However, if ensuring sustainable quantities of high-quality chocolate is your concern, then the future looks sweet. As for the microbial minions, their story is still unfolding. But as you enjoy your holiday chocolate, spare a thought for these tiny unsung heroes.

This article appeared in print under the headline "Chocolate's dark secrets"

Box of delights?

Taste-testing high-quality chocolates is a thankless job, but somebody's got to do it. At Chocolate Arts in Vancouver, Canada, Mark Pennington lets me try a world-spanning array. The flavour differences are subtle, and I'm initially at a loss for words. Like vintners, chocolatiers have their own terminology, says Pennington, who is Barry Callebaut's gourmet sales manager for western Canada.

Common descriptors are fruity, earthy, nutty and roasted. A chocolate might be fruity with notes of red fruit like dried cherries, or earthy with hints of grass or moss. Descriptive subcategories could also include vegetal, herbaceous, or asparagus, Pennington says (the latter perhaps not a good thing in either wine or chocolate).

Anya Keefe, co-owner of Krave Chocolat, elaborates on the grape analogy. Cocoa beans from different regions have their own terroir – distinctive flavours, influenced by the surrounding soil, crops and vegetation. Chocolate traceable to a specific region or plantation is known as "single origin". Keefe's favourite is grown in the volcanic soils of São Tomé and Príncipe, a small island off the west coast of central Africa. She describes the taste as bright, acidic and earthy, like the smokiness of lapsang souchong tea.

"Tasting is both objective and subjective," says Eagranie Yuh, a chemist-turned-chocolatier and author of The Chocolate Tasting Kit. "I teach people to taste with five senses: look at the chocolate, smell the chocolate, listen to the chocolate's snap, taste the chocolate (let it melt, don't munch) and pay attention to its texture.

Some chocolates naturally have a spicy flavour. "In some of the Caribbean chocolates some swear they taste nutmeg and mace, which is very consistent with what grows around those plantations," says Pennington. Good chocolates are often described by their fruitiness – with hints of banana, mango, passion fruit or plum. Chocolates from beans grown in Madagascar are often said to taste like red berries – cherries, cranberries or Swedish lingonberries, he adds.

Lesley Evans Ogden reluctantly takes on the thankless task of testing chocolate

Armed with my new vocabulary, I did a blind taste test of fine chocolates from Ecuador, Brazil, Madagascar, Tanzania, Venezuela and Ivory Coast. My strong favourite was a delicious, Brazilian single-plantation variety, one I would naively describe as rich, fruity, and floral with hints of coffee.

Interestingly, my second choice was the Barry Callebaut's "Ocoa" Ivory Coast blend produced by controlled fermentation (see main story). Although my chocolate palette was previously limited to "dark chocolate equals yum", chocolate-tasting is a new skill I am willing to cultivate.