COCOA QUALITY IN RELATION TO PRE-HARVEST CONDITIONS

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Foreword

This report was written for the subject F350-305 and contains 4 credits. It was written in cooperation with the department of Agronomy and Integrated Food Science Group at the Wageningen Agricultural University, the Netherlands. The aim of the literature study was to investigate the relationship between pre-harvest conditions and cocoa quality. Though some (but little) research has been done on this topic, sofar nobody took the time or was in the opportunity to summarize and discuss the available information in one report. I hope this report contributes to a better understanding of the relationship between cocoa quality and pre-harvest conditions and consequently, may lead to a better appreciation of the growers.

Who does not want to write about cocoa? Like many others, also I surrendered to the internal desire to know more about cocoa and chocolate products. I am grateful to Wouter and Anita, because they were the ones opening the door to this mysterious world, in which nobody exactly knows why chocolate is so nice as it is. Wouter, thank you for your continuous support, enthusiasm and all the "chocolate" discussions about which chocolate bars taste nicest. Anita, thank you for your advice on how to write a comprehensive report. Thank you both for your efforts to make the best out of this literature study.

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1 General introduction

Cocoa or chocolate products are luxury goods which are consumed for their specific flavour and mouthfeel (Lockwood and Eskes, 1995). Chocolate is not something that nature provides, but has to be processed from cocoa beans, implying that different actors and, accordingly, different stages are involved in cocoa production. The various actors in the production-chain from cocoa seed to chocolate are the breeder, grower, traders (exporters), cocoa press-industry, chocolate manufacturer and finally the consumer. Consumers are the ones who should be prepared to buy the cocoa products and thus determine to a large extent the quality *requirements* of the end-products. This means that the quality requirements set by the consumers influence the complete production-chain, determining at each stage which quality demands have to be met in order to obtain the end-product as is defined by the consumers. Apart from these (dictating) consumer requirements, every actor sets his own specific quality requirements. For example, the growers are mainly interested in obtaining a good price for their beans, while the press-industry is amongst others interested in physical bean traits, like cocoa butter and moisture content and bean size and distribution.

Next to the fact that quality demands are set by the actors, quality is also *affected* by the various actors. Before cocoa is consumed as a finished product, a long way has been covered with attacks on quality at several stages of the production-chain. Though, lots of research has been done on post-harvest technologies (fermentation and drying of beans) and their effect on cocoa bean quality, little is known about the effect of pre-harvest conditions (including cultural practices and environmental factors) on cocoa quality. Therefore, this literature study aims at revealing the effect of these factors on cocoa quality. In chapter 1, an overview is given of the quality requirements of the different actors involved in cocoa processing (relation actors - quality requirements). Subsequently, in chapter 2 the effect of pre-harvest conditions on cocoa quality is described (relation cocoa grower - effect on quality). Finally, chapter 3 discusses how the grower can influence cocoa quality prior to the harvest.

The subject of this literature study is restricted to bulk (Forastero) cocoa, because, in global terms, 95% of the cocoa is bulk cocoa (Fowler, 1994). However, in some instances fine flavour (Criollo and Trinitario) cocoa will be discussed where appropriate (see Annex I for the main differences between Forastero, Criollo and Trinitario cocoa).

2 Cocoa quality requirements of the different actors involved in cocoa processing

2.1 Introduction

As already mentioned, the cocoa quality requirements of the different actors involved in cocoa processing are not the same. In table 2.1 an overview is presented of the various quality components in relation to the actors. The table should be interpreted as follows: all actors involved in the hierarchy deal with certain raw materials (inputs) on which specific quality requirements are posed: breeders deal with different tree varieties, growers with seeds, traders with beans etc. Moreover, each actor produces an end-product. This end-product becomes the input for the next actor up in the hierarchy. For example, the cocoa press-industry initially deals with beans and processes these beans into cocoa butter, powder and mass. These products are the inputs of the chocolate manufacturer, the next actor up in the hierarchy, who processes the butter, powder and mass into cocoa and chocolate products. In the table the quality components which are considered important to the actors are summarized.

Table 2.1: Cocoa quality requirements of the different actors involved in cocoa processing

		Breeder	Grower	Traders	Press-ind.	Chocolate manufacturer			Consumer
	INPUTS	**treevar.**	**seeds**	**beans**	**beans**	**butter**	**powder**	**mass**	**chocolate**
FOOD SAFETY	**food safety:**								×
	biocide residues				×	×	×	×	
	heavy metals				×	×	×	×	
	microbiology & mycotoxins				×	×	×	×	
	for. mat/insects				×	×	×	×	
	PAH's/PCB's/Org. solvents				×	×	×	×	
	theobromine/caffeine				×	×	×	×	
SENSORY TRAITS	*flavour/aroma*	×				×	×	×	×
	colour	×			×		×	×	×
	mouthfeel	×				×		×	×
	hardness					×			×
	fineness						×	×	×
	absence of off-flavours:		×	×					×
	smoky				×	×	×	×	
	hammy				×	×	×	×	
	mouldy				×	×	×	×	
	acid				×	×	×	×	
	bitter/astringent				×	×	×	×	
	musty				×	×	×	×	
PHYSICAL TRAITS	*bean count, weight, or size*	×	×	×					
	bean size dist.				×				
	defective beans		×	×	×				
	cocoa butter content	×			×		×	×	
	shell content	×			×		×		
	moisture content	×	×	×	×		×	×	
	acidity (pH)			×	×		×		
	freshness (FFA- content)					×			

In table 2.1 the quality components have been grouped in three main groups: food safety, sensory bean traits and physical bean traits. In the subsequent paragraphs the categorization is explained and the constituting components are discussed.

2.2 Food safety

Food safety includes components that directly or indirectly influence the health conditions of the consumers: the people at the end of the production-chain, who consume various chocolates or chocolate products. Consequently, the maximum amounts of these components permitted in cocoa are often determined by law.

2.2.1 Biocide residues

During cocoa bean production and storage, biocides are used against pests and diseases. Growers and warehouse keepers are the main users of biocides. Though Zijderveld (1994) argues that biocide residues e.g. Lindane in cocoa products are not of real concern at this moment, this should not justify its use, since biocides can be a threat to human health and the environment.

2.2.2 Heavy metals

Some heavy metals like copper and zinc are necessary in our diet as trace elements. When copper is found in cocoa beans or products, it is most often the result of the use of "Bordeaux mixture", a fungicide, which is a mixture of copper and sulphur. Other heavy metals like lead and cadmium might cause some problems when present in cocoa beans. Cadmium is especially a problem for cocoa beans of certain origins, particularly the Far East and Middle and South America. Sometimes, West African cocoa beans also have relatively high levels (Zijderveld, 1994). It is not always clear where the high amounts of cadmium come from. One explanation is that acidic soils of volcanic origin are a cause of high cadmium levels in cocoa beans, but this only accounts for beans derived from Malaysia, Papua New Guinea and Java (Gerritsma, pers. com.; Anon, 1996b).

2.2.3 Microbiology and mycotoxins

The appearance of *Salmonella* and other pathogens in cocoa beans is a matter of concern. Though the beans are sterilized during roasting, microbiological levels should be kept as low as possible.

Next to *Salmonella*, the mould *Aspergillus flavus* can be a serious problem since it secretes aflatoxin, a mycotoxin. In very low doses aflatoxin is already dangerous for our health. In cocoa it seems that, thanks to natural inhibitors, it is difficult for the *Aspergillus flavus* to produce aflatoxin. However, there is always a risk and therefore such moulds should be avoided in cocoa beans. The moisture content and temperature are important factors. Both growers and traders/transporters who handle and store beans play a role (Zijderveld, 1994).

2.2.4 Foreign materials and insects

Various examples of foreign materials can be given: stones, wood, dust, fibres, metals, rodent hairs, rodent excrements, bird excrements, insects, larvae, etc (Zijderveld, 1994). All these products should not be present in or between cocoa beans. Especially during breaking, winnowing and grinding of the beans such foreign materials cause problems. They can arrive in or between the beans e.g. during drying or transportation of beans. In particular the growers and traders are responsible for the presence of these foreign materials.

2.2.5 PAH's, PCB's and organic solvents

Cocoa beans have been identified having relatively high amounts of Polycyclic Aromatic Hydrocarbons (PAH's). It is not considered to be a case of serious concern, but further analyses may be necessary to find out what causes those higher amounts. The exposure to smoke during (sun) drying might be one of the causes (Zijderveld, 1994).
Poly Chloro Biphenyls (PCB's) and organic solvents should not be present in cocoa beans. Unfortunately, no detailed information exists on the levels of PAH's, PCB's and organic solvents that are found in cocoa beans. Certain solvents are limited among others by German Food Laws: perchlore ethylene, trichloro ethene, trichloro methane, benzene, toluene and xylene (Zijderveld, 1994). In particular the use of methyl bromides will be prohibited in the near future, since it also contributes to the destruction of the ozone layer. Methyl bromides are used in order to control damage caused by insects during storage, which is of concern to both the trader and manufacturer. Currently, alternatives are sought for the use of methyl bromides.

2.2.6 Theobromine and caffeine

Both theobromine and caffeine are (heart) stimulants. Their physiological effects are dose dependent. Up to 500 mg causes pleasant alertness and arousal. Above this level, many more physiological effects might occur, such as increased anxiety and restlessness, irritability, insomnia and elevated body temperature. Above 1000 mg, heart problems might occur and more than 10 g is lethal to humans (Anon, 1996a). The amount of caffeine and theobromine present in 1 oz chocolate is about 10 and 100 mg respectively (Anon, 1996a). In other words,

the amounts of these stimulants in chocolate are too low to cause any heart problems. The only physiological effect that can arise is pleasant alertness and arousal.
Pharmaceutical companies extract theobromine from cocoa as an ingredient for medicines. However, only a tiny proportion of the cocoa is used for this purpose (Dand, 1993).

2.3 Sensory bean traits

Sensory bean traits include those bean features that can be observed by smelling, tasting, feeling and looking at the beans. Especially to consumers these sensory traits are important, since it determines the appeal of the end-product and thus the willingness to buy cocoa and chocolate products.

2.3.1 Aroma and/or flavour

One of the most important properties of cocoa and chocolate products is the characteristic flavour. Unfortunately, it is extremely difficult to define flavour objectively, particularly since certain properties do not appear until the product has been processed and can only be assessed by tasting (Hullot, 1995). Moreover, cocoa is usually judged on the absence of off-flavours (see §2.3.6) (Hullot, 1995; Biehl, 1995). However, the intensity of clearly identified descriptors can be measured in absolute terms using a flavour profile (Théry, 1995). It seems that cocoa beans can boast about 500 different flavours that can be distinguished by the palate (Cros, 1995), as compared to 8 in carrots or onions. Fine flavour cocoas have special additional flavours as compared to bulk cocoa and are used to make dark chocolate (Fowler, 1995).
Some chocolate manufacturers demand cocoa butter with no flavour at all, because they do not want to "spoil" the taste of their own cocoa mass, which they themselves produce. This tasteless cocoa butter can be achieved by deodorizing the cocoa butter. Moreover, chocolate manufacturers can influence the flavour of their end-product by mixing cocoas from different origins. On the contrary, the flavour of the beans (raw material) depends on the genotype, post-harvest processing and roasting, and the origin of the beans and is thus mainly in the hands of the grower and the breeder (see §3.2.1).

2.3.2 *Colour*

The colour of the beans (cotyledons) is of concern, as well as the colour of the cocoa mass and powder. Beans can be white or purple, depending on the genotype. A white colour of the cotyledons of cocoa beans is one of the most important characteristics that determine a superior quality. A white colour gives the cured bean a light brown colour upon breaking which is highly appreciated (Wellensiek, 1931).
In the case of cocoa mass and powder, colour is influenced by the beans, the alkalisation process and to a lesser extent by the roasting process. Powder colour can range from very light brown to black, with brownish and reddish tinges in between (Théry, 1995). A dark colour is achieved by alkalisation, whereas a light colour can be generally obtained by using certain cocoa beans, like the ones from Java and Madagascar. Though powder colour was once the main criterion for cocoa powder (Théry, 1995), nowadays the importance of colour of the cocoa mass and powder depends on its application.
Like is the case with cocoa flavour, the colour of the beans, cocoa mass and powder is especially under the control of the breeder and grower, since it depends mainly on the genotype and alkalisation process.

2.3.3 *Mouthfeel or viscosity*

Mouthfeel or viscosity is closely related to cocoa butter hardness (see §2.3.4). In fact, cocoa butter hardness is a physical expression of what is meant by mouthfeel. Mouthfeel is a typical example of a consumer's requirement, whereby the consumer requires a chocolate that melts in the mouth. This depends on the melting characteristics of the cocoa butter (Zijderveld, 1994; Fowler, 1995), whereby the melting point is more or less the same as the temperature in the mouth, being between 31° and 35° C. The chocolate manufacturer can influence the mouthfeel of his end-product by mixing butters of different hardness. Moreover, an industrial process exists to fractionate cocoa butter (Fowler, 1995).

2.3.4 *Cocoa butter hardness*

Generally, manufacturers prefer a harder (i.e. melting point around 35°C) cocoa butter. Hardness is important to counteract the softening effect of milk fat in chocolates. Moreover, it improves the heat resistance of the chocolate and gives a better "snap" to the bar. Harder cocoa butter attracts higher prices. However, one exception is cocoa butter used for ice creams, whereby a softer butter is required (Fowler, 1995). In addition to the melting point, the hardness of cocoa butter can be measured by means of determining the iodine value (Zijderveld, 1994). Namely, this number indicates the amount of double bonds, thus saturated fats in cocoa butter. In other words, the lower the iodine value, the higher the amount of saturated fats and consequently, the harder the butter: 33 represents a hard butter (Malaysian butter), 36 represents a medium-hard butter (butter from Ivory Coast) and 40 represents a soft butter (Brazilian butter). Cocoa butter hardness mainly depends on the temperature during pod maturation (see §3.2.3).

2.3.5 Fineness

Fineness of cocoa powder is defined as the percentage of particles that do not pass through a 75-micron mesh (Théry, 1995). In general, customers of the press-industry (chocolate manufacturers) are looking for the highest possible percentage of fine particles (Théry, 1995). The finer the powder, the less the powder in a product can be detected in the mouth. Moreover, fine powder sedimentation is slower, which is a major advantage in manufacturing chocolate drinks and dairy products. However, very fine powders do have a few disadvantages linked to their physical properties: difficulties with transport, packing, static electricity, etc. (Théry, 1995). Moreover, when cocoa powder is too fine, more cocoa butter is needed to process the powder.

2.3.6 Absence of off-flavours

The frequency of occurrence of off-flavours varies between the countries of origin. In general, Malaysian cocoas can be acid, and there is a risk of mouldy and smoky tastes of beans of West African (Ivory Coast and Nigeria) origin (Daviron, 1995). For many manufacturers, off-flavours cause the largest number of rejections and therefore the degree of off-flavours determines to a large extent the quality standards (see annex II). Off-flavours are a problem because of the following reasons. First of all, beans with an off-flavour can contaminate each other since cocoa is fragile and absorbs moisture and odours (Hullot, 1995). Secondly, there is a risk that these off-flavours will carry through to the final product. Finally, some of the off-flavours cannot be removed during processing.

Smoky

The smoky off-flavour is caused by smoke. It is particularly prevalent with artificial drying when there is a leak in the system and smoke comes into direct contact with the cocoa beans. Sometimes smoke on or around the plantation causes this phenomenon. A few smoky beans can contaminate the whole batch (Hullot, 1995). Moreover, it is not possible to remove a smoky flavour during processing (Zijderveld, 1994). The growers and traders (in some cases drying of cocoa beans is in the hands of the traders) are the ones who should prevent the beans from becoming smoky.

Hammy

Hammy is often confused with smoky beans. The real hammy flavour seems to originate from over-fermentation (Zijderveld, 1994) and/or prolonged drying (Fowler, 1995). As is the case with the smoky off-flavour, the hammy off-flavour is the responsibility of the growers and traders.

In general a discount is imposed on batches that contain in between 1 and 3 % smoky or hammy beans. Batches with more than 3 % smoky or hammy beans will be rejected (Hullot, 1995).

Mouldy

Mouldy cocoa beans are defined as "Cocoa beans on the internal parts of which signs of mould or rot are visible to the naked eye" (Hullot, 1995). The mouldy off-flavour originates from mould in and on cocoa beans. Mould causes a distinctive flavour in the end product and cannot be removed during processing. Moreover, some moulds secrete mycotoxins that are harmful to consumers (see §2.2.3). Damp, germinated, over-fermented or broken beans run a greater risk of going mouldy. Drying, storage and transport conditions are essential factors in preventing a mouldy off-flavour, as there is less risk of mould if the bean moisture content is kept below 8% (Hullot, 1995). Sometimes a mouldy type flavour originates from pesticides (Zijderveld, 1994). In other words, mouldy off-flavours depend on the behaviour of the growers, traders and warehouse keepers.

Beans sometimes have white, crystalline spots known as "white spot", apparently due to theobromine concentrations. This does not really affect cocoa quality, but white spot is often mistaken for mould and consequently some batches are unfairly penalized (Hullot, 1995).

Acid

Acidity is caused by fermentation of the pulp and is thus under the control of the grower. Acids migrate into the cotyledons. This acidification of the cotyledons is necessary for the development of cocoa flavour precursors (Fowler, 1995). Some acidity is appreciated by the consumers and is most of the time described as fresh, together with fruity (Zijderveld, 1994). However, excessive acidification reduces the level of cocoa flavour (Biehl *et al.*, 1985). Contrary to the smoky, mouldy and bitter and astringent (see next paragraph) off-flavours, acidity can be removed during chocolate manufacture (Fowler, 1995). However, removal of acidity usually reveals other significant faults in the cocoa such as lack of cocoa flavour.

Bitter and astringent

To a certain degree bitter and astringent tastes are really wanted in cocoa flavour, like is the case with acid tastes. It is not liked, however, if present in excess. Bitterness and astringency cannot be removed during processing. Causes of these off-flavours are: non fermenting or poor fermenting and these off-flavours are again under the control of the grower. Poor fermenting causes purple and/or slaty beans (see defective beans §2.4.3).

Musty

This flavour can result from fat oxidation in cocoa beans which have been stored too long and at too high temperatures (Zijderveld, 1994). Consequently, the musty off-flavour is in the hands of traders and warehouse keepers.

2.4 Physical bean traits

Physical bean traits are especially important to the trader and press-industry. To the trader because they determine (next to the absence of off-flavours) the quality standard and thus price of the beans, to the manufacturer because they determine to a large extent the processability of the beans (see §§2.4.1 and 2.4.2).

2.4.1 Bean count, size and weight

Bean size or weight is often expressed in bean count: number of beans per 100 grammes. Ideally, 100 grammes should contain 100 beans. Bean size or weight is negatively related to shell content, and positively related to cocoa butter content (Toxopeus and Wessel, 1970; Zijderveld, 1994; Lockwood and Eskes, 1995; Hullot, 1995). Thus, the larger the bean the lower the shell content and the higher the cocoa butter content. In other words, bigger beans are preferred since a high cocoa butter content is very important to manufacturers. Moreover, bigger beans are easier to deshell (Zijderveld, 1994).
Beansize is highly heritable (see §3.3.1) and is thus under control of the breeder, but also of the grower through the choice of planting material.

2.4.2 Bean size distribution

Bean size distribution or uniformity is important during roasting, since it prevents the problem of over-roasted and under-roasted beans. Moreover, it is easier to adjust breakers, roasters etc. to one uniform beansize than to a broad range of beansizes (Zijderveld, 1994), because otherwise machines have to be reset every time many different beansizes are present, hence wasting time (Hullot, 1995).

2.4.3 Defective beans

Defective beans include: slaty, violet/purple or pale beans; flat, shrivelled, shivered, germinated, broken and insect damaged beans. The main cause of slaty, purple/violet or pale bean defects is that the beans are insufficiently fermented. It affects flavour, especially in the case of slaty beans, resulting in astringent and bitter cocoas. Here, bean colour is a result of defective processing, but bean (cotyledon) colour could also be related to the genotype (see §2.3.2). Especially the growers are the ones who are able to decrease the number of defective beans. In general, all the defects influence quality, bean yield and processability. In germinated beans e.g. the process of breaking down fat and proteins has already started (Zijderveld, 1994). Moreover, germinated beans are more susceptible to mould.

2.4.4 Cocoa butter content

Cocoa butter is economically the most valuable part of the cocoa bean and influences the texture, mouthfeel and melting characteristics of the chocolate. Cocoa butter content of beans varies from 50 to over 60% depending on genotype (Lockwood and Eskes, 1995), environment and season (Toxopeus and Wessel, 1970). Cocoa butter arrives in the chocolate through two channels: as part of the cocoa mass or powder in the recipe and as added cocoa butter (Fowler, 1995). In contrast to flavour, cocoa butter equivalents can be obtained from other sources (Lockwood and Eskes, 1995). In some countries, like Denmark, Ireland and the UK, up to 5% of the cocoa butter may be replaced by other vegetable fats, whereas in amongst others the Netherlands these chocolates are officially not classified as chocolate. Instead they are classified as cocoa fantasy. At present the issue of allowing 5% alternative fats in chocolate is discussed in the EU (Anon, 1997).

2.4.5 *Shell content*

Shell content of finished (fermented and dried) cocoa beans varies from 11-17% of the bean weight, depending on beansize (thus genotype) and environment (see §3.3.3). Amongst others in breeding programmes and through the choice of variety, which are in the hands of the breeder and grower respectively, the shell content can be influenced. In the past, cocoa shells had some value as an ingredient in cattle feed. Today, it is considered waste. Cocoa bean processors have to pay to get rid of the shell, therefore, a low shell content is preferred (Zijderveld, 1994).

2.4.6 *Moisture content*

Cocoa beans should not have a moisture content higher than 7.5% at time of export. However, to avoid too brittle shells, moisture content should not be lower than 6%. For example, cocoa beans may crack as a result of the low moisture content when they come under pressure during storage. The risk of mould growth increases when moisture contents exceed 8%, the problem being even more pronounced at tropical temperatures (Zijderveld, 1994). Moisture content depends on the duration of drying and on the genotype (see §3.3.3) and is thus mainly under control of the grower.

2.4.7 *Acidity (pH)*

The acidity or pH is an important feature of cocoa powder (Théry, 1995). It varies from 5.5 to 8.5. It affects colour and taste of the powder. The latter is already described in §2.3.6, whereby excessive acidification is characterised as an off-flavour. The powder should preferably have the same pH as the product it is used with. In dairy products the pH should be between 6.5 and 7, whereas in cooking chocolate a pH of above 7 is preferred.

2.4.8 *Freshness: FFA content*

The FFA (free fatty acid) content is one of the best indicators of bean quality. Most bad things that can happen to beans result in an increase of the FFA content. Fresh beans have an FFA content below 1%. When beans are not stored carefully and/or too long, an increase in FFA content takes place. Also, as a result of poor post-harvest practices, such as the inclusion of rotten, black beans from diseased pods and germinated beans from overripe pods, the FFA content increases. What happens is that the fat starts to deteriorate (FFA content >1.3%), giving a softening effect to the cocoa butter which is undesirable. FFA contents are limited by legislation in many countries: in the EEC it is 1.75%. Surprisingly, there is no corresponding limit in the cocoa bean contracts (Hullot, 1995; Fowler, 1995), though at present negotiations take place about it.

3 Impact of pre-harvest conditions on cocoa quality

In the next paragraphs, the relationships that so far have been established between the different quality components and pre-harvest conditions will be discussed. Again the quality components will be discussed according to the earlier made distinction, being food safety, sensory bean traits and physical bean traits.

3.1 Relation food safety - pre-harvest conditions

3.1.1 Biocide residues and heavy metals

control of pests and diseases

The amount of biocides used determine to a large extent the biocide residues and heavy metals present in cocoa beans. The grower can reduce the need for chemicals by preventing the build up of pests and diseases in the field by applying certain cultural practices (sanitation, growing resistant varieties). However, the growers are not the only ones using chemicals. Warehouse keepers use fungicides, like methyl bromide, in order to kill storage pests. Though this is not under the control of the grower, he can reduce the need for chemical control during storage by delivering his beans in a good state, being well fermented and dried, with a moisture content between 6 and 7.5% (see §2.4.6), reducing the risk that the beans become mouldy or rotten.

As already mentioned in §2.2.2, there is also a link between soil type and the presence of heavy metals in cocoa. High amounts of cadmium in cocoa beans is often related to acidic soils of volcanic origin on which the cocoa was grown.

Nowadays consuming countries' authorities monitor chemical residues, and tolerances are continually lowered. In other words, the demand for environmentally friendly produced cocoa beans increases. Despite this, the main control of insect pests is still chemical. Fortunately, some alternatives to chemical pest control have been developed (Dand, 1993): In Malaysia, growers practice 'rampasan', the removal and destruction of all pods from the trees during the low season, to try and break the life cycle of the cocoa pod borer (*Acrocercops cramerella*); in Vanuatu, to protect a research station's cocoa from rose beetles (*Adoretus versutus*) that flew into the plantation at night, the director planted a physical barrier of broad leafed plants around the edge of the cocoa stand. The purpose of the layer of green leafed protection was to prevent the majority of the insects reaching the cocoa leaves; in cocoa plantations in Papua New Guinea, biological control is practised. The ant *Anoplolepis longipes* has been introduced, which reduced the numbers of mirids and other pests; finally, also in Java biological control is practised (Toxopeus and Wessel, 1983). Namely the *Helopeltis* bug, which attacks pods as well as young shoots, is controlled by black cocoa ants (*Dolichoderus bituberculatis* Mayr). This relationship was already observed before 1908 on an estate farm in East Java. In contrast to the situation in Papua New Guinea, in Java *Anoplolepis longipes* drove away the black cocoa ant and wherever this ant dominated in cocoa plantations, high *Helopeltis* numbers usually occurred (Giesberger, 1983). Next to the fact that alternatives to chemical pest control have been developed, organically (i.e. without the use of any biocide or chemical fertilizer) produced cocoa and thus chocolate and chocolate products exist. It means that chemicals are also not sprayed against e.g. excessive weed growth. Though, a lot of work (like hand weeding) is involved in growing cocoa organically, the growers will be rewarded for the extra work, since they obtain a better price for their cocoa beans.

3.1.2 Theobromine and caffeine content

planting material

The amount of theobromine and caffeine present in cocoa differs between varieties. White (Criollo) beans contain less theobromine, but more caffeine than purple (Forastero) beans (Hardy and Rodrigues, 1953). The corresponding theobromine and caffeine values are 0.558 and 0.266% respectively for white beans, and 0.771 and 0.132% respectively for purple Forastero beans (Hardy and Rodrigues, 1953).

3.2 Relation sensory bean traits - pre-harvest conditions

3.2.1 Flavour

planting material (genotype)

First of all, flavour development depends on the planting material and is the property of the mother tree (Clapperton *et al.*, 1994a). Flavours, developed from different planting materials, are clearly distinguishable and differ in cocoa flavour intensity, acid taste, bitterness, astringency and fruity/floral taints (Clapperton *et al.*, 1993, 1994b). The majority of these dominant flavour characteristics are heritable (Clapperton *et al.*, 1996). However, not all desirable cocoa quality characteristics, like flavour, colour and butter content, can be found in one genotype (Clapperton *et al.*, 1993).

Secondly, the impact of technological processes (post-harvest processing and roasting) on flavour development is great. In fact, technological processes merely help the bean to express its potential, which is linked to the genotype (Cros, 1995). Fermentation is the key factor in this expression: it leads not only to the development of precursors that will be consumed

during roasting, but also to that of a volatile fraction that is of crucial importance for end product quality (Cros, 1995). As opposed to the development of "normal" flavour, off-flavours are the result of defective processing and handling (Clapperton, 1994).
Thirdly, flavour differs between origins, though are associated with distinct varieties (planting material). Cocoas from certain origins can be distinguished, like Venezuelan Criollo, Ecuadorean Nacional "Arriba" flavour, the semi-fine cocoa obtained from Trinitarios in Java and Papua New Guinea, and the bulk cocoa obtained from Forasteros grown in West Africa (Lockwood and Eskes, 1995). Whether the distinct flavours are more the result of the variety or the geographical origin is not clear.

cocoa pod ripeness

Cocoa in Ghana is in general harvested at stages of fruit development which appear riper than is the case in Malaysia. This has a positive effect on flavour. The danger of insect and pest attacks on ripe pods is one explanation of the early harvest of pods in Malaysia (Biehl, 1995). Also in Madagascar cocoa is harvested premature, since there is a considerable risk of theft (Gerritsma, pers. com.). In contrast to its effect on flavour, time of harvesting does not effect bean composition (Haworth, 1953).

soil fertility

A relationship has been established between "poor" cocoa soils in Trinidad and nitrogen content in the leaves of the trees, which appeared to be higher than of trees grown on "good" soils. Consequently, cocoa trees growing on the poorer soils might produce cocoa beans with higher nitrogen contents. A high amount of nitrogen in beans is undesirable in fine flavour cocoa, since it demands a longer period for fermentation (Hardy and Rodrigues, 1953). Unfortunately, Haworth's (1953) investigation could not confirm this result.

3.2.2 Bean colour

planting material

In general, white beans are derived from Criollo varieties (fine flavour cocoas) and purple beans from Forastero varieties (bulk cocoas). A white cotyledon colour is preferred and this objective can be achieved by a single selection on white cotyledon-colour (Wellensiek, 1931).

3.2.3 *Cocoa butter hardness*

temperature

Cocoa butter hardness is strongly correlated with temperature during pod maturation (Berbert and Alvim, 1972). The higher the temperature during pod maturation, the harder the butter. Consequently, in general, Asian (Malaysian and Indonesian) cocoa butter is harder than West-African, and both are harder than South-American (Brazilian) cocoa butter (see §2.3.4). As is already mentioned in §2.3.4, harder butter is more valuable. The genetic effect on cocoa butter hardness is small compared to the environmental one (Lockwood and Eskes, 1995; Fowler, 1995), but is still there. According to Figueira *et al.* (1996) cocoa butter hardness can be improved through selection. However more research needs to be done on the heritability of cocoa butter hardness.

3.3 Relation physical bean traits - pre-harvest conditions

3.3.1 *Bean size*

planting material

Average weight of a single bean is greater for Criollo beans than for Forastero beans, and tends to be greater for white than for purple beans (Hardy and Rodrigues, 1953).

Bean size tends to be greatest in Trinitario types, though this character is found to be extremely variable. Bean size is highly heritable (Cilas *et al.*, 1989; Clapperton *et al.*, 1994a), depending both on the mother tree and the father tree (Clapperton *et al.*, 1994a).

rainfall

A period of water stress during development of pods results in a negative correlation between pod husk and number of beans and bean size (weight). This means that pods with heavier husks contain fewer beans with lower weights, whereas in the main crop season, when pod development is not interrupted by a period of water stress, pods with a heavier husk contain more beans with higher weights (positive correlation). Moreover, mean bean weight is higher in the main crop season than in the light crop season. According to Toxopeus and Wessel (1970) the mean bean weight does not depend on the number of beans in the pod, irrespective of water supply to the trees (Toxopeus and Wessel, 1970). This is in contrast to findings of Cilas *et al.* (1989), who argue that mean bean weight seems to depend partly on pod filling rate.

age of tree

The mean weight of beans tends to fall over successive harvests, depending partly on pod filling rate (Cilas *et al.*, 1989). However, no relation exists between bean composition and age of tree (Haworth, 1953).

pod filling

Pod filling rate seems to depend on the number of midges (*Forcipomya*) present, which are able to fertilize the ovules. In general, there are too little midges to fertilize all ovules (Toxopeus and Jacob, 1970). This problem becomes more pronounced as the cocoa plantation ages, since the increase in the number of flowers (thus ovules) is faster than the growth of midges (Lockwood and Edwards, 1980).

Secondly, pod filling depends on the age of the tree. The older the tree, the more pods will develop on the canopy branches (instead of seedling trunk), resulting in smaller pods and fewer beans per pod (Pound, 1932).

Thirdly, pod filling is influenced by seasonality. The effect of the occurrence of a period of water stress is already described. Moreover, pollination frequencies and thus pod filling depend on the availability of flowers in different seasons of the year (Toxopeus and Jacob, 1980).

3.3.2 Bean composition

planting material

Moisture contents seem to be higher for Criollo beans (48.3 and 43.1% fresh weight for white and purple beans resp.) than for Forastero beans (39.4% fresh weight), and tend to be higher for white than for purple beans. Fat contents show the reverse trends, being greater for purple beans: 52.4% (oven-dry weight) for Forastero and 50.4% (oven-dry weight) for purple Criollo beans, versus 47.0% for white Criollo beans (Hardy and Rodrigues, 1953).

season

Shell percentage is mainly a function of bean weight. However, it is also affected by season. The shell percentage decreases with increasing bean weight and beans of the same weight have a higher shell percentage when produced in the main crop season than when produced in the light crop growing season, which is preceded by a period of waterstress. Consequently, cocoa butter content is also much higher in the main crop season than in the light crop (Toxopeus and Wessel, 1970).

4 Discussion

Many quality components as mentioned in table 2.1 are influenced by the grower. This is especially true for the off-flavours. However, most of the off-flavours are caused during post-harvest processing which is beyond the scope of this research. Furthermore, the quality components influenced by pre-harvest conditions, are often not fully under control of the grower. In many cases an environmental factor is included. For example, cocoa butter hardness is for the biggest part dependent on the temperature during pod maturation. Though the grower can choose a variety that is known to produce hard cocoa butter, he cannot influence the temperature during pod development.

Through the choice of planting material the grower can influence the following quality components: the amount of theobromine and caffeine in the beans, flavour, bean colour, beansize and bean composition. In general, beans with a low theobromine and caffeine content, with a good flavour (no off-flavours), white colour, with a bean count of 100 beans per 100 grammes and a high fat, low shell and low moisture content are preferred. However, not all these desirable quality components can be found in one variety, thus a compromise has to be made between the pro's and con's of a cocoa variety. In respect of this research, which is only concerned with bulk cocoa, cocoa automatically refers to beans having a higher theobromine and a lower caffeine content. Moreover, no white bulk cocoa exists. Hence, these three quality components fully depend on the planting material, whereas the other bean features as listed above also depend on other (environmental) components.

Cocoa flavour can be influenced by the grower (prior to the harvest!) through the choice of planting material, time of harvest and level of soil fertility. Though it also differs between origins, this is not under control of the growers. A grower can decide when to harvest his pods. Taking into account that the grower is aware of the effect of cocoa pod ripeness on cocoa flavour, he is prepared to harvest his pods at a riper stage of fruit development at any cost if, however, he would be paid a better price for his more tasty cocoa! Soil fertility management is also under control of the grower. As was argued, poorer soils lead to higher N contents in beans. Though this is an unfavourable characteristic of fine flavour cocoas, because of its longer fermentation period, in bulk cocoa a long fermentation period is indeed desirable (though over-fermentation should be prevented), since it leads to the development of more flavour precursors, hence a better taste! Moreover, it means that farmers who do not apply fertilizers produce better quality (bulk) cocoa. On the other hand, it should not mean that farmers should neglect their soil fertility, because this will eventually lead to lower yields, thus less income for the grower.

Next to the fact that beansize is extremely heritable, is also depends on the distribution of rainfall throughout the year and the age of the trees. Though the grower can choose a variety that produces big beans, he should be aware of the fact that the mean bean weight will be less in the light crop season. However, he can decide to remove all pods in the light crop season ("rampasan"), thereby preventing the build-up of diseases. In fact, experiments should be done to find out whether supplementary irrigation during pod maturation increases mean bean weight. Experiments should also be done on the exact effect of the age of the tree on beansize, to find out whether the effect is negligible as compared to the genetic component.
Bean composition also contains an environmental component. The grower can minimise the impact of the environment by growing a variety that produces big beans. Namely, big beans automatically contain a higher fat content and lower shell content, because of the positive correlation between beansize and fat content and negative correlation between beansize and shell content.
Finally, alternatives already exist for the use of chemical pest control (like the control of *Helopeltis* with the black cocoa ant) and even organically produced cocoa exists. In addition, the amount of biocide residues and heavy metals present in cocoa beans should also be linked to planting material. Instead of growing varieties that are mainly high yielding, growers should choose varieties that are resistant to certain pests and diseases. In other words, growers should ensure their trees are healthy and able to resist diseases.
In short, within the context of this literature study which is concerned with the effect of pre-harvest conditions on bulk cocoa quality, it seemed that the quality components influenced by pre-harvest conditions, are often not fully under control of the grower. In many cases an environmental factor is included. However, through the choice of planting material, time of harvest, soil fertility management and certain cultural practices (alternatives to pest control), growers can influence cocoa flavour, beansize, bean composition and the amount of biocide residues and heavy metals in cocoa beans. To a lesser extent, cocoa butter hardness is influenced, though more research needs to be done on the relation between cocoa butter hardness and planting material.
As is clear, no overall definition exists of a good quality cocoa. The definition given depends on the actor and on the input the actor is dealing with. In other words, is the definition concerned with the cocoa seeds; trees; beans; butter, mass and powder; or the end-product, being chocolate? However, cocoa quality starts with the raw material, being beans, so a definition should relate to cocoa bean quality. Until now, mainly qualitative descriptions are used to define cocoa quality, since certain cocoa properties can only be assessed by tasting. Ways should be sought to define cocoa quality quantitatively, so as to enable better comparison between cocoas from different producers or countries. Moreover, the definition

should not only be related to bean count, absence of off-flavours and bean defects, but also to flavour, bean composition and absence of biocide residues and heavy metals. In other words, growers' should be rewarded when producing better quality beans! Otherwise, instead of the grower, the press-industry will be rewarded for e.g. a high cocoa butter content when selling the butter to the chocolate manufacturer. In general, when the growers' are paid a better price for their good quality beans, their incentives to grow better quality beans will increase. Consequently, this good cocoa will be reflected in the end-product.

5 Summary

Many actors are involved in the production chain from cocoa seed to chocolate bar, being the breeder, grower, traders, press-industry, chocolate manufacturer and the consumers. Apart from dictating consumer demands, each actor in the production chain sets his own specific quality requirements. Next to the fact that quality demands are set by the actors, quality is also influenced by the various actors. Though, lots of research has been done about the effect of post-harvest technologies (fermentation and drying of beans) on cocoa bean quality, little is known about the effect of pre-harvest conditions on cocoa (bulk cocoa) quality. Therefore, this literature study aims at revealing the effect of these factors on cocoa quality.

The quality requirements are divided into three main groups, namely food safety, sensory bean traits and physical bean traits. It seems that food safety is of concern to the press-industry, chocolate manufacturers and the consumers. However, more important to the chocolate manufacturers and consumers are the sensory traits, since they determine the appeal of the end-product. The breeders are to a lesser extent concerned with sensory bean traits. Physical bean traits are especially important to the traders and press-industry, but also to the breeders and growers. To the trader and growers, because they determine (next to the absence of off-flavours) the quality standard and thus price of the beans, to the manufacturer because they determine to a large extent the processability of the beans.

With regard to the effect of pre-harvest conditions on cocoa (bulk cocoa) quality, it seems that the quality components influenced by pre-harvest conditions are often not fully under control of the grower. In many cases an environmental factor is included. However, through the choice of planting material the grower can influence various quality components, like cocoa flavour, beansize and bean composition. To a lesser extent, cocoa butter hardness is influenced by the planting material. Next to the choice of planting material, time of harvest and soil fertility management seem important with respect to cocoa flavour. Beansize also depends on the distribution of rainfall throughout the year (environmental component) which is also the case with bean composition. Moreover, bean composition is related to beansize. Biocide residues and heavy metals can be reduced by using alternatives to pest control, such as the black cocoa ant (*Dolichoderus bituberculatis* Mayr) against *Helopeltis*. Moreover, resistant varieties can be grown.

Ways should be sought to define cocoa quality quantitatively, so as to enable better comparison between cocoas from different producers or countries. Moreover, the definition should not only be related to bean count, absence of off-flavours and bean defects, but also to cocoa flavour, bean composition and absence of biocide residues and heavy metals. In other words, growers' should be rewarded when producing better quality beans! In general, when the growers' are paid a better price for their good quality beans, their incentives to grow better quality beans will increase. Consequently, this better cocoa will be reflected in the end-product.

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Annex I: Main differences between Criollo, Forastero and Trinitario cocoa

	Criollo	Forastero	Trinitario
Pod husk characters			
Texture	Soft	Hard	Mostly hard
Colour	Red	Green	Variable
Bean characters			
No. pod^{-1}	20-30	30+	30+
Cotelydon colour	White, ivory, pale-purple	Pale to deep purple	Variable

(Source: Toxopeus, 1985)

Annex II: Cocoa quality standards

COMPARISON OF VARIOUS GRADING STANDARDS

COUNTRY	STANDARD AUTHORITY	DESCRIPTION	BEAN COUNT PER 100 G	FAULTS (BY PERCENTAGE) MOULD	SLATE	INF.	GERM	FLAT	VIOLET	% MOISTURE	% FOREIGN MATTER	OTHER SPECIFICATIONS AND COMMENTS
	AFCC	Good Fermented	approx 100 (h)	5	5	(d)	NS	(d)	NS	NS	NS	Rejection possible if bean count above 120.
		Fair Fermented	approx 100 (h)	10	10	(d)	NS	(d)	NS	NS	NS	
		Fair Average Quality	approx 100 (h)	12	12	(d)	NS	(d)	NS	NS	NS	
	CAL	Good Fermented	100	5	5	(d)	NS	NS	NS	NS	NS	To be reasonably free from flat & germinated beans, fragments & pieces
		Fair Fermented	100	10	10	(d)	NS	NS	NS	NS	NS	of shell and virtually free from foreign matter, adulteration & infestation
(a)	FAO Model Ordinance	Grade I	(b)	3	3	3	(c)	(c)	NS	7.5	0	To be of merchantable quality, all cocoa must be free of foreign odours, and must not be adulterated.
		Grade II	(b)	4	8	6	(c)	(c)	NS	7.5	0	
		Sub-standard (SS)	NS	Cocoa which exceeds Grade II limits								Can only be marketed under special contract.
Brazil	National Foreign Trade Council	Superior	NS	4	2	(d)	2	(e)	NS	8.0	NS	Max. of each individual defect 2%, sum not to exceed 4%.
		Good Fair	NS	6	4	(d)	4	(e)	NS	8.0	NS	Max. of each individual defect 4%, sum not to exceed 8%.
		Subgrade	NS	8	8	5	10	(e)	NS	8.0	1	Slight smoke odour admissible.
Cameroon		Grade I	(b)	3	3	3	(c)	(c)	NS	7.5	0	FAO standards. To be of merchantable quality, all cocoa must be free of foreign odours, and must not be adulterated.
		Grade II	(b)	4	8	6	(c)	(c)	NS	7.5	0	
		Sub-standard (SS)	NS	Cocoa which exceeds Grade II limits								Can only be marketed under special contract.
Congo	OCC	Supérieure	NS	3	3	3	3	3	NS	NS	NS	Max. of 3% of infested, germinated or flat.
		Courante	NS	4	8	6	6	6	NS	NS	NS	Max. of 6% of infested, germinated or flat.
		Limite	NS	NS	20	12	12	12	NS	NS	NS	Bags of Supérieure marked with 1 disk, Courante with 2 and Limite with 3.
Côte d'Ivoire	Ministry of Agriculture	Grade 1	uniform	3	3	3	(c)	(c)	(c)	8.0	0	Lots must be of uniform colour and flavour - free of musty or smoky flavour - max. 10% in excess of or below average of 1/3 of the average weight of the beans (Grade 1 only).
		Grade 2	NS	4	8	6	(c)	(c)	(c)	8.0	0	
		Sous-grade	NS	Cocoa which exceeds Grade II limits								Any cocoa which does not meet Grade 2 specs. Export prohibited.
Dominican Republic	Cocoa Department Ministry of Agriculture	Sanchez	150	4	NS	3	3	(e)	NS	9.5	1	Smoky beans not permitted - maximum defect count on exportable cocoa 8%.
		Hispaniola, Gr. I	120	3	1	3	3	(e)	10	7.5	0	Cocoa which does not meet grading standards must be marked "stocklot" on the bags and documents and may be sold on special contract against sample only.
		Hispaniola, Gr. II	130	1	3	3	3	(e)	15	7.5	0	
Ecuador	Ministry of Industry, Commerce, etc	ASSPS	71-74	0	5	0	0	0	10	NS	0	
		ASSS	75-77	1	9	(d)	(d)	(d)	15	NS	0	
		ASS	81-83	3	12	(d)	(d)	(d)	20	NS	0	
		ASNS	81-83	2	13	(d)	(d)	(d)	25	NS	0	
		ASW	80-91	5	18	(d)	(d)	(d)	25	NS	0	
		ASES	80-83	2	18	(d)	(d)	(d)	30	NS	0	
		ASE	91-95	6	30	(d)	(d)	(d)	25	NS	0	Natural may include 1% flat, 1% Monilia damaged, 1% insect
		Natural	80-83	4	19	(d)	(d)	(d)	30	NS	0	damaged and 1% black beans.
Gabon		Supérieure	NS	3	3	3	3	3	NS	NS	NS	Max. of 3% of infested, germinated or flat.
		Courante	NS	4	8	6	6	6	NS	NS	NS	Max. of 6% of infested, germinated or flat.
		Limite	NS	NS	20	12	.12	12	NS	NS	NS	
Ghana	Ministry of Agriculture	Grade I	NS	3	3	3	(c)	(c)	NS	7.5	0	
		Grade II	NS	4	8	6	(c)	(c)	NS	7.5	0	
Indonesia	INCA	Grade AA I	≤85	3	3	3	(c)	(c)	NS	7.5	0	To be of merchantable quality, all cocoa must be free of foreign
		Grade AA II	≤85	4	8	6	(c)	(c)	NS	7.5	0	odours, and must not be adulterated.
		Grade A I	≤100	3	3	3	(c)	(c)	NS	7.5	0	
		Grade A II	≤100	4	8	6	(c)	(c)	NS	7.5	0	Live insects - none
		Grade B I	101-110	3	3	3	(c)	(c)	NS	7.5	0	
		Grade B II	101-110	4	8	6	(c)	(c)	NS	7.5	0	Broken beans/nib or shell ≤ 3%
		Grade C I	111-120	3	3	3	(c)	(c)	NS	7.5	0	
		Grade C II	111-120	4	8	6	(c)	(c)	NS	7.5	0	"F" in the description denotes fine flavour
		Subgrade		Cocoa which exceeds Grade II limits								

See following page for the key

COMPARISON OF VARIOUS GRADING STANDARDS, cont.

COUNTRY	STANDARD AUTHORITY	DESCRIPTION	BEAN COUNT PER 100 G	FAULTS (BY PERCENTAGE) MOULD	SLATE	INF.	GERM	FLAT	VIOLET	% MOISTURE	% FOREIGN MATTER	OTHER SPECIFICATIONS AND COMMENTS
Malaysia	Federal Agricultural Marketing Authority (FAMA) Applies voluntarily to both Sabah and Peninsula	SMC I - A	≤100	3	3	2.5	(c)	NS	NS	7.5	0	Cocoa showing live infestation (more than 10 live insects per bag) is rejected unless fumigated at owner's request.
		SMC I - B	>100≤110	3	3	2.5	(c)	NS	NS	7.5	0	
		SMC I - C	>110≤120	3	3	2.5	(c)	NS	NS	7.5	0	
		SMC II - A	≤100	4	8	5	(c)	NS	NS	7.5	0	Export of ungraded cocoa from the mainland is prohibited.
		SMC II - B	>100≤110	4	8	5	(c)	NS	NS	7.5	0	The Sabah Cocoa Grading Council, a trade association, has pledged that its membership will adhere voluntarily to the FAMA scheme and has appointed three independent superintendence firms to do the sampling for it.
		SMC II - C	>110≤120	4	8	5	(c)	NS	NS	7.5	0	
		Sub-standard	>120	>4	>8	>5	(c)	NS	NS	NS	NS	
Nigeria	Federal Produce Inspection Service (FPIS)	Grade I	(b)	3	3	3	(c)	(c)	NS	7.5	0	To be of merchantable quality, all cocoa must be free of foreign odours and must not be adulterated. Can only be marketed under special contract.
		Grade II	(b)	4	8	6	(c)	(c)	NS	7.5	0	Since the cocoa trade has been privatized these FAO standards have not been rigorously applied to exports.
		Sub-standard (SS)	NS	Cocoa which exceeds Grade II limits								
Papua New Guinea	Cocoa Board	Export Quality	100	5	1	(d)	(f)	(f)	NS	5.5-7.5	1	Board approved fermenting and drying process free from foul or foreign odours.
Sierra Leone	SLPMB	Grade I	98	3	3	3	3	3	NS	NS	NS	Max. of 15% of mould, slaty, infested, germinated or flat.
		Grade II	98	4	8	6	6	6	NS	NS	NS	Max. of 30% of mould, slaty, infested, germinated or flat.
		Subgrade		Cocoa which exceeds Grade II limits								Cocoa to be free of smoky or hammy flavour.
Solomon Islands	Commodities Export Marketing Authority	Grade I	NS	3	3	3	(c)	(c)	NS	NS	0	Cocoa for export must be fermented, thoroughly dry, free from abnormal or foreign odours and free from adulteration, reasonably
		Grade II	NS	4	8	6	(c)	(c)	NS	NS	0	free from adulteration, reasonably free from live insects, broken beans, fragments and pieces of shell.
Togo		Grade I	(b)	3	3	3	(c)	(c)	NS	7.5	0	FAO standards. To be of merchantable quality, all cocoa must be free of foreign
		Grade II	(b)	4	8	6	(c)	(c)	NS	7.5	0	odours, and must not be adulterated.
		Sub-standard (SS)	NS	Cocoa which exceeds Grade II limits								Can only be marketed under special contract.
Vanuatu	Dept. of Agriculture Livestock & Forestry	I-A	<100	3	3	3	(c)	(c)	NS	7.0	NS	These standards were proposed in 1986 and were in the process
		I-B	101-120	3	3	3	(c)	(c)	NS	7.0	NS	of being implemented in 1987.
		II	>120	4	<8	<6	(c)	(c)	NS	7.0	NS	Their current application has not yet been confirmed, however.
		Sub-standard	122-200	5-10	>8	6-20	(c)	(c)	NS	7.0	NS	Before adoption of this system the Papua New Guinea grading
		Inferior	>200	>10	>50	>20	(c)	(c)	NS	7.0	NS	practice was followed, with 8% maximum moisture contents.
United States	21 Code of Fed. Reg.	FDA Defect Action Levels (DALs)	NS	4	NS	4	NS	NS	NS	NS	0	Cocoa must be sound, reasonably free of foreign matter, foreign odour. Free of live insect infestation and other adulteration. Total defect count may not exceed 6%.
Western Samoa	1969 Cocoa Act	Export Standard	100	5	5	(c)	5	(e)	NS	5.5 - 7.5	1	< 5% in total of slaty, flat, broken, fragments, germinated or defective beans. Free from foul and foreign odours.
Zaire		Bonne Qualité	80	5	5	5	NS	NS	NS	NS	NS	Max. 5% mould and infested.
		Courante	81-85	6	5	5	NS	NS	NS	NS	NS	Max. 5% mould and infested.

Key:

- NS Not specified
- (a) This ordinance has been adopted by several countries, in some cases with modifications, but it has no force of law per se.
- (b) Not more than 12 per cent of the beans should be outside the range of +/- one-third of the average weight.
- (c) Included in insect infested.
- (d) Included in mould.
- (e) Included in germinated.
- (f) Included in foreign matter.
- (g) Detailed schedule of discounts according to bean size.
- (h) If description includes 'Main Crop'.

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