

CHOCOLATE

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Part 1

Good morning everybody. It's nice to see such a big audience. When I was asked to give a topic to give a talk, on a topic, that was of interest to both scientists and non scientists, and I thought for a few minutes and then I thought one subject that is dear to many people's hearts is chocolate. Is there anybody here who doesn't like chocolate? Put your hand up if you don't. Oh yeah, the odd one, but not many, and indeed there have been surveys that the population about how much they like chocolate, this is a recent survey from women in the United States, and that shows that the average consumption of chocolate is more than five kilos per person per year. More than 93 percent of the population eat chocolate. Three percent feel guilty about eating chocolate. So chocolate - Some people feel they shouldn't enjoy it but they do. 67 percent prefer milk chocolate to dark chocolate. And 52 percent feel that eating chocolate makes them feel happy. So some people turn to chocolate when they are feeling a bit down and they eat a bar of chocolate and it makes them feel happy. So what I want to do today is to talk to you a bit about where chocolate comes from, how it's made, a bit about the history of chocolate making, and a bit about the quality attributes, what manufacturers think consumers require when they buy a bar of chocolate.

So let's look - start off by looking at where cocoa comes from, because cocoa is one of most important ingredients of chocolate, that gives it its flavour, and cocoa is derived from the fruit of the cacao tree which is the name of *Theobroma cacao* that is the systematic name and that actually means *food of the gods*. So for centuries, cocoa has been identified as the very food with very special qualities and this green band here is the band covering tropical rain forest which is the main area where cocoa trees grow. So a lot of cocoa comes from Central and South America, some from regions of Africa, and some from Borneo and Indonesia. And those are the main sort of cocoa growing countries around the world. Cocoa is often very important economic crop for these countries. We will talk a bit more about the economics later on.

Ok let's start off by looking at the history of cocoa. For many centuries cocoa was drunk as a drink before the actual bars of chocolate developed. And we know that cacao trees were common in Central and South America hundreds of years ago. The tree was cultivated by the Maya people in Central America and also by the Aztecs. And the Mayas go back to 250 in the current era, 250 to 900 in the current era. And the Aztecs around 1400 in the current era. So the history of cocoa, we know that cocoa was an important crop for these peoples many hundred of years ago. So *Theobroma cacao* means food of the gods, and that was the name they gave to the trees that produce this fruit they associated with very special qualities.

The beans were - cocoa beans - were used as sources of currency and the production of spiced drink which was called 'chocolatl', and 100 beans bought - was enough to buy a slave, so each bean had a very high value to the local population and it's reported that Aztec emperor Montezuma drank 50 jars a day, and it was associated with being an aphrodisiac which means it helps his sex life, so it was obviously a very special drink with a very high value and with very important properties attributed to it.

Part 2

We can see from some of the pottery that has been recovered from the Mayan Period that drinking chocolate was an important activity of the people. So in this picture we have a Mayan noble man saying to his slave, that he doesn't want to drink any more chocolate. So he has obviously been drinking a lot. And here in this picture we can see a Mayan person here, and a cocoa tree here with the pod - cocoa growing in pods on the tree, so this is showing how the Mayan individual was picking pods from the tree to make cocoa. And I think there is another figure over here, but I can't quite work that one out.

So cocoa was very important in Central and South America. Of course the Spanish conquered South America, conquered Mexico in 16th century round about 1521, and the Spanish were curious about the Mexican customs, about the Aztec customs and they began to drink chocolate and found the quality of drinking chocolate, and the pleasure it brought them was very special. And they started to ship cacao seeds back to Spain. And indeed, I think it is reported that some of the Spaniards fought quite fierce battles against the Aztecs, and they found, they were looking for big treasure troves and they found big hoard of cocoa beans which the Aztecs considered as an important treasure.

The history of cocoa in Europe then developed from the 16th century, and by the middle of the 17th century, around 1657, chocolate houses started to open in London so these were clubs basically where members of the aristocracy would gather and meet with their friends, and would drink cups of chocolate, discuss politics, and some other matters. And by the 18th century, a British magazine, (it was actually *The Spectator*), warned the readers to be careful with romances, chocolate, novels and similar inflamers, which meant that again this is presenting chocolate as something rather dangerous, with rather special aphrodisiac type qualities.

But then the product that we know today as chocolate developed in the 19th century originally in Switzerland, but by the middle of the 19th century Joseph Fry and his sons developed the first chocolate bar, and they helped set up chocolate companies, and Fry's was the chocolate company that existed in Britain until a few years ago when it was taken over by another chocolate making company. So the history of chocolate goes back to about the mid 19th century.

And throughout the ages chocolate has been associated with very special qualities. And this is a quote from Montezuma, the Aztec Emperor in mid 16th century. He said that the cocoa was a divine drink which builds up resistance, and fights fatigue and a cup of this precious drink, cocoa, permits a man to walk for a whole day without food. So he was regarding it as being providing him with a lot of energy, stimulation, and being a very precious drink. And from the mid 19th century chocolate is a perfect food as wholesome as it was delicious, a beneficent restorer of exhausted power, it is the best friend of those engaged in literary pursuits, This was written by a writer in the middle of the 19th century in England. So throughout the centuries both cocoa and chocolate have been regarded as having special qualities and indeed we now know that chocolate is quite a concentrated source of energy, and people going on explorations and arduous conditions who need lots of energy might take lots of bars of chocolate with them to provide that energy.

Part 3

There are a lot of quotes about chocolate. I was looking through the internet and I came up with few quotes. One of them is 'Money talks but chocolate sings'. Another quote was that 'Chocolate is nature's way of making up for Mondays', which I thought was quite nice. And 'strength is the capacity to break a chocolate bar into four pieces with your bare hands, and then eat just one of the pieces'. I also thought that was quite a nice quote.

Ok so now we are now going to start looking at the chocolate making process and this we start off with the cacao, or Theobroma cacao tree or cacao tree. So here we can see a cacao tree and we see that cocoa grows in these pods. So there are a number of orange or yellow colour pods growing on the tree in this tropical forest.

And then if you start to cut open one of the pods you can see that there are actually a number of beans within the pods and they are surrounded by white fleshy outer coating. And within a single coating pod there may be about fifty beans within just one of the pods and of course there are a number of pods growing on a tree.

But at this stage, the beans will have none of the characteristics of chocolate. They won't have any flavour. They won't have a very dark colour. They won't have any of the qualities that you associate with cocoa. Sometimes I wonder how cocoa was originally discovered because the beans themselves don't taste of anything, and I have this picture in my mind, (which is pure imagination) that maybe there was a cacao tree growing close to some person cooking something on his fire, maybe one of the pods fell off from the tree, fell into the fire, and he started smelling quite an attractive aroma, and he thought 'ah, let's look at into this further'. But that's just my imagination.

OK, so how do we actually manufacture cocoa from these pods? So first of all we have to cut the pods from trees, and when we cut open the pods we see that each of the beans is surrounded by this white fleshy pulp, and the first step is to try and separate the beans from this white fleshy pulp that surrounds each bean. And so initially we transfer the

beans with adhering pulp to boxes, so we stack them up in boxes and then they are left in the sun for a few days and during storage for a few days there are microorganisms within the pods, within the fleshy outer parts, and so the flesh around the beans starts to ferment, that means that the nature of the white fleshy substance changes because of the action of microorganism. And during this process the temperature rises because this is a process which generates heat, and the temperature may reach about 45 to 50 degrees Celsius. So maybe the ambient temperature in these countries, may be 30 to 35 degrees Celsius, but the heating effect during this fermentation process. Occasionally you need to mix air into the pile so you may just stir them with a stick to allow air - the pods to be exposed to the air, and then during this process the action of microorganisms causes the white fleshy pulp to become liquid, so you can then separate the beans from the liquid that is surrounding them. And then you can place the beans in shallow trays just to dry in the sun, and at this stage, what we have to do is separate the flesh from the beans, the beans still have no flavour; but then a very important process is the roasting process. So we roast the beans now and grind them to produce the powder, and that powder is known as cocoa powder.

Part 4

So this roasting process takes place at a temperature above the boiling point of water, so typically a temperature between about 110 and 220 degrees Celsius. And within each bean, initially within the beans there will be a whitish colour but during the roasting process the white colour changes to a brown colour and the flavour develops, and this just is a sort of industrial scale where these vessels would hold large numbers of beans. They would be heated and would rotate allowing the beans to be exposed to a heating element at the bottom of the vessel and the beans would generate flavour during this roasting process.

So having initially roasted the beans and then ground them from the cocoa powder we then have a number of steps to transform this cocoa powder into a bar of chocolate. And this is a very simple formulation which you can make a bar of chocolate from. So I will just talk to you a little bit about what each of the ingredient is and what it contributes to the chocolate.

So the first ingredient is cocoa butter. This is the fat that comes from the cocoa bean. When you start grinding the bean you can press out the fat to separate the fat from the powder. And there is legislation in place in many countries around the world about how much fat from the cocoa tree you need in a bar of chocolate. In some countries, they allow small amounts of fat from other sources, but normally almost all the fat in a bar of chocolate comes either from the cocoa bean or if it's from milk chocolate it may come from milk powder.

And the fat actually is very important for the quality of the chocolate. It helps to give the chocolate the correct texture so we all expect certain things from chocolate so - such that if you pick up a bar of chocolate, it should be solid at room temperature. When we hold it in our fingers, it shouldn't melt in our fingers. It should still remain solid. But when

we put it in our mouth, it should start to melt, and quite rapidly. And all these textural characteristics come from the fat, the cocoa butter that is present in the chocolate. And there are very few other fat that actually have that are very characteristic melting profile, because when you come to think of it, if you hold a bar of chocolate in our fingers that might be maybe 30 degrees Celsius. Within our mouth, it may be 35 to 37 degrees Celsius. With only a few degrees we are expecting a very big change in chocolate from being the solid material to being more or less fully liquid in our mouth. So that's quite a challenge for a food scientist to develop any alternative product. That is, you can replace that properties of chocolate, cocoa butter; you can do that, but legislation normally says that almost all the fat in chocolate has to come from cocoa bean.

The cocoa powder of course is also a very important component, and this contributes a lot of flavour of the chocolate, so lots of the characteristic flavour is contributed by the cocoa powder. And then quite a lot of the chocolate would be sugar or sucrose. So sugar obviously gives the sweetness to the chocolate. And the last ingredient that is normally present in the bar of chocolate is a product called lecithin. This is a product which is described as an emulsifier. It actually comes from the soya bean and it's a by-product during the production of the soybean oil, in the soybean industry. And the reason for including this emulsifier is that if you have this emulsifier in it, you can use a lot less fat in the product. And the fat is the very expensive part of chocolate. Sugar is quite cheap, cocoa powder is much cheaper than the fat. And just by using a small amount of this material, lecithin, we can cut the amount of fat from about 36 %, down to about 30 %, and still get the same mouth feel, still manufacture a product that has a good quality in our mouth.

Part 5

Obviously there is a whole variety of other recipes in other chocolates; there may be milk powder in it to give milk chocolate. There may be nuts present in a bar. There may be other components. But these are the essential basic ingredients of a bar of chocolate.

So going back to the manufacture of the chocolate, we've described how we make cocoa powder and then we can mix the cocoa powder, with the fat and the sugar and the emulsifier, but then the next step, when we just mix them we have to mill the product to reduce the particle size, because our mouth can detect large particles, they feel rather gritty; it is very important that all the solid particles in the chocolate - they've got very small particles size so we can get the smooth feel that we expect in a bar of chocolate when it melts in our mouth. So milling helps to reduce the particle size down to less than about 20 microns which is quite small. So we can't actually detect individual particles then in our mouth. All we get is smooth overall texture.

Ok, so, having milled this mixture, we then come to another important step called *conching*. And this step is very important for the development of flavour in a chocolate because when we just mix the ingredients if we were to consume the product at that stage, we would find it was perhaps rather bitter, rather acid, a lot of the chocolate flavour would be there, but there would be other flavours that are not so attractive that

are associated with that product. So what we do is the process of conching. This involves heating a chocolate mass with stirring so often. This bowl might rotate, and we have a sort of a paddle sitting in a bowl and so the rotating a bowl of chocolate slaps up against the paddle and falls back into the mixture. And this exposes the chocolate to the air for long periods of time so typically for a plain chocolate you might use the temperature 70 °C for up to 24 hours even up to 48 hours if you want to make a very high quality chocolate. And during this time the flavour will improve. The product will become less bitter, less acid, much smoother and at the end of this process you should have a product that tastes just like you would expect for a good quality bar of chocolate. There have been new processes developed to speed this up because of course these days industrial time is money, and long processes like this mean you've got a very expensive product so there are alternative processes that we reduce the time and therefore the product will be cheaper to make but it's quite difficult to get as good a flavour if you go for a shorter process.

Ok so having conched the chocolate, we then have to prepare bars of chocolate, and we have to prepare the chocolate for moulding into bars. And chocolate must be heated and cooled under the controlled conditions to produce the chocolate suitable for pouring into a mould. And this is necessary to achieve good quality chocolate. So we need to heat the product under controlled conditions and cool it but it still has to be fluid when we pour it into the mould because clearly a chocolate mould looks something like this. So these are moulds where we have small impressions in a plastic or metal container. The chocolate has to be liquid when it goes into these containers, these moulds. But it has to set to form a solid material. And indeed when it sets it has to pull away from the surface of the mould so you can actually remove it from the mould quite easily without damaging it. So we say that it needs to be fluid. It needs to have a low viscosity when we pour in to the mould. It then needs to set to a solid material and it then needs to contract during that, while it sets. It needs to pull away from the walls of the mould, it needs to become smaller, as it contracts, and therefore when you turn the mould upside down, it will simply fall out.

Part 6

So this gives an outline of the whole conching process that we've talked about; once we've got the cocoa, mixing the ingredients, milling, conching. And often, well, there may be a period of storage before that, before the final processing stage. We then melt and cool and heat the chocolate under controlled conditions before use. And the fat in the chocolate is partly solidified before pouring it into a mould, or coating it on a biscuit, but it's not fully solidified. So only a very small part of the fat, in fact maybe 1% of the fat is solidified before you actually pour it into the mould. Otherwise it becomes too thick, and it won't fill the mould properly.

So then you can coat a biscuit with your molten chocolate, or you can pour the product into the mould. You can pass it through a cooling tunnel to make it set, so you might cool it to perhaps temperatures of 5 °C, so during that time it sets solid and contracts in

the mould, so that it can be removed from the moulds, and then you can wrap it and package it. And if you go into a chocolate factory these days it's a very high speed process. Large - thousands of bars of chocolate are made per minute or per hour, and it's highly automated. There are very few people working in a chocolate factory. It's highly automated process, and it makes very high numbers of products.

So what I want to do now is to talk a little bit about the quality of chocolate. What makes a good quality chocolate? And clearly we have already talked about a few of the points that are important to consider in making a good quality chocolate. But we need to bear in mind that chocolate comes in lots of different forms. So it may be a bar of plain chocolate. It may be a bar of milk chocolate. There may be other ingredients in it, caramel or something like that. It may be coated on to a biscuit, and clearly in this type of product, one of the important things is that the surface of the chocolate has picked up some of the decoration, in fact the decoration comes from the mould that the chocolate has been moulded in. So the plastic or metal mould will have these markings on it and as the chocolate solidifies it has to pick up these markings from the mould.

Here we can see, you can have lots of different surfaces on the chocolate. You may have some white decorations, powders, different shapes, and obviously on a biscuit, the requirements are somewhat different here, we might have a rippled surface like this. And one of the things to remember about the chocolate biscuit is that the chocolate is always the expensive part. The biscuit is very cheap, so the manufacturer wants to use as thin a layer of chocolate as possible, so it costs him as little money as possible to make that chocolate. And when you coat a biscuit with chocolate the manufacturer will try to ensure that it's quite fluid because then when he blows air across the biscuit a lot of the chocolate will flow off the surface, and so the layer of the chocolate will be quite thin. So there are a lot of tricks the manufacturer will use to try and make sure that he uses as little chocolate as possible but clearly, he has to make a product that the consumers will buy that is attractive to consumers. So it's a compromise. The manufacturer wants to use as little chocolate as possible probably the consumers won't buy the product that uses too little chocolate. So he has to use enough chocolate that people will buy it. Very much a compromise. But all of these types of products introduce demands into the composition of the chocolate, any property of the chocolate.

Part 7

So many of you may have ideas, your own ideas about what you think makes a good bar of chocolate. But these are some of the things that manufacturers think are important, so obviously they've done surveys of the consumers to try and understand what consumers think are important.

So one of the things we've already talked about, you expect a bar of chocolate to be hard at room temperature. So room temperature, well, if you are sitting in Bahrain it may be 30 °C. If you are sitting in Iceland it may be 5 °C, but wherever you are it's important that if you leave a bar of chocolate on a bench it doesn't melt, it's quite hard and solid.

If you compare milk chocolate with plain chocolate, one of the differences you probably will have noticed as consumers is that milk chocolate tends to be softer than plain chocolate. And it tends to be when it starts to be picked up in your fingers, milk chocolate tends to melt rather more than plain chocolate does. Clearly it's very important for the fat in the product to be fully melted in the mouth. And I've said the mouth temperature's about 35 °C to 37 °C, and it's only the fat that melts. None of the other ingredients in the chocolate change at all. Or the sugar will dissolve in your saliva in your mouth but the fat will melt. So you are relying entirely on the fat to give you the melting profile that you want.

And again you'll tend to find that milk chocolate will melt at a somewhat lower temperature, much more easily in the mouth than plain chocolate. But if it doesn't melt in the mouth, what you find is that the product will be very waxy and unpleasant to eat. So when you start to chew it, if it's not melted fully, it has an unpleasant texture in your mouth.

I mentioned before that there should be no finger marking. What that means is when you pick up a piece of chocolate you don't want it to melt in your fingers. You don't want it to become, to soften too much, you don't want the surface to become marked because it's melting in your fingers, so no finger marking. It should have a good snap. So what that means is that if you have a bar of chocolate, you break it. You don't want it to bend slowly, you want it to snap. So all these things manufactures think important in a good quality bar of chocolate.

It should have a good gloss. What that means is that when you look at the surface of the bar of chocolate, light should reflect off the surface; it should appear glossy, like gloss paint. Sometimes one defect you can find in chocolate is that the surface may become dull, and this becomes rather unattractive to consumers. Consumers like to see a nice glossy bar of chocolate.

Another thing that manufactures think is important, but I'm not sure how obvious it is, that when you put a piece of chocolate in your mouth, manufactures think it's important that you get a cooling sensation from that chocolate. That means that as the chocolate melts, it takes heat away from your tongue, and you get the feeling that your tongue is slightly cooled by the chocolate. It gives a very pleasant cool sensation. And this is associated with the melting of the fat in the chocolate because the fat melts quite quickly over a very narrow temperature range, and in order to convert solid to liquid, you have to put in heat, so the solid fat in the chocolate takes heat from your tongue gives it a cooling impression. And manufactures think that it is important for consumers.

Clearly good processing characteristics require that chocolate needs to be able to pick up markings in the mould. It needs to, perhaps if you want a rippled effect on a biscuit, it needs to develop that ripple effect, during the processing, needs to pull away from the mould, needs to contract well; lots of requirements during processing.

It should have good storage characteristics. The life time, the shelf life of the bar of chocolate if nobody eats it, is about a year or 18 months. It's really quite long. And that's quite unusual for a food product. A lot of food products will deteriorate in much shorter

times than that. Chocolate should be stable for one or two years without deteriorating. One of the main changes you can get in the chocolate that is not satisfactory is the development called *bloom*. There are different sorts of *bloom*.

This is a bloom surface in a bar of chocolate which may well have started off, if you consider one square. It may well have started off with a dark glossy surface, but here what's happened is that chocolate has been left, perhaps in the damp atmosphere, and these are just sugar crystals on the surface of the chocolate that have separated out from the chocolate and given the surface this very unattractive appearance. And that's described as sugar bloom. There is also a similar phenomenon that can happen which is where you get patches of white fat on the surface of the chocolate, which is called fat bloom. And these don't do you any harm. I mean, the problem is that some consumers looked at it and think over chocolate has gone mouldy. But it hasn't gone mouldy, and the taste will be unchanged, but just the appearance is changed. And it's not considered very attractive for consumers, if they see this sort of change. So manufacturers will go to great length to process the chocolate and store it in such a way that it doesn't change in this way.

Part 8

So processing characteristics of chocolate. We've talked about a bit before. A bar of chocolate needs to give good contraction to the mould. It needs to pull away cleanly from the mould as it solidifies in the mould. It needs to pick up decorative markings from the surface of the mould if that's what the manufacture requires. If the mould has surface markings, then the chocolate should pick those up. Good weight control. This is particularly important in the case of the chocolate biscuit that I mentioned earlier where the manufacturers are aiming to use as little as chocolate as possible. A robust product not affected by adverse temperatures. So the temperature in the factory where the chocolate is being made may be quite warm, because a lot of the machinery will give out heat as well and the ambient temperature may be quite warm. So it mustn't melt before it's packaged. It must, it will be quite robust and resistant to melting.

And very often chocolate manufacturers will work with quite large masses of semi-liquid chocolate before the final processing stage. This needs to remain stable over long periods of time. And the chocolate should have good hardness and heat resistance when packaged. So lots of processing characteristics. I mentioned earlier that 3% in that surveyed people considered felt rather guilty when they eat chocolate. They thought chocolate was nice but maybe they shouldn't be eating it. Perhaps it is a little bit naughty. Clearly this woman isn't suffering too much from guilt. 'The only way to get rid of temptation is to yield to it,' to give in to it, and eat the chocolate.

But we maybe should spend one or two minutes looking at the nutritional quality of chocolate. Should we feel guilty about eating bars of chocolate or should we not? Obviously one of the major components of chocolate is fat, and fat has also lot of sugar in chocolate. So these ingredients are quite high in energy, so one of the problems we certainly have been, in many countries around the world these days is the problems of

obesity, of people putting on too much weight. Clearly large amount of chocolate would help to contribute to that, if we don't use that energy in some way by running a marathon or something like that. So clearly a chocolate bar is quite a good source of energy if you need it. But excess intake of energy can cause obesity.

However, in recent years there's been a lot of research particularly funded by chocolate manufacturers who obviously want to, they have to sell good stories to consumers. But looking at some of the, a lot of researchers have looked at on the beneficial effect of the some of the minor components in chocolate. And indeed there are some beneficial components in chocolate as well. Some have got anti-oxidant properties which help to protect the body from cells degrading which in the long term can lead to various diseases. Also some of the components might help to reduce blood pressure. There are some vitamins and some minerals in chocolate that are beneficial, some nutrients. So it is not all bad news. Some of these components are present at quite low level, so though reducing blood pressure may be in effect of some of the ingredients relatively high levels, I don't think we should make too much of these beneficial effects because a lot of these ingredients at present at quite low levels in a chocolate . But there is a lot of interest in the affect of some of the minor components on the brain as well. Whether they stimulates the brain or whether they give beneficial effect on the way your brain functions. And there is lots of research going on this area looking at some of the minor components in chocolate. And some of them do seem to be quite beneficial. Certain chocolate contains components that give you an energy lift, make you suffer less in anxiety, and may cause reduction in pain even. So there are some good effects of some of the ingredients in chocolate, as well as some negative effect. So it's a clearly a balance as with all foods. And that's very often the message nutritionists give is that you need a mixed diet well because almost all foods have beneficial ingredients and some ingredients that are less beneficial. And therefore you need to have a wide range of food in your diet in order to have the optimal healthy life style.

Part 9

Just to finish off, we ought to look into a few more quote about chocolate. 'There is nothing better than the good friend, except that a good friend with chocolate'. 'Stress wouldn't be so hard to take, if it were chocolate covered'. I have seen recently on a T shirt: 'Emergency Alert: if the wearer of this shirt is found vacant, listless, or depressed, give him chocolate immediately'. And finally, I'm not sure about this one, but anyway. 'Forget love, I'd rather fall in chocolate'. Thanks for your attention.

(Questions and Answers)

