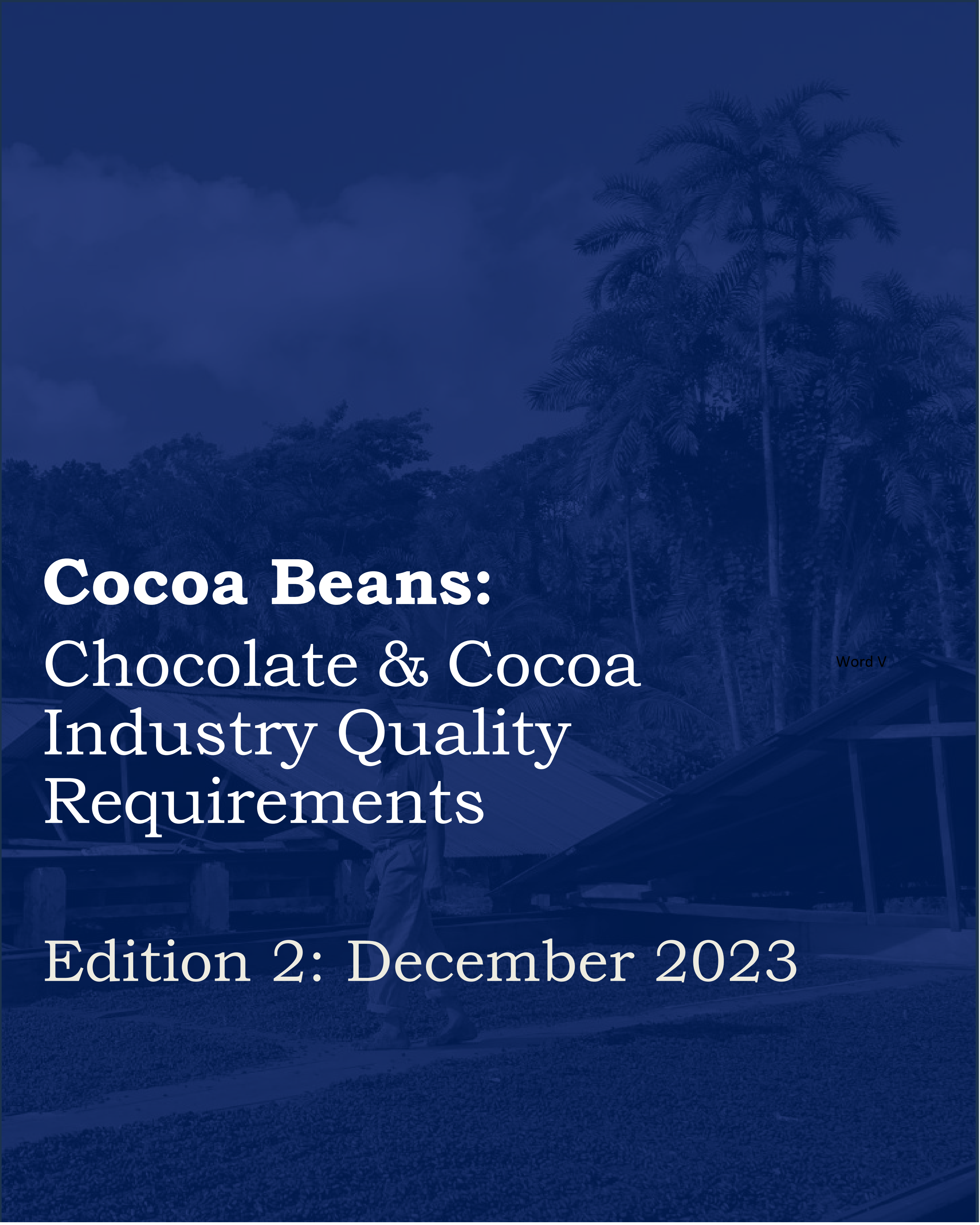

Cocoa Beans:
Chocolate & Cocoa Industry Quality Requirements

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Chocolate, Biscuits and Confectionery of Europe

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Disclaimer:

The CAOBISCO ECA Cocoa Beans: Chocolate and Cocoa Industry Quality Requirements Guide can in no case be taken as a legal reference document. The present guide is only used as an information tool for actors along the cocoa supply chain. The English version of the guide is the reference version. This guide has been developed with input from experts from the European cocoa and chocolate industry and academia. The views and opinions expressed here are those of the editors and contributors and do not necessarily reflect those of their institutions. Since the legislation and standards for cocoa quality, and recommendations for best practices, continue to evolve, readers are advised to check the web links provided for current information. It is anticipated that this guide will be updated as new information becomes available and specific comments and suggestions for improvements should be addressed to the Secretariats at CAOBISCO: caobisco@caobisco.eu and ECA: info@eurococoa.com

Cover: Drying cocoa beans at the Montserrat Cocoa Farmers’ Cooperative, San Antonio Estate, Gran Couva, Trinidad”. Photo: D. Sukha

[1]JRF contributors in 2015: ADM, Armajaro, Barry Callebaut, Cargill, Casa Luker, Cemoi, Dutch Cocoa, Ferrero, Guittard, Mars, Mondelez, Nederland, Nestlé, Olam, Storck, Touton, Valrhona. Current JRF contributors: Barry Callebaut, Cargill, Cemoi, Dutch Cocoa, Ferrero, Guittard, Luker Chocolate, Mars, Mondelez, Nestlé, OFI, Ritter Sport, Storck

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Contents

Introduction

"Various types of cocoa beans are needed to meet the demands of a complex market for chocolate and cocoa-derived products in which food safety, traceability, efficiency and cost effectiveness are key factors alongside consumer demands for taste and quality."

The European Cocoa Industry needs a sustainable and consistent supply of cocoa beans with the quality attributes to meet our diverse requirements. We are working with our partners in the cocoa supply chain to ensure that cocoa is sourced, and products are manufactured in a responsible manner from an economic, environmental and social point of view. Various types of cocoa beans are needed to meet the demands of a complex market for chocolate and cocoa-derived products in which food safety, traceability, efficiency and cost effectiveness are key factors alongside consumer demands for taste and quality. We all need cocoa beans which will allow us to produce products that are safe to eat and comply with European legislation and other international food safety standards. As the source of unique cocoa flavour and nutritional components, the importance of a consistently high standard of quality in cocoa beans cannot be over emphasised. Chocolate sells in a very competitive market, where quality and value are paramount. If the quality of the cocoa beans is poor, final products suffer and the industry as a whole loses as consumers turn to other snack foods.

This second edition of the "Cocoa Beans: Chocolate and Cocoa Industry Requirements" has been revised to reflect the changes in legislation relating to food safety and traceability that have been introduced since the first edition which was published in 2015. Moreover, the sections outlining how bean quality can be affected by the practices adopted on farm and at all subsequent stages in the supply chain through to the factory gate have been updated to reflect new knowledge on best practices. In this way, it is hoped that the guide continues to provide stakeholders across the cocoa value chain with the information on industry needs, food safety requirements and Good Agricultural Practices (GAP) as part of the way forward for a more sustainable and equitable cocoa sector.

This publication "Cocoa Beans: Chocolate and Cocoa Industry Requirements" was first published in 2015, and was based on the UK Biscuit, Cake, Chocolate and Confectionery Alliance (BCCCA) publication "Cocoa Beans- Chocolate Manufacturers' Quality Requirements" which was last revised in 1996 (BCCCA, 1996).

The focus will remain on factors affecting quality of cocoa beans from post-harvest through to the factory gate, but as in the BCCCA publication, aspects such as GAP, environmental factors, including soil conditions, and planting materials will be covered where they also have an impact. This edition will also make reference to the new legislation being introduced as part of the European Green Deal to address climate change and environmental degradation, particularly where it impacts on aspects of cocoa production such as reducing pesticide usage and de-forestation-free supply-chains. We hope that the information included, and links to suggestions for Further Reading, will be useful to all those in the cocoa sector striving to create more ESG (Environmental, Social, and Governance) compliant cocoa value chains that involve implementing sustainable practices across the entire cocoa supply chain, from farming and processing to distribution and consumption.

In Part I of this guide, the industry's requirements with regard to cocoa bean quality are set out in detail under a number of headings as before but are updated on the basis of new information that has become available. Most of these requirements can be met by sound methods of cultivation and appropriate fermentation and drying practices, although some are governed by factors beyond the control of the grower. Part II describes some of the quality standards currently used in producing countries and by the cocoa trade. In Part III the factors influencing the quality requirements are highlighted and recommendations for practices that will promote good quality are provided.

These recommendations follow those made in several sources including the publications from Codex Alimentarius, the ICCO's Consultative Board, and industry publications. Cocoa growing, post-harvest practices and quality evaluation methods vary widely, and further information sources are available for detailed guidance suited to particular situations (for example see Schwan & Fleet, (2014) Wood & Lass, (1985) and Umaharan (2018). However, summary protocols for the small-scale preparation of cocoa samples for evaluation as cocoa mass (cocoa liquor) and chocolates, including methods suitable for fermenting small quantities of cocoa beans, are appended. Full details of protocols for sampling and processing samples into cocoa mass and chocolate for the purpose of sensory evaluation are available from the Guide for the Assessment of Cacao Quality and Flavour (Cacao of Excellence, 2023) which has been compiled by the Cacao of Excellence programme of the Alliance of Bioversity International and CIAT, in collaboration with the members of the Working Group on the development of the International Standards for the Assessment of Cacao Quality and Flavour (ISCQF). Readers are advised to check the website www.cacaoofexcellence.org for any updates to this guide including the protocols, glossary of terms and flavour wheel.

Part 1
Aspects of Cocoa Bean Quality

1. Flavour
2. Food Safety
3. Physical Characteristics
4. Cocoa Butter Characteristics
5. Colour Potential - “Colourability”
6. Traceability, Geographical Indications & Certification

Part 1:
Aspects of Cocoa Bean Quality

"Although the term "cocoa" is generally used for the plant and its products in many English speaking countries, this document will refer to "cacao" for the plant and the unprocessed seeds of the species *Theobroma cacao* L."

Although the term "cocoa" is generally used for the plant and its products in many English speaking countries, this document will refer to "cacao" for the plant and the unprocessed seeds of the species *Theobroma cacao* L. Once the cacao seeds, commonly known as "beans", are harvested, fermented and dried, the product is known as cocoa. Beans are shelled and roasted, and then ground to form a paste known as cocoa mass or liquor. Some cocoa mass is pressed to extract the fat, known as cocoa butter, leaving a product known as cocoa cake. The cocoa cake is then pulverised to give defatted cocoa powder which is used in drinks and confectionary. Cocoa mass and butter are usually combined with sugar, milk and other ingredients to form chocolate. There are European and Codex standards which define the composition and labelling of certain of these cocoa products[1]. The focus of this publication will be cocoa beans, though reference will be made to some quality aspects of these cocoa products especially in relation to food safety regulations and processing characteristics.

In this publication the word "quality" is used in its broadest sense to include not just the all-important aspects of flavour and food safety, but also the physical characteristics that have a direct bearing on manufacturing performance, and aspects such as traceability, geographical indications and certification to indicate the sustainability of the production methods.

The different aspects of quality are discussed under the following headings:-

1. Flavour
2. Food Safety
3. Physical Characteristics
    3.1 Consistency
    3.2 Yield of Edible Material
4. Cocoa Butter Characteristics
5. Colour potential - "Colourability"
6. Sustainability, Traceability, Certification and Geographical Indications

These are the key criteria affecting a manufacturer's assessment of the "value" of a particular parcel and hence the price the buyer will pay for it.

[1]See for example EC Directive 2000/36/EC (EU, 2000/36) and CODEX standards CXS_105 Rev 2001 last Amended 2016 for cocoa powders (CAC, 1981 Rev. 2001), CAC CXS_141 1983 Rev 2001 last Amended 2022 for cocoa mass (liquor) and CXS_86-1981 Rev. 2001 last Amended 2016 for cocoa butter (CAC, 2016.)

1.Flavour

Flavour is a key criterion of quality for manufacturers of cocoa products. The flavour criterion includes both the core attributes, including cacao intensity, together with any complementary flavour notes, and the absence of flavour defects.

Flavour is a key criterion of quality for manufacturers of cocoa products. The flavour criterion includes both the core attributes, including cacao (chocolate) intensity, together with any complementary flavour notes, and the absence of flavour defects. Defects include effects of under-fermentation, over- fermentation and taints. The cut-test, which is used in grading cocoa beans for the market, and is described in Appendix A, may give an indication of gross flavour defects, *e.g.* excessive bitterness and astringency from a high proportion of slaty beans, or mouldy/musty notes from mouldy or infested beans as well as putrid aromas alluding to over fermentation. Other than these examples, however, the cut test is not a reliable indicator of complete flavour quality.

To assess the flavour of a sample of cocoa beans it must be roasted and turned into either a course powder, cocoa mass or made into chocolate and tasted. This is usually done by a taste panel of between six to ten experienced tasters[1]. However, for particular applications, single expert tasters with many years' experience can also be used effectively for detection of off-flavours and, providing that more tasting repetitions are carried out for increased statistical rigour, also for comprehensive flavour description.
Cocoa mass tasting is routinely used in many factories to prevent the introduction of cocoa mass with off-flavours entering chocolate production lines. Cocoa mass samples can be tasted directly without the addition of cocoa butter, sugar and milk products which dilute the taste impression and impart flavour notes unrelated to the cocoa beans being tested.

Tasting of chocolates has some disadvantages since additional time is needed for the flavour to stabilise after the samples are prepared, and the samples do not keep as well as cocoa mass, either deep frozen or at ambient temperature. Moreover, chocolate samples are often difficult to prepare to normal standards on the farms and estates where the beans are produced due to the need for processing equipment.

[1]ISO13299:2016 recommends a minimum of 8 for quantitative profiles and 4 for consensus profiles, The Guide for the Assessment of Cacao Quality and Flavour (Cacao of Excellence, 2023)) recommends a minimum of 6 panellists for quantitative sensory profiles (based on data analysis) and 4 for conventional sensoy profiles (agreed final values).

Samples can be evaluated for cacao intensity, residual acidity, bitterness and astringency characteristics which are normally present in cocoa mass and chocolates, as well as the presence of any off-flavours and any complementary flavours such as fruity or floral notes. The sensory evaluation methods and terminologies used by manufacturers and research institutions often vary. However, the recently published "Guide for the Assessment of Cacao Quality and Flavour" (Cacao of Excellence, 2023) aims to establish a common language for a clear communication throughout the cocoa value chain. This guide has been compiled by the Cacao of Excellence programme of the Alliance of Bioversity International and CIAT, in collaboration with the members of the Working Group on the development of the International Standards for the Assessment of Cacao Quality and Flavour (ISCQF). It contains a full set of protocols, established through consultation with industry and academic experts, to (1) sample the cocoa beans to be evaluated, (2) assess its physical quality, (3) process it into coarse powder, cocoa mass and chocolate and (4) carry out the sensory evaluation of these products. A summary of the protocols for the small-scale preparation of cocoa mass and chocolates, and their flavour evaluation, which were the basis of the ISCQF and have been used by the internationally recognised "Cacao of Excellence" and "Heirloom Cacao Preservation" initiatives are provided in Appendix B.

Additionally, the FCC has included an Optional Clause in its commercial contract rules – "Off Flavours in Cocoa Beans". If the Parties have failed to agree upon the selection of an independent taste panel then CIRAD (Centre de coopération Internationale en Recherche Agronomique pour le Développement) will be appointed to undertake the independent assessment of the specific off flavours or, if CIRAD are unable to act, such other competent body as may be nominated by the Federation.

Figure 1. Beans from different types of cacao vary in levels of pigmentation. Photo: G. Ramos.

The inherent potential flavour of a particular source of cocoa beans is determined principally by the variety of the trees (see the CacaoNet Global Strategy for Conservation and Use of Cacao Genetic Resources (CacaoNet, 2012) for further details on cacao's genetic diversity). Traditionally, the trade has considered there to be three main types, "Criollo", "Forastero" and "Trinitario".[2] The type of cacao historically grown in MesoAmerica and the circum-Caribbean region is known to the cocoa trade as "Criollo" (meaning native) and is characterised as having lightly pigmented beans which require little fermentation. The flavour is characterised as being delicate and sweet with caramel, honey and fresh hazelnut notes. "Forastero" (meaning foreign-from another part of the country) was the term originally used for the Amazonian types, which entered the trade as cocoa cultivation spread to other regions. Although a new nomenclature for the various Amazonian types based on their genetics has been proposed (Motomayor, et al., 2008, Zhang et al., 2012), the term "Forastero" is still used by the trade to refer to mainstream cocoas. These include those characterised as Lower Amazon Amelonado varieties, traditionally grown in West Africa, Brazil and Indonesia, and mixed hybrid varieties which often include one or more of the Upper Amazon genetic groups in their ancestry. "Forastero" cocoa is characterised by mid to dark purple beans which present a strong cacao intensity when properly fermented and processed. The term "Trinitario" (meaning native of Trinidad), although perhaps only originally applied to the hybrid populations between Criollo and Amazonian types occurring in Trinidad, has since been used to describe various hybrid types, which are now known in the trade for their floral/ fruity flavours. The Ecuadorian "Nacional" type, probably derived from a local Amazon

[2]Historically, the cocoa trade used names based on pod morphology and origin to categorise different cocoa types and sometimes referred to them as "varieties" though often the distinctions were not based on their genetic background. Cheesman (1944) proposed a revised classification based on the terms Criollo, Forastero and Trinitario (with the latter referring to recent hybrid types). These names are still widely used in the trade though they still do not always refer to cocoas of a specific cultivar or variety

population with some hybridisation with Trinitario types, is also known for its distinctive flavour characterised by floral and fresh nut notes.

It is important to note that there is considerable genetic diversity within each group, and that advancements in research continue to refine our understanding of the impact of genetics on flavour quality. Certain quality traits, including some flavour characteristics, have been shown to be heritable (Clapperton et al., 1994; Sukha et al., 2017) but most breeding work has focussed on yield and disease resistance traits, rather than flavour, particularly for varieties developed in West Africa and Southeast Asia. However, national programmes in some countries in Latin America and the Caribbean region have placed increasing emphasis on developing varieties with traditional flavours but with yields more comparable with more recently introduced clones (for example Loor et al., 2019). There are also initiatives to explore cacao genetic diversity for interesting flavour attributes (see pg 14) and to develop markers that may be useful in breeding for flavour attributes (for example Colonges et al., 2022).

Today, so called "fine flavour" cocoas represent approximately 12% of the total world crop (ICCO, 2023). Fine flavour cocoas are characterised by their exceptional flavour and aromatic qualities, and often associated with specific cacao varieties, regions, or genetic groups that produce cocoa beans with unique and desirable flavour profiles. These cocoas are required by some chocolate manufacturers who pay a premium for them. They are chiefly used in the manufacture of specialty and high cocoa solids chocolates, usually from a blend of different types of beans, to give a distinctive flavour profile to the finished chocolate. Careful post-harvest processing is needed to optimise the flavour attributes, and ensure the consistency in quality required, for farmers to obtain the premium prices needed to make growing such varieties economic.

Mainstream "Forastero" cocoa, such as many of the cocoas produced by Côte d'Ivoire, Ghana, Nigeria, Cameroon, Indonesia and Brazil, is sometimes referred to as "bulk" cocoa since it is produced and traded in large quantities for use in the production of mass-market chocolate, cocoa powder, cocoa butter and other cocoa-based products. The various mainstream cocoas, which are grown principally in West Africa and Brazil, are similar in that they possess a good, strong, cacao intensity with few pronounced complementary flavours. Although the planting materials may share a similar genetic background, differences in post-harvest processing may lead to variations in the level of cacao intensity, and in some cases the generation of off-flavours. These mainstream cocoas, when they are well prepared, are eminently suited to the manufacture of milk chocolate, which forms a major part of the global chocolate market. However, some high-yielding varieties contributing to mainstream cocoa supply, such as CCN51, need specific post-harvest processing practices to ensure they do not have off-flavours, which limit their use in chocolate production (see section 1.4).

Figure 2. Quality evaluation panel at the Cocoa Research Institute of Ghana.
Photo: S. Opoku

There are indications that in addition to the effects of genetic background and post- harvest practices, the climate and soil may also contribute to flavour differences, referred to as the "terroir" effect as in wine production (Sukha D, Butler, Comissiong, & Umaharan, 2014). There are several recent initiatives which aim to recognise and celebrate the diversity of cocoa flavours which are the result of all of these factors, and to promote the linkages within the supply chain which will help reward those producing high quality cocoa:

- Heirloom Cacao Preservation Initiative is a partnership between the Fine Chocolate Industry Association and USDA/ARS which aims to identify the finest flavoured cocoas, understand their genetic diversity and find ways to preserve them and reward the growers who cultivate them. Further details can be found from the website: https://www.finechocolateindustry.org/
- Cacao of Excellence is an initiative supported by research institutions, chocolate manufacturers and cocoa organizations. It describes itself as a unique global platform discovering, convening, promoting and rewarding cacao producers of excellence from all producing origins for superior cacao quality and flavour diversity. Since 2009, Cacao of Excellence has been the entry point for cacao producers to participate in the Cacao of Excellence Awards, a prestigious global cacao competition that recognises the work of cacao farmers and celebrates the quality and flavour diversity of cacao produced around the world. National Organization Committees have been established in each of the participating countries to ensure that samples, of either commercial or experimental origin, are submitted for evaluation by panels of experts. Further details are available from the website: www.cacaoofexcellence.org
- MOCCA: Maximising Opportunities in Coffee and Cacao in the Americas is an initiative funded by USDA and lead by Technoserve/Lutheran World Relief to help farmers grow their incomes through measures including technical support to improve post-harvest processing, facilitate supply of planting materials and facilitating access to higher value markets. Further details are available from the website: https://mocca.org/en/

Whatever the genetic background of the trees producing the cocoa, the development of flavour is also dependent on correct fermentation and drying procedures, and further processing steps such as roasting, alkalisation or conching. All types of cocoas can suffer from several off-flavours and these are described below, along with the method of assessment or detection. The causes of the off-flavours, and guidance on good practices which can minimise them, are discussed in detail in Part III of this publication.

1.1. Mouldy off-flavours

These arise from the presence of moulds primarily inside the beans, and samples with as little as 3% of internally mouldy beans can impart a mouldy/earthy flavour to cocoa mass, henceforth to chocolate. This type of off-flavour cannot be removed during processing by the manufacturer. The main causes of the flavour defect are prolonged fermentation, inadequate or too slow drying (for example, due to poor weather conditions) and adsorption of moisture during transport or storage under adverse conditions. The presence of mouldy beans is revealed by the cut test. Note that there are legal limits for mouldy beans set by US FDA and authorities in other countries, as well as levels established in ISO 2451. These are used in CMAA and FCC contracts (see Quality Standards In the Cocoa Trade

Figure 3. Beans with internal mould can give rise to off-flavours.
Photo: M. Gilmour / R. Dand.

Mould growth also results in increased levels of free fatty acids (FFA) in cocoa butter (see 4. Cocoa Butter Characteristics) and specific moulds could even lead to the formation of mycotoxins (see 2.9 Mycotoxins, including Ochratoxin A (OTA).

1.2. Smoky off-flavours

Contamination by smoke from wood fires or other sources during drying or storage causes a characteristic smoky off-flavour in cocoa mass and chocolate. This is another off-flavour which cannot be removed during chocolate manufacture. The presence of smoky beans in a sample may be detected by crushing some beans in the hand, or preferably in a mortar, and sniffing them. This is a quick test but it is not as reliable as cocoa mass tasting or making up samples of chocolate on a small scale. A smoky off-flavour is sometimes described as “hammy” because it is reminiscent of smoke-cured bacon. Hammy off-flavours can also arise from over-fermentation although it is quite easy to distinguish between the two defects. In smoke contaminated beans the hammy note is dominant. In over-fermented cocoa it occurs as a minor note against a putrid, ammoniacal or occasionally soapy/phenolic background. The presence of phenols, such as guaiacol, is probably common to both smoke contaminated and over-fermented cocoas. The off-flavour can be prevented by ensuring proper fermentation and avoiding contact with all sources of smoke contamination during drying and storage.

Preventing exposure to smoke will also reduce contamination of the cocoa by mineral oil hydrocarbons (MOSH/MOAH) and polycyclic aromatic hydrocarbons (PAH) which are a food safety concern (See 2.7 Mineral oil hydrocarbons and 2.8 Polycyclic Aromatic Hydrocarbons for further details).

1.3. Musty off-flavours

Musty off-flavours are sometimes perceived as stale, damp, mildew, decaying notes often (but not always) associated with mouldy off-flavours. A musty off-flavour can be very unpleasant and should be rejected when present at high levels.

1.4. Acid taste

Acid taste is due to excessive amounts of certain acids which are formed during fermentation. Two acids are involved: acetic acid which is volatile and lactic acid which is non-volatile. It should be stressed that there is no connection between the presence of acetic and/or lactic acids and the Free Fatty Acid (FFA) content which is dealt with later.
Appropriate drying will reduce the acidity in the fermented beans, however if this is conducted too quickly the acidity will remain in the cocoa. During manufacture, the acetic acid present in dried beans will normally be reduced to an acceptably low level, but the non-volatile lactic acid remains and if present in excess will cause an off-flavour in chocolate. Furthermore, the presence of excessive acidity usually correlates with poor development of cacao intensity. The presence of acetic acid is readily detected by smelling the beans, but the acidity due to lactic acid can only be detected by tasting cocoa mass samples or chocolate made from them.

A high degree of acidity is usually associated with a pH of 5.0 or less in the dried beans. The pH of cocoa mass prepared from properly fermented and dried West African beans in which the perceived acidity is very slight or absent is around 5.5. Control of pH, however, is not an assurance of good cacao intensity and if measures are taken to raise the pH, by neutralising for instance, they will not achieve an acceptable level of cacao intensity.

For some cocoas, acidity can be reduced by storing the unopened pods for a few days before commencing fermentation (Meyer *et al.,* 1989). However, care must be taken that only undamaged pods are stored to reduce the risk of ochratoxin A formation. Acidity may also be reduced by the combined action of removing about 20% of the pulp prior to fermentation and reducing the fermentation time. The disadvantage of this treatment is that cocoa flavour may not be fully developed, although on balance, limited cocoa flavour development with slightly increased bitterness and astringency may be perceived as a lesser flavour defect than excessive acidity (Schwan and Wheals, 2004).

Although acid taste may be reduced if the fermentation is extended for an extra 4 or 5 days, usually with extra turning of the fermenting beans, this leads to serious off-flavour problems. The pH of the beans is increased but this leads to mould growth and putrefaction and the production of ammoniacal off-flavours mentioned above. Acid taste, which might have been corrected by the manufacturer during processing, is replaced by these much more serious off flavours which make the beans virtually unusable.

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1.5. Bitterness & Astringency

Some bitterness and astringency is part of the complex of overall flavour development but if either is present in excess it becomes objectionable.

Figure 4. Unfermented/slaty (above) and partially fermented (below) beans.
Photo: C. Rohsius / D. Sukha.

Some bitterness and astringency are part of the complex of overall flavour development but if either is present in excess it becomes objectionable. Excessive bitterness and astringency cannot be removed by normal factory processing.

These flavours are associated with poor fermentation and/or certain varieties. Unfermented or slaty beans, as revealed in the cut test, can result in extremely bitter and astringent cocoa mass. The Ghana Cocoa Board, for example, sets a maximum limit of 3% slaty beans for Grade 1 cocoa to ensure it does not.impart excessive astringency to chocolate. Fully purple beans also produce bitter and astringent flavours. While excessive amounts of slaty and purple beans should be avoided, chocolate manufacturers do not expect to receive beans which are all fully brown. Even cocoa that has been correctly harvested, fermented and sun-dried may contain a proportion of partly brown/purple beans.

Studies have shown that planting materials differ markedly in astringency and in their concentrations of polyphenols which contribute directly to that flavour characteristic (for example Elwers et al., 2009). The concentrations of polyphenols are reduced markedly during post-harvest processing but not to the same limiting concentration for all planting materials, assuming that a standardised processing treatment has been used.

1.6. Contamination

Cocoa beans must always be handled and treated as a food grade material.

Cocoa beans can absorb off-flavours from other products such as copra, rubber, oil based fuels, chemicals, paints, cement etc, both in stores and in vessels/containers used to transport cocoa. The high fat content of cocoa beans acts as an extremely effective absorbent for all manner of taints. Cocoa beans must always be handled and treated as a food grade material and, as a general rule, bagging materials and warehouses used to handle and stock cocoa beans should be used exclusively for that purpose (See Part 3.3C).

SUMMARY OF CAUSES OF MAJOR OFF-FLAVOURS

Mould

- Prolonged fermentation
- Slow or inadequate drying
- Storage under highly humid conditions
- Germinated beans and damaged beans are prone to becoming mouldy

Excessive acid taste

- Deep box fermentation
- Inappropriate turning
- Too rapid drying

Smoky

- Contamination by smoke during drying due to inappropriate fuel, bad design, faulty operation or poor maintenance of dryer.
- By exposure of dried beans in store to smoke contamination

Excessive bitterness and astringency

- Certain planting materials
- Lack of fermentation

2. Food Safety

It is essential that cocoa and chocolate products, in common with all other food products, should be safe to eat.

It is essential that cocoa and chocolate products, in common with all other food products, should be safe to eat. It follows that the ingredients, including cocoa beans, should not contain any impurities which could be present in the finished foods and prove injurious to the health of the consumer. There is a responsibility throughout the supply chain to ensure that raw materials and products meet all national and international legislative requirements enforced at point of entry and in the market place.

A number of organisations have been set up to establish standards for food safety management so that risks at any stage of the foods supply chain, from the farm to the consumer, can be identified and controlled.

These include:

The Codex Alimentarius Commission

Created in 1963 by FAO and WHO to develop harmonised international food standards, guidelines and codes of practice to protect the health of consumers and ensure fair practices in the food trade. The Commission also promotes coordination of all food standards work undertaken by international governmental and non-governmental organizations. https://www.fao.org/codexalimentarius

International Organisation for Standardization

The ISO 22000 family of International Standards contains a number of standards each focussing on different aspects of food safety management. https://www.iso.org/iso-22000-food-safety-management

In Europe, there is an integrated approach to food safety through farm-to-table measures and adequate monitoring. The framework for this was established in EC Regulation 178/2002 and its amendments, and EC Regulation 2019/1381 on the transparency and sustainability of the EU risk assessment in the food chain . Regulation 178/2002 includes the establishment of the European Food Safety Authority (EFSA) which provides scientific advice and scientific and technical support in all areas impacting on food safety. It also established the Rapid Alert System for Food and Feed (RASFF) which enables information exchange to facilitate the restriction or the withdrawal of unsafe food from the market and share information on rejections of food consignments by an EU border post. The Regulations set out food safety standards, risk assessment/management procedures and the responsibilities of those involved in food businesses to ensure compliance with the legislation and traceability of foodstuffs at all stages of the food chain, from the production, processing, transport and distribution stages through to the supply of food. For further information see https://eur-lex.europa.eu/legal-content/EN/TXT/

EU food business operators must comply with the EU hygiene legislation (Regulations 852/2004, 853/2004, 2017/625 and associated regulations) and put in place, implement and maintain a permanent procedure, or procedures, based on HACCP (Hazard Analysis and Critical Control Point) principles to ensure that food is produced safely and public health is protected. (See https://food.ec.europa.eu/safety/biological-safety/food-hygiene_en and Commission Notice on implementation of food safety management systems (2022/C 355/01).
Guidelines have been published for good manufacturing practices in the cocoa, chocolate and confectionery industry (CAOBISCO, 2011) (ICA, 1991) and (Syndicat du Chocolat, 2012).

The commission has established a regulation on maximum levels for certain contaminants in food (Regulation 2023/915). This regulation includes: mycotoxins (including OTA), heavy metals (including cadmium and lead), polycyclic aromatic hydrocarbons (PAH), dioxins and PCBs and many others. Maximum residue level of pesticides are established in Regulation 396/2005.

The principal food safety concerns for the cocoa industry are:

- Allergens
- Dioxins & PCBs
- Microbiological Hazards
- Foreign Matter
- Heavy Metals
- Infestation
- Mineral Oil Hydrocarbons
- Polycyclic Aromatic Hydrocarbons (PAH)
- Mycotoxins including Ochratoxin A (OTA)
- Pesticide Residues

2.1. Allergens

Food allergies are life changing and can be fatal. Chocolate, biscuit and confectionery manufacturers face specific challenges, since allergens such as peanuts, treenuts, milk, eggs, soya and gluten-containing cereals are commonly used.

For allergens present as an ingredient, it is a legal requirement that these are clearly labelled in the ingredients list (EU Regulation 1169/2011)) and practical guidance on the implementation of allergen management is included in the Commission Notice on the implementation of food safety management systems 2022/C 355/01. For allergens present as potential traces in finished products due to cross contact during manufacturing, precautionary labelling should be the last resort after other means of control have been evaluated, in order to offer the allergic consumer the best information available. Beyond allergen management in manufacturing, it is important to review the supply chain since there may be allergenic components present in ingredients or present through cross contact. ILSI Europe has published various guidance documents to help improve the assessment and management of food allergen risks (For more details see https://ilsi.eu/scientific-activities/food-safety/food-allergy/).

2.2.Microbiological Hazards

Raw cacao beans are a natural agricultural product and, as such, manufacturers recognise that there is an intrinsic risk of microbiological contamination of finished cocoa-based products. Cocoa and chocolate factories and the manufacturing processes are designed to sterilise the beans and so eliminate the risk of contamination by pathogenic organisms such as Salmonella. They follow stringent HACCP-based systems as outlined in the CAOBISCO Guide to Hygiene (CAOBISCO, 2011) and have to meet requirements for validation of preventative measures (kill step) as set in EU legislation (EC Regulation 178/2002), Codex Alimentarius HACCP (CAC CXC-1, 2020) and FSMA (FDA) requirements. Cocoa beans which have been mistreated at origin or during shipping and storage can acquire a level of contamination which exceeds the design capabilities of the sterilising treatments. Excessive microbiological contamination can result from too slow or inadequate drying, storage of wet beans, and contamination during drying or storage by animals including livestock and rodents. In addition to the care that should be taken to minimise contamination at source there must also be an effective hygiene barrier in cocoa and chocolate factories between incoming raw materials and finished goods. This obligation applies to all processing of cocoa beans to both final and intermediate products.

2.3.Dioxins & PCBs

Dioxins are a group of harmful chemically-related compounds that are persistent environmental pollutants (POPs) which can originate from natural sources (such as volcanic eruptions and forest fires) though they are mostly formed as by-products of industrial processes. There are also dioxin-like polychlorinated biphenyls (PCBs) which have similar toxic properties. Since these contaminants are very widespread and contaminate many foods and feedstuffs, the Codex Alimentarius Commission has adopted a Code of Practice (CAC CXC 62-2006 Rev 2018) for the Prevention and Reduction of Dioxin and Dioxin- like PCB Contamination in Food and Feeds and levels are monitored and controlled by various food safety authorities.

In Europe, Regulation 2023/915 (repealing Regulation 1881/2006) establishes maximum limits for these contaminants in a range of foodstuffs following EFSA assessments of dietary exposure in 2001 and 2018. Although typically not significantly contaminated with dioxins, the following limits have been set for vegetable fats and oils, including cocoa butter:

Sum of dioxins (WHO-PCDD/ F-TEQ)[1] 0.75 pg/g fat

Sum of dioxins and dioxin-like PCBs (WHO-PCDD/F-PCB- TEQ): 1.25 pg/g fat

Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 (ICES - 6): 40 ng/g fat

[1]Dioxins (sum of polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), expressed as World Health Organisation (WHO) toxic equivalent using the WHO-toxic equivalency factors (WHO-TEFs)) and sum of dioxins and dioxin- like PCBs (sum of PCDDs, PCDFs and polychlorinated biphenyls (PCBs), expressed as WHO toxic equivalent using the WHO-TEFs) See http://data.europa.eu/eli/reg/2017/644/oj for further details).

2.4.Foreign Matter

Contamination of cocoa bean parcels with foreign matter should be avoided at all stages of the supply chain from fermentation through drying and subsequent handling. Bulk supplies should be cleaned and graded before bags are filled since foreign matter not only affects the wholesomeness of the product but may also affect the flavour, cause damage to plant and machinery and reduce the yield of edible material (see 3.2.5 Foreign matter for further details).

2.5. Heavy Metals

Heavy metals which are toxic to humans, can be found in various agricultural raw materials, including cocoa. Some food safety authorities have set maximum limits for certain metals in foods based on their assessments of the tolerable weekly intake (TWI) ("safe level"), and mean dietary exposure of groups and sub-groups of their populations, to protect the health of consumers. EU maximum limits for environmental contaminants are reviewed on a regular basis, and the introduction of maximum limits for nickel in cocoa products is currently under consideration based on an updated EFSA Scientific Opinion (EFSA Contam panel, 2020). All maximum limits are subject to future revision to take account of the latest evidence and data, but there are currently no maximum regulatory limits under European legislation for arsenic or mercury in cocoa products. Maximum limits are in force for heavy metals in cocoa products in some countries and states, for example for cadmium (Cd) and lead (Pb) under Prop65 in California.

2.5.1 Cadmium:

Cadmium (Cd) can accumulate in human tissue over time and can cause kidney and bone damage as well as being a carcinogen. Maximum limits for Cd in cocoa products have been in force in Europe since 2019 under EU Regulation 2023/915 (see Table 1). The Codex Alimentarius Commission (CAC) set up a working group in 2014 to develop harmonised maximum levels which will protect consumer health and facilitate international trade. After several years of extensive discussions, the levels adopted by Codex for Cd are 0.3mg/kg for the category of chocolate containing up to 30 percent cocoa total solids on a dry matter basis and 0.7mg/kg for the 30 to 50 percent category, whilst noting the reservations of some delegations including that from the EU. A level of 2.0 mg/kg cocoa powder (100% total cocoa solids on a dry matter basis) is still in the process of being adopted by Codex, though with reservations expressed by some delegations, having reached Stage 5 of the 8 stage process. A Code of Practice for the Prevention and Reduction of Cadmium in Cocoa Beans was adopted by Codex in 2022 (CAC CXC81, 2022). The Cd problem relates to beans from certain regions of some producing countries, particularly in the Latin America and Caribbean area. Although high levels in the beans are generally associated with naturally high levels of Cd in the soil, levels are known to be affected by a number of factors including the physical and chemical nature of the soil, the variety of cacao and anthropogenic factors including the use of contaminated fertilisers, composts and irrigation water. See Section 3 for suggestions on ways to mitigate against Cd uptake..

Emerging Issue: Aluminium

EFSA continues to collect and analyse information on the occurrence of aluminium (Al) in food, and its health implications, following their opinion in 2008 that intake may exceed the Tolerable Weekly Intake for a significant proportion of the European population. Cocoa and chocolate were noted as having high Al contents compared to most other foods, based on the available data. Efforts are underway to determine possible entry points for Al contamination in the cocoa supply chain, with a focus on potential sources of environmental contamination since soils naturally contain Al. Although there are currently no maximum limits, the Belgian authorities have action limits in place for Al in cocoa and cocoa products (estimated acceptable concentrations (EAC) ranging from for example 50mg/kg for chocolate spread to 150mg/kg for cocoa powder. Further details available from https://www.favv-afsca.be/scientificcommittee/opinions/2020/_docu

Table 1.

EU Maximum Limits for Cadmium in Cocoa Products applicable from 1st January 2019 (Commission Regulation (EU) 2023/915 replacing Commission Regulation (EU) No 488/2014)).

Specific cocoa and chocolate products as listed below - Milk chocolate with <30% total ·dry cocoa solids	0.10mg/kg as from 1 Jan 2019
Chocolate with <50% total dry cocoa solids; milk chocolate with ≥ 30% total dry cocoa ·solids	0.30mg/kg as from 1 Jan 2019
Chocolate with ≥ 50% total dry cocoa solids ·	0.80mg/kg as from 1 Jan 2019
Cocoa powder sold to the final consumer or as an ingredient in sweetened cocoa powder sold to the final consumer (drinking chocolate)	0.60mg/kg as from 1 Jan 2019

‘For the specific cocoa and chocolate products the definitions set out in points A. 2, 3 and 4 of Annex I to Directive 2000/36/EC of the European Parliament and of the Council of 23 June 2000 relating to cocoa and chocolate products intended for human consumption (OJ L 197, 3.8.2000, p. 19) apply

2.5.2 Lead:

This heavy metal can accumulate in human tissue over time and can cause damage to the kidney and the cardiovascular system. However, food safety authorities are particularly concerned about lead intake by pregnant women, infants and children since lead has a serious effect on neurodevelopment. EFSA updated its scientific opinion on lead in food in 2013 ((EFSA CONTAM, 2010 rev 2013) following an assessment of dietary exposure for the European population in 2012 (EFSA, 2012). A maximum lead level of 0.10mg / kg has been set for oils and fats (this category includes cocoa butter) (EU Regulation 2023/915**)**. Lead levels in cocoa and chocolate products should continue to be carefully monitored and steps taken throughout the supply chain to minimise contamination.

Lead can occur naturally in the soil though, depending on soil factors such as pH and organic matter content, it is often insoluble and thus not taken up by the plant. However, lead can be released into the environment during forest fires, mining, smelting and petroleum extraction operations and when fossil fuels are burned (Baligar, Fageria, & Elrashidi, 1998). Contamination attributed to car exhaust fumes has considerably decreased since lead has been removed as an additive from petrol in most countries, though traffic fumes may still be a source of contamination and cocoa should not be dried or stored close to busy roads. Codex has published a code of practice for the prevention and reduction of lead contamination in foods (CAC CXC 56- 2004 rev 2021)

Click here for further sources of information.

2.6. Infestation

Cocoa beans frequently become infested at origin by several species of insects and other pest species including the tropical warehouse moth (*Ephestia cautella*), Indian meal moth (*Plodia interpunctella*), dried fruit beetle (*Carpophilus spp.*), foreign grain beetle (*Ahasverus advena*), red-rust grain beetle (*Cryptolestes ferrugineus*), the tobacco beetle (*Lasiodema serricorne*) and the coffee bean weevil (*Araecerus fasciculatus*). If these infestations are not treated at origin by effective pre-shipment fumigation, these species will survive the voyage to traders, processors and manufacturers. If not then controlled at port of entry, the infestation will spread to cocoa stores and chocolate factories and spoil finished goods.

Over recent years disinfestation in Europe has been complicated by the EU being a signatory to the Montréal protocol, which has banned the use of methyl bromide as a fumigant. This has been further complicated in certain countries where stringent requirements on the fumigation process have been imposed, notably in the Netherlands, which makes fumigation an expensive and lengthy process as the cocoa has to be moved from the warehouse to a fumigation chamber to be processed. An alternative to methyl bromide is phosphine (hydrogen phosphide PH^3), generated from compounds such as aluminium phosphide or in the form of a cylinderised gas. While phosphine is an effective fumigant, it requires much longer to penetrate the stack of cocoa and achieve reliable kill of both the adult and larval stages of pests compared to methyl bromide. Another fumigant that has been registered for use on stored cocoa in some countries, including the Netherlands and Belgium, is sulfuryl fluoride.

Although trials using this fumigant have shown it be fast and effective, without any adverse effects on the quality of the cocoa beans and their processing (Noppe, Buckley, & Ruebsamen, 2012), EFSA has made only a tentative assessment of maximum residue levels for cocoa since insufficient trial data and an analytical method for the enforcement of the proposed residue definitions are still required (EFSA 2021) and a decision regarding its re-registration for use in the USA is still awaited. Various alternatives have been offered; ranging from the removal of oxygen from the cocoa stack in order to asphyxiate the pests to putting the cocoa in refrigerated containers and reducing the temperature to well below freezing point to kill the pests. Other attempts have included storing the cocoa in temperature-controlled warehouses thereby keeping the pest activity to a minimum but without eradicating the infestation. It should be noted that the comments above are related to cocoa stored in bags, the most likely mode of cocoa to be transported and used by the cocoa industry, but given the rise of bulk, loose cocoa, disinfestation still presents issues. Sieving at points prior to/and during storage, removes insects that are not present within the beans themselves but must be accompanied by appropriate containment and/or fumigation of the sieving residue.

While prevention remains the best option, it is possible that infestation will occur, particularly at origin and in consuming regions where the climate is tropical. Care needs to be taken at all stages of transport and storage from farm to export that infestation is kept to a minimum by ensuring clean surroundings and that, if required, the cocoa is fumigated by a reputable agent before shipment.
Click here for sources of further information.

2.7.Mineral Oil Hydrocarbons

Cocoa products, in common with many other foods, could potentially be exposed to mineral oil hydrocarbons (MOH) at various points in the chain from the farm to the consumer since they are found in various packaging materials and food additives as well as arising from contamination by lubricants, fuels, and debris from tyres and road bitumen (Figure 5).

The term MOH summarizes two groups; mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH). EFSA has recently published a draft scientific opinion on MOH (currently under public consultation) in which It provisionally concludes that dietary exposure to MOSH does not raise concern for human health, though it recommends that potential long term effects continue to be investigated (EFSA, 2023). However, concerns remain regarding the potential carcinogenicity and genotoxicity of MOAH, specifically related to 3 or more aromatic rings, with a lack of toxicological information on the effects of 1-2 ring MOAH. The scientific opinion has also clearly defined substances which are considered part of the MOH group and substances which are not.

Prior to the release of the EFSA draft scientific opinion, the EU Member States drafted a joint statement regarding the presence of MOAH in food in April 2022 (with clarification in October 2022) (see SCoPAFF, 2022). This proposes a uniform enforcement approach which will remain in force until maximum levels are set once the consultation process is completed:

- "the Member States agreed to withdraw and, if necessary, to recall products from the market, when the sum of the concentrations of MOAH in food are at or above the following maximum LOQs"
- 0.5 mg/kg for dry foods with a low fat/oil content (≤ 4% fat/oil)
- 1 mg/kg for foods with a higher fat/oil content (> 4% fat/oil, ≤ 50% fat/oil)
- 2 mg/kg for fats/ oils or foods with >50% fat/oil

Moreover, representatives of the German Food Control Authorities and Food Federation Germany have recommended benchmark limits for MOH based on monitoring data collected from an extensive range of sources and investigations on the sources of MOH contamination through food supply chains. The benchmarks set for chocolate and cocoa-based confectionery were set at 9 mg/kg for MOSH and its analogues (C10-C50)[3], but at "not quantifiable" (levels as per EU statement above) for the MOAH due to their potential carcinogenic /genotoxic nature (see LAV/Lebensmittelverband, 2022).

Since the effects of MOAH on human health continue to be investigated and the analytical methodology for MOH continue to be refined, reference to the EFSA and EU Joint Research Centre websites for the latest information is recommended. There are a number of approaches which can be taken to minimize MOH contamination in cocoa products and these were investigated in projects supported by the BDSI and Foundation of the German Cocoa and Chocolate Industry (BDSI Toolbox MOSH_MOAH) (see Matissek, 2014; Matissek, Raters, Dingel, & Schnapka, 2014; Schnapka et al. 2022) and the CAOBISCO/ECA Joint Research Fund (JRF MOH studyhttps://jointcocoaresearchfund.eu/fileadmin/downloads/20210408-moh.pdf).

Cocoa beans might be exposed to MOH contamination during drying, particularly from fuel or fumes from oil fired burners when cocoa beans are dried artificially in direct dryers (i.e. those without gas/air heat exchangers), or from exhaust fumes and debris if they are dried close to roads (see 2.8 PAH and Part III 3.b drying). Cocoa beans and cocoa products may also be contaminated by fuels and lubricants used on machinery and from packaging materials during transportation and storage (see Part III Storage and Part III Transportation and Shipping) and also by technical equipment during processing

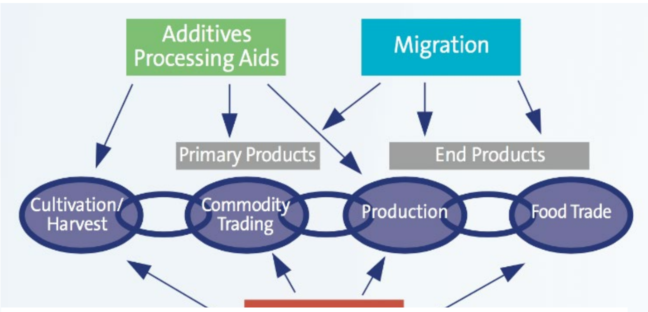


Figure 5. MOSH and MOAH contamination sources in) the food chain. (Matissek et al. 2014)

[3] Note that there is a Maximum Limit of 30 mg/kg for fraction C16 to C35 MOSH in food contact materials used for confectionery in Belgium Inventaire limites d'actions v15 NL (favv-afsca.be)

to cocoa butter and other products. Recycled cardboard packaging, including the dressings used to line containers for shipping, may be contaminated by mineral oil-based printing inks from the recycled paper used to produce it. Such inks would also be a potential source of contamination if used on jute bags.

Jute Bags

Another important source of contamination can be jute sacks manufactured using fibres which have been processed (batched) using mineral oils rather than vegetable oils. Laboratory tests have shown that MOH can migrate from contaminated jute onto the shell of the cocoa beans, and eventually to the cocoa nib. Higher levels of contamination are associated with broken beans where the shell is damaged and no longer able to act as a barrier to migration. Although the use of mineral oils in the manufacture of sacks sent to Europe was largely stopped in the late 1990s, they are widely used elsewhere. In 1998, the International Jute Organisation (IJO) adopted 'special criteria for the manufacture of jute bags used in the packaging of selected foods (cocoa beans, coffee beans and shelled nuts)'. The batching oil shall only contain non-toxic ingredients and it shall not contain compounds that produce off-flavours or off-tastes in food.

The IJO also specifies limits for the presence of unsaponifiable material in the bags (less than 1250 mg/kg jute fibre). This limit was adopted by the ICCO in March 1999 and it was stated that the methods to be adopted in determining the limits were to follow British Standard 3845:1990 on methods for the determination of added oil content of jute yarn, rove and fabric (with subsequent saponification using the methodology described in WG 1/90 of the International Union of Pure and Applied Chemistry (IUPAC). Further, the organoleptic properties of the bags were included such that no undesirable odours or odours untypical of jute shall be present. No unacceptable odours shall develop after artificial ageing of the bags. The ageing procedure to be followed shall be the one described in European Standard EN 766 on bags for the transport of food aid.

Despite all the measures taken, the sector still faces challenges with mineral oil contamination originating from jute bags as indicated by the results from the JRF MOH study [click here for summary].

As a response a Technical Working Group, involving representatives from the cocoa and confectionery industry, FCC, ICCO, trade organisations and jute bag manufacturers, has been recently established to address the challenge that jute bag derived MOH contamination poses to the cocoa industry.

Click here for further sources of information.

Figure 6. Jute bag with label to show that it meets the IJO food grade standard Photo: M. Gilmour.

COCOA GAP - MITIGATION OF MOH RESIDUES

- ✓ GAP to prevent contamination during drying at the farms (see also 2.7).
- ✓ All sacks must be batched using vegetable oil (food grade) and virtually free from MOH contamination.
- ✓ Any cardboard used during shipping must be free from virtually free from MOH contamination.
- ✓ Avoid contact with lubrication oils, fuel oils and exhaust gases during transportation.
- ✓ Avoid contamination in cocoa/ chocolate processing with oils/lubricants, ensure oils/ lubricants used in processing are food grade (H1) in case of incidental contact.
- ✓ Careful handling of beans to prevent excessive broken beans/damage to shell.
- ✓ Effective de-shelling of beans.

2.8.Polycyclic Aromatic Hydrocarbons (PAH)

Polycyclic aromatic hydrocarbons are a group of compounds present in the environment as a result of past and current incomplete combustion (burning) of organic substances (*e.g.* wood, gas, diesel) and geochemical processes. Some of these compounds are genotoxic and carcinogenic and food safety authorities recommend that levels in foods should be as low as reasonably achievable to protect public health. Foods, including cocoa products, can become contaminated by deposition of soot particles from the air, by growing in contaminated soils or contact with contaminated water, or during post- harvest processing. For cocoa, the principal source is from smoke contamination during artificial drying. It is therefore essential to ensure the guidelines on good drying and storage practices in Section 3.Post-harvest:Drying are followed, with particular attention given to the design and adequate maintenance of artificial dryers, to minimize PAH contamination. Furthermore, since most of the PAH contamination will reside on the outer surface of the bean, it is also important that bean breakage is kept to a minimum, and the removal of the shell fraction during processing is carefully carried out.

The EU has set maximum limits for some of these PAHs in a number of foods, including cocoa beans and derived products (Regulation (EC)2023/915) where the levels are established on a fat basis since PAH concentrate in the cocoa butter (see Table 2). The EU has indicated that the levels of PAH in cocoa beans and derived products should continue to be regularly monitored with a view to assessing the possibility for further decreasing the maximum levels in future.

Indeed, the EU has subsequently set maximum limits for PAH in cocoa fibre and derived products. The limits are set on a wet weight basis since cocoa fibre products are low in fat and produced from the shell of cocoa bean and are thus likely to contain higher levels of PAHs than cocoa products produced from the cocoa nibs .The cocoa fibre and derived products are intermediate products in the production chain and are used as an ingredient in the preparation of low calorie, high fibre food.

Figure 7. Smoke from a fire below a drying table can contaminate beans with PAH.
Photo: D. Sukha.

Table 2.

EU Maximum Limits for PAH in Cocoa Products (Commission Regulation 2023/915).

	Maximum levels (µ/kg)	
	Benzo(a)pyrene	Sum of benzo(a)pyrene, benzo(a) anthracene, benzo(b)fluoranthene and chrysene*
Cocoa beans and derived products with the exception of the products referred to below	5.0 µg/kg fat	30,0 µ/kg fat
Cocoa fibre and products derived from cocoa fibre, intended for use as an ingredient in food.	3,0 µg/kg	15,0 µ/kg

* Lower bound concentrations are calculated on the assumption that all the values of the four substances below the limit of quantification are zero.

COCOA GAP - MITIGATION OF PAH RESIDUES

- ✓ Sun-dry where possible (protect beans from rain).
- ✓ Use indirect drying if sun drying not possible.
- ✓ Direct drying with wood or diesel fires are not to be used.
- ✓ Avoid smoke contamination
  - Well maintained, functional exhaust/ chimney
  - Regular maintenance of dryers required.
- ✓ Handle beans carefully to avoid broken beans
- ✓ Carry out effective de-shelling of beans

See 3. Post-harvest: Drying for more information.

Click here for sources of further information.

2.9. Mycotoxins, including Ochratoxin A (OTA)

Mycotoxins are a group of naturally occurring toxic chemicals produced by certain moulds (fungi) which affect a number of food crops and commodities. For cocoa, the most important mycotoxin is ochratoxin A (OTA) produced by *Aspergillus* moulds, though aflatoxins and some other mycotoxins have also been detected. Following the EFSA risk assessment of OTA in 2020 which took into account new scientific evidence, the EU has revised its legislation for maximum levels of OTA in foodstuffs and established a new maximum level for cocoa powder (Table 3) and a review of maximum limits for other mycotoxins, including aflatoxins[4] is expected in 2023. It is important that measures are taken to minimise the formation of OTA during post-harvest processing, storage and transportation. Furthermore, it is important that de-shelling of the cocoa beans is carried out carefully since most of the mycotoxin is found on the outside of the bean. Further information and recommendations on good practices is provided in the Codex Code of Practice for the prevention and reduction of Ochratoxin A contamination in cocoa (CAC-CXC72, 2013)

Figure 8. Diseased and insect damaged pods may allow proliferation of ochratoxigenic fungi. Photo: M. Gilmour.

Table 3.

EU Maximum Limit for Ochratoxin A (OTA) in Cocoa Powder Commission Regulation (EU) 2023/915

	Maximum levels (OTA µg/kg)
Cocoa Powder	3.0

COCOA GAP - MITIGATION OF OTA RESIDUES

- ✓ Discard insect damaged/rotten/ mummified pods.
- ✓ Avoid wounding pods with machete.
- ✓ Do not store harvested pods longer than 7 days.
- ✓ Follow heap fermentation, sun drying guidelines.
- ✓ Dry cocoa down to ≤ 8% moisture.
- ✓ Careful handling of beans.
- ✓ Effective de-shelling of beans. See Part 3 for more details.

[4] Note that maximum limits for aflatoxins apply to all foodstuffs in Germany and Denmark (Aflatoxin B1 must not exceed 2 µg/kg and the sum of aflatoxins B1, B2, G1 and G2 must not exceed 4 µg/kg in all foodstuffs) see https://www.gesetze-im-internet.de/kmv/KmV.pdf

2.10. Pesticide Residues

Despite the protective barrier of the cacao pods and shells (if undamaged), the use of pesticides, and other plant protection products, on cacao trees and in cocoa stores can lead to the presence of residues in cocoa products. There is a growing body of knowledge and increasing public awareness of this subject which have led to limits being set for the maximum level of pesticide residues in raw materials including cocoa beans. The cocoa industry requires that all supplies of cocoa beans and products comply with these limits and will monitor closely the levels of pesticide residues on all cocoa raw materials. In Europe, all cocoa and cocoa products must comply with EU Regulation 396/2005 and its amendments, which set out Maximum Residue Levels (MRLs) of pesticides in or on food or feed of plant and animal origin. Where no specific MRL for a particular pesticide has been established, or in the case of pesticides that are banned in Europe, the default level of 0.010mg/kg is applied. For residues of pesticides which are carcinogenic, mutagenic and reprotoxic (CMR), measurement uncertainty cannot be taken into consideration, in many European member states, when assessing compliance of a result. For cocoa, the MRLs are determined on “beans after removal of shells”, as referred to in Regulation EC 178/2006. However, in some other countries MRLs are determined on whole beans (*i.e.* prior to removal of the shell or seed coat). Lists of the strategic pesticides used on cocoa, with their current MRLs, and also those pesticides that MUST NOT be used on cocoa can be found in the Pesticide Use in Cocoa: Practical Manual (Bateman and Crozier, 2023) available from https://www.icco.org/icco-documentation/pesticide-use-in-cocoa-practial-manual-fourth-edition/

What are MRLs?

The Maximum Residue Level (MRL) is the highest amount of a pesticide residue that is legally tolerated in or on food when pesticides are applied correctly. The amounts of residues found in food must be safe for consumers and must be as low as reasonably achievable (ALARA).

The MRL for a given crop/active ingredient combination is usually determined by measurement during a number of field trials, where the crop has been treated according to Good Agricultural Practice (GAP) and an appropriate pre-harvest interval (ie the time between the last pesticide application and harvest) has elapsed. For many pesticides, however, this is set at the lowest limit of analytical determination (Limit of Determination, LOD) – since only major crops have been evaluated and understanding of the Acceptable Daily Intake (ADI) is incomplete (*i.e.* producers or public bodies have not submitted MRL data – often because these were not required in the past). In Europe, the default lowest limit (LOD) is 0,01 mg/kg and this MRL applies for any active ingredient/crop combinations unless they are specified in an annex of EU Reg. 396/2005 (see the EU Pesticides Database)

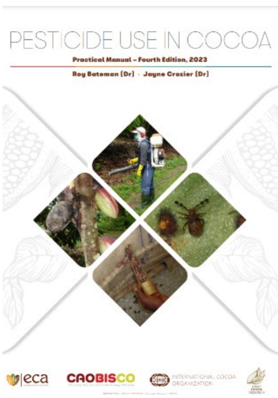


Figure 9. 2023 Edition Pesticides Use In Cocoa

The issue of pesticide residues is kept under constant review by food safety and environmental protection agencies. Information on active compounds that are under review, and newly introduced maximum levels and restrictions can be found on various websites including:

Codex Alimentarius:

https://www.fao.org/fao-who-codexalimentarius/thematic-areas/pesticides/en/

European Food Safety Agency :

https://www.efsa.europa.eu/en/topics/topic/pesticides

European Commission:

https://agriculture.ec.europa.eu/sustainability/environmental-sustainability/low-input-farming/pesticides_en

https://food.ec.europa.eu/plants/pesticides

US Environmental Protection Agency:

https://www.epa.gov/pesticides

Japanese Ministry of Health, Labour and Welfare:

https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryou/shokuhin/index_00006.html

Search engine for MRLs of Agricultural Chemicals in Foods (ffcr.or.jp)

Pesticides can have an important role in controlling the pests and diseases that would otherwise lead to high percentage loss of the cocoa crop, or adversely affect its quality. However, they must be used appropriately (the right pesticide at the right time at the right dosage), safely and responsibly, as part of an Integrated Crop and Pest Management (ICPM) strategy, which minimises risks to the operator, the farmer and his community, the environment and the consumer. Pesticides can also be used as fumigants to control storage pests and prevent deterioration of quality during transportation and storage. See sections Part III Pest and Disease Control and Storage.

COCOA GAP - MITIGATION OF PESTICIDE RESIDUES IN COCOA PRODUCTION

- ✓ Usage must comply with all national and international regulations.
- ✓ Spraying as part of Integrated Crop and Pest Management (IPM).
- ✓ Manage tree architecture to allow for air circulation and easy access to pods when applying pesticides,
- ✓ Correct equipment, timing (respecting any pre-harvest interval) and target.
- Recommended pesticide.
- ✓ Even application.
- ✓ Personal protective equipment.
- ✓ Correct disposal of containers.
- ✓ Avoid pesticide cross-contamination (drying tables, storage areas, etc.)
- ✓

Click here for further sources of information.

COCOA GAP - MITIGATION OF PESTICIDE RESIDUES DURING FUMIGATION, STORAGE & TRANSPORT

- ✓ Usage must comply with all national and international regulations.
- ✓ Cocoa stored according to Good Warehousing Practice.
- ✓ Correct equipment, timing and target.
- ✓ Recommended pesticide.
- ✓ Personal protective equipment. Correct
- ✓ disposal of containers.
- ✓ Monitoring and assessment to ensure effectiveness.
- ✓ Prevent cross-contamination from pesticides used on other crops or to control termites, for example on pallets.

Click here for further sources of information.

3. Physical Characteristics

3.1. Consistency

It is very important that the quality of cocoa, both from bag to bag within a particular consignment, and between different consignments of the same mark, is consistent.

It is very important that the quality of cocoa, both from bag to bag within a particular consignment, and between different consignments of the same mark, is consistent. Since manufacturers aim to produce chocolate of consistent quality, a mark or origin which can be relied upon to supply beans of consistent quality will be valued more highly than one of heterogeneous quality. Consistency refers not only to the amount of defective beans but also the bean sizes and degree of fermentation.

To some extent consistency can be achieved by mixing beans, but all the cocoa being mixed should be of the same grade standard. It is not advisable to mix or blend poor quality cocoa with good quality cocoa to obtain a cocoa that just meets average minimum grade standards. While the value of the poor cocoa can be increased in this way, the value of the good cocoa is correspondingly reduced and future demand for that cocoa will diminish.

Mainstream cocoas from sources with a reputation for supplying cocoas where the quality can often very close to the prescribed Grade 1 standards tend to sell at a discount to mainstream cocoas which are consistently well within the standards. Cocoa which is very near to the prescribed Grade 1 standards may contain as many as 8 or 9% defective beans and this cocoa is unsuitable for good quality chocolate. The mixing or blending at origin of cocoas of different grades should not be practised.

3.2.Yield of Edible Material

The yield of the useful part of the bean significantly affects its value to the manufacturer and hence the price he is willing to pay for the cocoa. A number of factors which can be measured objectively affect the amount of edible material (cocoa nib), and in particular the amount of cocoa butter, that can be obtained from a parcel of cocoa. Some of the factors affecting yield such as bean size, shell content and fat content are largely determined by climatic and genetic factors, whilst others can be influenced by good post- harvest, storage and transportation practices. One of the most significant factors that can be addressed by the grower is the removal of foreign matter, see Section 3.2.5. A parcel of cocoa which consists of whole single cocoa beans is worth more than one which includes foreign matter, even if that matter is of cocoa material. It is noted that while the grower has the capacity to deliver clean cocoa (by visually sorting out any foreign matter during drying), there is the temptation by some growers and exporters to blend in a degree of foreign matter in order to meet the minimum requirements of the export contract. This is regrettable and could be avoided by reducing the amount of foreign matter acceptable under the contracts (or the national quality standard in case of farmer fixed price); paying more for such clean cocoa so that the parties are clear what the premium is for; and by introducing traceability to the cocoa chain.

3.2.1 Bean size and uniformity:

The weight of a cocoa bean should be at least 1.0g. Smaller beans have higher shell contents and, consequently, less nib, which may also have a lower percentage of fat. Small beans can be used (provided the parcel is homogeneous) but require adjustment to factory processes which is inconvenient and costly - causing a reduction in plant throughput. For this reason beans should be sold on the basis of a bean size classification, *e.g.* Less than 100 beans per 100g, 100 to 110g, more than 120/100g etc (See Part II for further information on bean count). Manufacturers also require beans to be reasonably uniform in size because it is difficult to achieve effective bean cleaning in a parcel containing beans that are very variable in size. A general guideline is that no more than 12% of the beans should be outside the range of plus or minus one third of the average weight. This distribution applies to most cocoa as harvested, but not after small beans have been blended into a parcel in order to bring the average bean size closer to the limit of a particular size classification. However, applying and checking this standard formally is time consuming unless specialised equipment is to hand. Informal judgement by eye on a given weight of a random sample of whole beans is usually sufficient; for example, if 72 of the smallest-looking beans taken from 600 grams of beans consisting of 600 beans collectively weigh less than 48 grams; there is a problem. By the same manner, if 72 of the largest-looking beans weigh more than 96 grams there is also the likelihood of blending. Note that ‘a single whole bean’ here does not include flat beans as they, by definition, have no nib and are therefore not whole beans. Such a test is unusual; the better option is to rely on the grower and to use traceability of the parcel to ensure uniformity.

3.2.2 Shell percentage:

Manufacturers require the shell to be loose enough to be easily removed during processing, but strong enough to remain unbroken under normal handling. The shell should also be free of adherent matter such as lumps of dried pulp, which are liable to interfere with the separation of nibs from shell. The shell of main crop West African cocoa beans normally makes up 11-12% of the total bean weight, a norm against which other cocoas are judged. Higher shell percentages mean less edible material and hence a lower value, although offering more protection to the nib. The shape of the seed and thickness of the seed coat varies with the type of cacao grown, and this together with varying post-harvest practices affect the shell weight.

Careful de-shelling is required as a first step in the production of edible cocoa products, especially since the shell is often the most contaminated part of the bean, for example for microbes (including moulds), PAH, OTA and some pesticide residues. The Codex Standard for Cocoa Mass and Cocoa Cake (CAC CXS 141-1982 Rev 2022) specifies that the shell and germ must be less than 5% m/m of the cocoa mass (cocoa liquor) calculated on the fat-free dry matter or not more than 1.75% calculated on an alkali free basis (for Cocoa Shell only). For cocoa cake, the shell and germ should not be more than 5% m/m calculated on the fat-free dry matter, or not more than 4.5% calculated on an alkali free basis (for Cocoa Shell only). Shell % in cocoa products can be estimated using a method based on the analysis of fatty acid tryptamides.

3.2.3 Fat percentage:

Cocoa butter is still generally the most valuable part of the bean and the potential yield of butter affects the price paid for a particular mark or grade of cocoa beans. Main crop cocoa from West Africa normally contains about 55-58% fat in the dry nib, with Ghanaian beans generally containing a higher percentage of fat than beans from either Côte d'Ivoire or Nigeria. Some typical values for a number of origins, expressed on a whole bean basis, are given in the table below (Pontillon, 1998). Pontillon notes that these values should be taken as indicative only, since the number of samples used to produce these figures varies for each origin and especially since fat percentages can vary considerably depending on factors such as the climate (seasonal and annual variations), geographic and genetic factors, and the methods used to extract the fat.

Origin	Fat % of whole bean	
	Pontillon 1998[1]	Industry Source[2]
Brazil - Bahia	44.6	
Cameroon	47.6	47.1/46.7
Cote d'Ivoire	46.7	46.4
Ecuador	43.6	44.2
Ghana	48.0	46.8/48.0
Indonesia: Sulawesi	45.6	39.9
Madagascar	43.5	
Nigeria	46.9	45.1/47.2
Papua New Guinea	44.0	
Sierra Leone	47.0	
Tanzania	47.6	45.7
Togo	47.0	

[1]Extract from: Cacao et chocolat : production, utilisation, caractéristiques. J. Pontillon, coordonnateur, © Technique & Documentation, 1998. [2]Additional data from industry sources on current typical values from main crop beans

3.2.4 Moisture content:

Manufacturers require cocoa beans to have a moisture content of approximately 7%. If it is above 8%, there is not only a loss of edible material, but also a risk of mould and bacterial growth with potentially serious consequences for food safety, flavour and processing quality (see Part 1, Section 2). If the moisture content is less than 6.5% the shell will be too brittle and the beans disintegrate to give high levels of broken beans (see Part 1, 3.2.5b). This is of particular importance if the cocoa is transported and/or stored in bulk as the beans are less well protected from damage if not bagged, and thus more likely to have higher levels of lipolysis giving rise to Free Fatty Acids.

3.2.5 Foreign matter:

The presence of foreign matter will also affect the yield of edible material and hence reduce the value of the cocoa to the chocolate manufacturer, and may also affect the flavour and be a source of contamination to the product.

Foreign matter in this case may be divided into two types, one that has no commercial value to the manufacturer and the other that has only a reduced value (known as "Residue" or Cocoa Related Matter).

3.2.5a Foreign matter with no commercial value:

The type of foreign matter which has no value to the manufacturer consists of material that is (a) not cocoa-related, *e.g.* sticks, stones etc., which can damage the manufacturer's machinery; or (b) cocoa-related but has no commercial value, *e.g.* placenta, pod husk and flat or shrivelled beans which contain very little nib *etc.*, which can be detrimental to the flavour as well as reducing the yield of edible material.

Figures 10 (above) Foreign matter. a) large pieces of husk, placenta and other material with no commercial value. Figure 11 (below) residue separated using a 5mm round hole sieve.
Photos: R. Dand / M. Gilmour.

3.2.5b Cocoa residue including broken beans and fragments:

Cocoa residue consists of broken beans and fragments of beans and shell. Some bean breakage is inevitable during shipping and storage, although from normal production the amount seldom exceeds 2%. The process of moving the cocoa in bulk form may generate more broken beans and fragments if not properly managed (*e.g.* limiting free fall, mechanical damage etc…). Higher levels can result in greater amounts of nibs and fragments being removed by bean cleaners with corresponding loss of edible material. There are two main areas of concern to the manufacturer. The first is that cocoa nibs of broken beans and fragments are likely to have a higher FFA content than whole beans, due to higher rates of lipolysis because of the greater surface area exposed to oxygen, and a higher likelihood of their being affected by mould. Moreover, the FFA content of butter from broken beans will continue to rise during storage and therefore cocoa beans containing high levels of broken beans and fragments cannot be stored for any appreciable period. The second area of concern is that broken beans and fragments are not easily processed as the effectiveness and consistency of the roasting process depends directly on the homogeneous size of the nibs. This difficulty also occurs with bean clusters – see Section 3.2.7.

Figure 12. Broken Beans. Photo: R. Dand /M. Gilmour.

3.2.6 Insect damaged beans:

Substantial insect damage results in a loss of usable nib and detracts from wholesomeness.

Figure 13. Insect damaged beans. Photo: R. Dand / M. Gilmour.

3.2.7 Clumped beans (clusters) and double beans:

Clumped beans and doubles are rejected together with foreign matter during cleaning and can represent a serious loss to manufacturers. Because they may not be collected in stab samples, the entire contents of sacks have to be inspected, either during grading of subsequent supplies or in cases of arbitration.

Figure 14. Bean clusters. Photo: R. Dand / M. Gilmour.

4. Cocoa Butter Characteristics

4.1. Free Fatty Acid (FFA)

FFA can have an impact on the hardness of cocoa butter and therefore its processing quality, specifically its crystallisation properties. High FFA butter makes poor quality chocolate, affects bloom, tempering, and can affect the flavour. Although some FFA may be released from the triglycerides constituting the cocoa butter during factory processing or through poor storage conditions of final products, high FFA levels are mainly associated with poor post-harvest practices. Lipase enzymes within the seed itself will start to breakdown the triglycerides during seed germination so timely harvesting of pods is important to prevent seeds germinating within overripe pods. However, the action of microbial lipases associated with pod diseases and poor drying and storage practices is likely to be the major source of FFA. The fat from whole and healthy beans which have been fermented and dried thoroughly without delay, stored properly and exported promptly from origin will generally have an FFA content of less than 1% and certainly less than 1.3%. Beans which contain fat with a higher FFA content may be due to the use of beans from diseased pods, very slow drying after fermentation (particularly where there are clusters of beans which have not been properly separated from the placenta), high % of broken beans, prolonged storage under humid conditions or with a moisture content above 8%, insect infestation during storage or prolonged storage of beans at tropical temperatures in the country of origin. These abuses can result in an FFA content above 1.75% which is the legal limit for cocoa butter within the EU (Directive 2000/36/EC) (EU, 2000) and in the Codex Standard for cocoa butter (CAC CXS 86-1981, Rev.-2016). As explained above, increased levels of broken beans and fragments can significantly increase the FFA content of the fat extracted. Cocoa butter with an FFA content of 1% or less, together with acceptable flavour in both butter and cocoa mass, is the best indication that the beans were sound at origin and have been prepared and stored properly.

Click here for further sources of information.

4.2. Hardness

Cocoa butter consists of a mixture of triglycerides, i.e. fats which are made up of glycerol and three fatty acids. Most of the triglycerides of cocoa butter contain stearic acid, palmitic acid and/or oleic acid but the proportions of these fatty acids vary and this results in different physical properties of the fat. This in turn affects the way chocolate behaves in the manufacturing process and the texture and appearance of the final product.

Manufacturers prefer cocoa butter that is relatively hard and consistent in this respect. Cocoa butter from most West African beans gives the desired physical properties. Butter from Cameroon and Brazilian beans tends to be softer, while butters from Southeast Asia tend to be harder, with temperature conditions during bean development likely to be one of the major factors contributing to these differences.

Cocoa butter from beans which contain high levels of FFA also tends to be softer than that from sound whole beans irrespective of the country of origin.

5. Colour Potential - “Colourability”

The colour of cocoa powder is an important attribute since it is often used as a colouring agent as well as for its flavour in various foods. Cocoa powder contains naturally occurring colorants, including flavonoids, and it is the extent to which these can be influenced during the alkalisation and roasting processes which is of particular interest to manufacturers. The levels and types of the chemicals responsible for colour potential are influenced by a complex of factors including the genetic background of the cocoa, climatic and soil conditions and post-harvest processes. Good fermentation is particularly important since it is essential for the oxidation and condensation reactions which result in the formation of new, very large and insoluble tannin compounds which give the characteristic brown colour to the bean. It is important that the fermentation is stopped at the right time by drying otherwise ‘over-fermented’ beans of a very dark colour are produced (Kamphuis, n.d.).

6 Sustainability, Traceability, Certification & Geographical Indications

The cocoa and chocolate industry are working closely with their partners in the cocoa supply chain, including origin country governments and local authorities, to improve the sustainability of cocoa sector and ensure that deforestation due to cocoa growing is halted, the human rights of those involved in the supply chain are respected and the livelihoods of cocoa farmers are improved. The ability to trace cocoa beans and cocoa products through all stages of production, processing and distribution is essential in ensuring food safety, quality, authenticity and accountability. Traceability is a key component of the systems needed to provide proof of compliance with legislation and to ensure that farmers receive fair prices for producing cocoa that meets specific requirements, for example for organic production, geographical indication or sustainability standards. It also provides a mechanism for feedback loops to ensure that farmers have access to training in good agricultural practices and support in developing their farm business plans. Many value chain actors have been designing and implementing traceability systems, often using new technologies such as Blockchain, GPS, RFID, QR Codes and Barcodes. Traceability continues to be a rapidly developing area especially with commitments made to prevent deforestation through the Cocoa & Forests Initiative and the new EU Regulation on deforestation-free products which entered into force in June 2023.

The EU is also developing a Corporate Sustainability Due Diligence Directive (CS3D) which sets out to foster sustainable and responsible corporate behaviour and to anchor human rights and environmental considerations throughout global value chains (IDH, 2023). Deforestation will be covered in the CS3D since it is one of the negative environmental impacts that the companies will need to cover by their due diligence processes, but the Due Diligence Duty will also require companies to identify and, where necessary, prevent, end or mitigate adverse impacts of their activities on human rights, including child labour and exploitation of workers.

EU Regulation on deforestation-free products (EUDR) (EU 2023/1115) is part of the EU's Green Deal strategy to address climate change and environmental degradation. Under EUDR, any operator or trader who places cocoa beans, or cocoa products, on the EU market, or exports from it, must be able to prove that the products do not originate from land deforested after 31st December 2020 or have contributed to forest degradation.

Products may only be traded to and from the EU when they are covered by a due diligence statement which will provide the geolocation coordinates of all the farm plots where these products were harvested. Geographic information linking products to the plot of land is gathered using remote sensing (*e.g.*.aerial photographs and satellite images) or other methods (*e.g.* photographs in the field with linked geotags and time stamps taken using mobile phones). For plots of land of more than 4 hectares, the geolocation is provided using polygons (latitude and longitude points of six decimal digits to describe the perimeter of each plot of land). For plots of land under 4 hectares, operators (and traders which are not SMEs) can use a polygon or a single point of latitude and longitude of six decimal digits to provide the geolocation.

The products must also have been produced in accordance with relevant legislation of the country of production. In addition to each country's national legislation, for cocoa beans and products from Côte d'Ivoire and Ghana this is likely to include compliance with the ARS-1000 African regional standard on sustainable cocoa ('ARS-1000') (see pg 40).

The EUDR will be enforced from the 30th of December 2024 though there is still a need for clarification over some definitions and details on how it will be implemented. Readers are advised to check the websites in the Sources of Further Information section for updates.

The European cocoa industry recognizes that certification standards covering social and economic, as well as a wider range of environmental issues, in the cocoa sector play a key role within a 'smart mix' of measures to promote greater sustainability of cocoa supply. Certification schemes vary in their main focus or strategy for

improving the sustainability of cocoa production, but they share similar objectives in seeking improvements in farmers' livelihoods, most often in conjunction with implementing good agricultural practices to improve quality and productivity.
The sustainability requirements will use criteria that aim for:

- Profitable farming based on good agricultural and business practices.
- Improving social conditions that respect human rights, workers' rights, health and safety, and support the eradication of forced labour and the worst forms of child labour.
- Sound environmental practices.

The traceability criteria require a rigorous record keeping system and supply chain management. The standards also acknowledge the reality of the existing supply chain and offer two separate paths to compliance:

- Physical traceability
- Mass Balance

Sustainability Standards

ISO 34101 Sustainable and traceable cocoa

The European Committee for Standardization (CEN) and the International Organization for Standardization (ISO) have published a standard for sustainable and traceable cocoa (ISO 34101 parts 1-4,) giving a common definition of sustainability and traceability in the cocoa sector. The standard was developed by stakeholders from all sectors of the cocoa industry, including representatives from both countries where the cocoa is grown and markets where it is consumed. It covers the organizational, economic, social and environmental aspects of cocoa farming. The stepwise approach, establishing three requirement levels (entry, medium and high) allows an organization that is sustainably producing cocoa beans initial certification to any level and encourages professionalization of cocoa farming so that the higher level can be reached. The standard has four parts:

Part 1 Requirements for cocoa sustainability management systems including post-harvest processes and traceability.

Part 2 Requirements for performance are typically related to economic, social, and environmental aspects to ensure sustainable and responsible practices throughout the supply chain.

Part 3: Requirements for traceability specifies the basic requirements for the design and implementation of traceability systems and also covers the requirements for a mass balance systems whereby cocoa conforming to the standard can be used together with nonconforming cocoa and which provides the necessary traceability within a manufacturing process.

Part 4: Requirements for certification schemes provides clarity on the requirements for certification schemes and certification bodies.

Note that only organizations that fulfil both the cocoa sustainability management system requirements of either ISO34101-1:2019 or ISO 34101-4:2019, Annex A or B, and the performance requirements of ISO 34101-2 can claim their cocoa beans have been sustainably produced.

ARS:1000 African regional standard for sustainable cocoa

The ARS:1000 standard for sustainable cocoa is being developed withing the framework of the African Regional Standards Organization (ARSO). The objective of ARS 1000 is to establish a common standard for sustainable cocoa production, applicable to all cocoa value chain actors with economic viability for farmers as a precondition for social and environmental sustainability. The standard will consist of the following three parts:

Part 1 Management System and Performance

Part 2 Quality and Traceability

Part 3 Cocoa Certification Scheme

The National Implementation Guides for the Standard are currently being developed by Ghana and Côte d'Ivoire together with the National traceability systems and frameworks for data collection, storage and security, and farmer support in the implementation of the standard.

A study of the ARS standard and its implementation guides, and a comparison of the requirements of the ARS, and the obligations of the forthcoming EU legislation has been published by the German Initiative on Sustainable Cocoa (GISCO) (Brack, 2023)

Geographic Indications

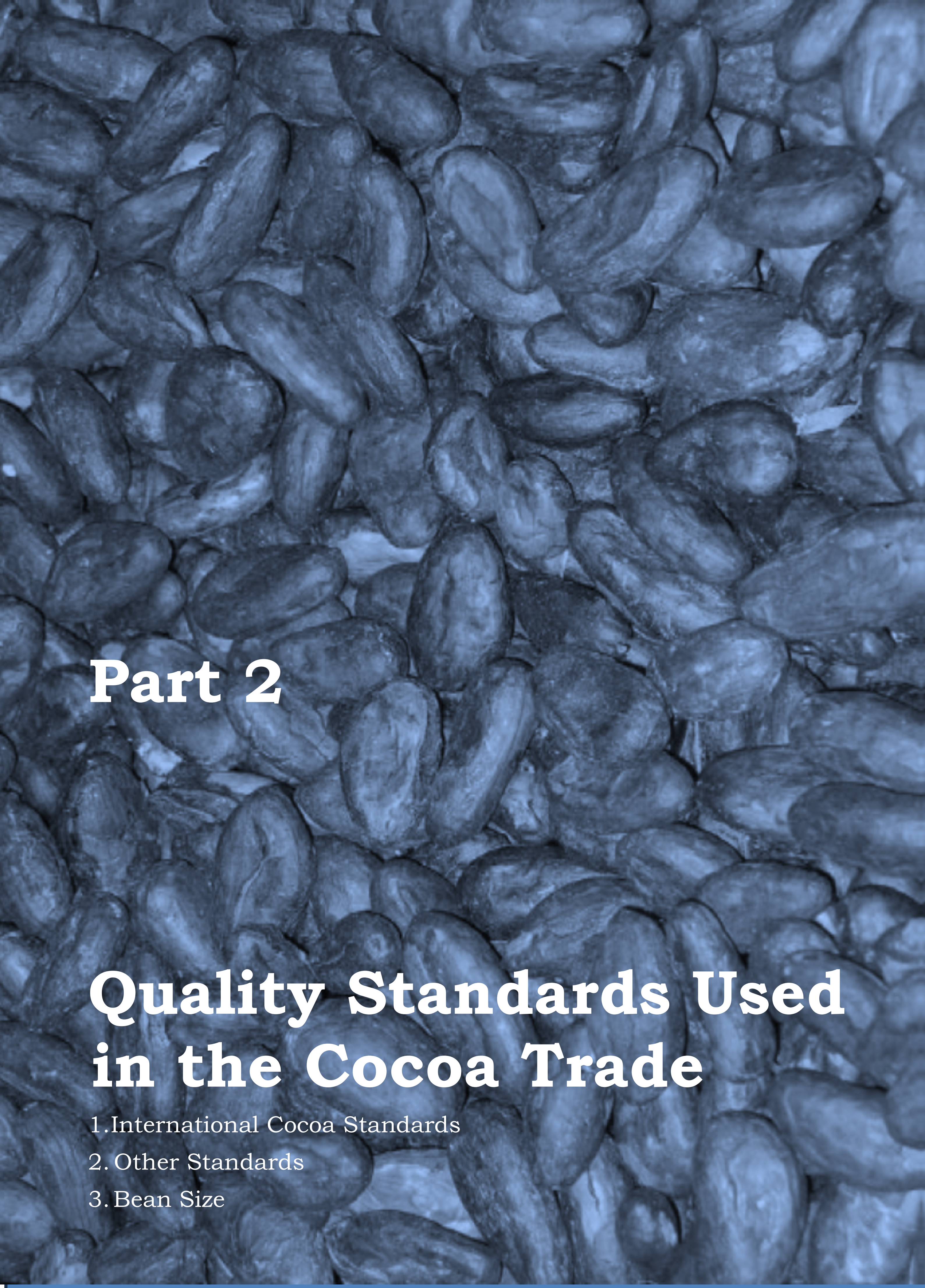
Geographic Indications (GI) can be linked to traceability and quality certification to highlight the unique characteristics of cocoa produced in specific regions where flavour quality and other unique attributes are associated with "terroir" effects (see page 13). GIs have recently been registered for a limited number of cocoa sources including Cacao Arriba (Ecuador), Montserrat Hills Cocoa (Trinidad) and Cacao de Caripito (Venezuela). It's important to note that the recognition and registration of GIs are often subject to national regulations and international agreements and there is still a need for better integration of instrumental and sensory attribute measurement, with rapid, affordable and non-destructive analytical approaches and modern traceability methods to fully realise the niche marketing potential for GI in cocoa (Fanning et al, 2023; Hernandez and Granados, 2021).

6. Summary Of Industry Requirements

For the production of good quality chocolate, manufacturers' seek cocoa beans with the following qualities:

Quality	Reference
Have good, intrinsic flavour attributes	P1: 1. Flavour
Free from off-flavours, particularly:-	
Smoke	P1: 1.2. Smoky off-flavours, P3: Drying
Mould	P1: 1.1. Mouldy off-flavours, P3: 2. Harvesting, P3: 3. Post-harvest
Excessive acidity	P1: 1.4. Acid taste, P3: 2. Harvesting, P3: 3. Post-harvest
Excessive bitterness and astringency	P1: 1.5. Bitterness and astringency, P3: 1. Planting material.
Be grown, harvested, fermented, dried and stored using recommended practices so as to ensure levels of contaminants are as low as reasonably achievable and comply with food safety legislation.	
Allergens	P1: 2.1. Allergens, P3: 5. Transportation & Shipping Practices
Microbiological Hazards	P1: 2.2. Microbiological Hazards, P3: 3. Post-harvest
Dioxins and PCBs	P1: 2.3. Dioxins and PCBs, P3: 3. Post-harvest
Foreign Matter	P1: 1.6. Contamination, P1: 2.4. Foreign Matter, P3: 3. Post-harvest
Heavy Metals	P1: 2.5. Heavy metals, P3: 1. Cadmium uptake mitigation
Infestation	P1: 2.6. Infestation, P3: Storage, P3: 5. Transportation & Shipping Practices
Mineral Oil Hydrocarbons Polycyclic	P1: 2.7. Mineral oil hydrocarbons, P3: 3. Post-harvest
Aromatic Hydrocarbons (PAH)	P1: 2.8. Polycyclic Aromatic Hydrocarbons (PAH), P3: 3. Post-harvest
Mycotoxins including OTA	P1: 2.9. Mycotoxins, including Ochratoxin A (OTA), P3: 2. Harvesting, P3: 3. Post-harvest
Pesticide Residues	P1: 2.10. Pesticide residues, P3: 1. Pre-harvest, P3: 3. Post-harvest

Quality	Reference
Well within the International Grade 1 standard	P1: 3. Physical Characteristics, Appendix A
Beans uniform in size and on average at least 1g in weight	P1: 3. Physical Characteristics, Part II Quality Standards, Appendix A
Be well fermented and thoroughly dried, with a moisture content of approximately 7%, with an absolute maximum of 8%	P1: 1. Moisture content, P3: 3. Post-harvest
Consistent in quality both within parcels and between shipments	P1: 3.1 Consistency
Essentially free from live insects	P1: 2.6 Infestation, P3: 3. Storage
Free from foreign matter	P1: 1.6 Contamination, P1: Foreign Matter, P3: 3. Post-harvest
Free fatty acid content less than 1%	P1: 4. Cocoa Butter Characteristics, P3: 3. Post-harvest
In addition, manufacturers prefer cocoa beans with:	
Fat content of 55-58% (dry nib basis)	P1: 4. Cocoa Butter Characteristics, P3: 1. Pre-harvest
Shell content of 11-12%	P1: 3.2 Yield of Edible Material, P3: 1. Pre-harvest
Hard cocoa butter	P1: 4. Cocoa Butter Characteristics, P3: 1. Pre-harvest



Part 2

Quality Standards Used in the Cocoa Trade

1. International Cocoa Standards
2. Other Standards
3. Bean Size

Quality Standards in the Cocoa Trade

The aspects of quality that have been described cover the subject in its broadest sense and all have a bearing on the price paid for beans from a particular source compared with other sources.

The aspects of quality that have been described cover the subject in its broadest sense and all have a bearing on the price paid for beans from a particular source compared with other sources. In a narrower sense "quality" may refer solely to the first two aspects: flavour and purity or wholesomeness and it is these aspects that are covered, at least in part, by various cocoa standards used by the trade.

These standards must use objective measurements. They cannot measure or ensure good flavour although they can, by means of the cut test (see Appendix A), detect gross flavour defects. The standards can also help to ensure good keeping quality.

There are various standards of which the most important are the International Cocoa Standards and the standards as defined in the physical contracts of the Federation of Cocoa Commerce, Ltd. (FCC) and, in the United States, the Cocoa Merchants Association of America, Inc. (CMAA).

It is worth mentioning that there are quality standards dictated in the cocoa futures contracts, used by market participants to hedge their physical commitments, however a chocolate manufacturer is not likely to source their beans through these markets as they are not designed for that purpose.

2.1 ISO Cocoa Standards

ISO 2451 defines the terms used and the grade standards used to classify cocoa beans. The grade standards are based on the cut test which allows certain gross flavour defects to be identified.

These standards, as issued by the International Standards Office (ISO), form the basis of the cocoa quality assessment regulations of several cocoa producing countries. ISO 2451 "Cocoa beans – Specification", originally issued in 1973, was revised in 2014, and again in 2017 to bring it into line with current commercial practices. It references two other ISO standards which have now been withdrawn:
ISO 1114 Cocoa beans – Cut Test and ISO 2291 Determination of moisture content (routine method)

ISO 2292 Sampling was also revised in 2017 and this revision related to clarification of bean size specifications.
Current versions of the Standards are available for purchase from the ISO website http://www.iso.org/iso/) which also provides further details on the process by which the Standards are developed.

The standard specifies that cocoa beans shall be:

- Fermented, then dried until their moisture content no longer exceeds 7.5% mass fraction.
- Free from any evidence of adulteration.
- Virtually free from living insects and other infestation.
- Free from odour contamination.
- Virtually free from any foreign matter.
- Reasonably free from broken beans, fragments and pieces of shell.
- Within the standard for violet or purple beans, typical of the specified grade or origin.
- Reasonably uniform in size, fit for production of a foodstuff.
- Reasonably free from bean clusters, flat beans, germinated beans, residue and sievings.

The Grade Standards lay down the following maximum limits for producing country internal classification for fermented beans:

	Maximum percentage of beans[1]		
	Mouldy	Slaty	Insect damaged, germinated or flat
Grade I	3%	3%	3%
Grade II	4%	8%	6%

1 The percentages in the last column apply to the combined total of all the defects specified in the column header.

ISO 2451 now also specifies bean size standards, defined by the bean count and usually expressed by the number of beans per 100g (see Appendix A for further details). The specifications are currently:

Large beans:
Bean count of less or equal to 100

Medium beans:
Bean count of 101 to 120

Small beans:
Bean count greater than 120

2.2. Other Standards Used in Contracts

Most of the world's cocoa is traded using the contracts of the FCC or CMAA, which historically have slightly different standards.

Most of the world's cocoa is traded using the contracts of the FCC or CMAA, which historically have slightly different standards. These standards do not imply acceptability for chocolate manufacture, however, merely the levels at which allowances become due under arbitration procedures.

From June 2015, the FCC terms require the cocoa to be of a certain condition; namely "In addition to any specified quality terms, the parcel shall consist of beans which shall be reasonably:

- Uniform in size,
- Uniform in fermentation,
- Dry,
- Homogenous in all other respects and the parcel shall be:
- Fit for the production of a foodstuff,
- Free from adulteration, contamination and rodents,
- Virtually free from live insects (including mites) or other type of infestation,
- Virtually free from germinated beans,
- Within the customary range for violet or purple beans of the specified grade/ origin."

It should be noted that the definition of Foreign Matter, Cocoa Related Matter and Sievings have specific meanings under FCC terms, see Appendix A. Either singularly or collectively; excessive Cocoa Related Matter, Flat Beans, Bean Clusters or Foreign Matter may result in an allowance.

If the term "Main crop" is used to describe the cocoa traded or is used in the quality parameters of the cocoa, then the size of the beans, measured by bean count, must be consistent with that of beans normally produced during the main harvest period of that particular origin. No allowance will be considered for a bean count of 100 beans or fewer per 100 grams. More than 100 beans per 100 grams may result in a quality claim, which if considered to be above 120 beans may result in the parcel having to be replaced rather than subject to an allowance.

Other FCC terms are available to describe the bean size standards:

STANDARD BEANS – means bean count ≤ 100

MEDIUM BEANS – means bean count 101-110

SMALL BEANS – means bean count 111-120

VERY SMALL BEANS – means bean count > 120

FCC contracts lay down two grades - good fermented and fair fermented. The maximum limits for these grades are:-

	Good fermented	Fair fermented
Slaty	5%	10%
Defectives	5%	10%

1 The percentages in the last column apply to the combined total of all the defects specified in the column header.

"Defectives" are defined as internally mouldy beans, or insect infested or insect damaged beans. The CMAA contract calls for cocoa beans to meet the United States Food and Drug Administration Standard, which stipulates a maximum 4% mouldy and 4% infested or damaged beans, but also no more than 6% of the two combined.

Note that cocoa which may comply with Grade 1 under the ISO standards as having 3% insect damaged and 3% mould would exceed the defective limits of the FCC definition of Good Fermented.

Finally, there are standards set down by different terminal or futures markets as a basis for deciding whether a particular parcel is suitable for tendering on the market in question at the contract price, or at a premium or discount. Again, these contract standards are not based on acceptability for chocolate manufacture.

There are also quality standards set by the authorities in cocoa origins which are their practical internal quality standard – against which the quality is assessed throughout the internal marketing chain in the country.

2.3. Bean Size

With new cocoa areas being opened up, there is increasing variation in bean size from a greater diversity of planting materials. It is becoming more important that beans are sold not only on the basis of the agreed quality standards but also on the basis of an agreed bean size and distribution criterion so that manufacturers know what they are buying and the seller's reputation is protected.

A number of origins and markets have their own particular criteria, for example:-

Nigeria defines cocoa as a main crop if 300 beans weigh 11ozs or above (104 beans/100g) and light crop if it does not meet this standard.

The futures markets based in London provides for an allowance if the bean count is greater than 100 beans/100g, with beans in excess of 120 beans/100g not being tenderable.

Part 3
Aspects of Cocoa Production Affecting the Quality Requirements

1. Pre-harvest
2. Harvesting
3. Post-harvest
4. Quality Control
5. Transportation & Shipping Practices

This publication does not set out to prescribe a method or methods of producing cocoa beans of good quality. This would involve going into the details of fermentation and drying suitable for many widely differing local conditions and is beyond the scope of this booklet.

The aim of this section is to highlight the main factors affecting the various aspects of quality. Recommendations follow those made in a number of sources including the Codex Codes of Practice for the Prevention and Reduction of Ochratoxin A Contamination of Cocoa (CAC CXC 72-2013) and Prevention and Reduction of Cadmium Contamination in Cocoa Beans (CAC CXC 81-2022), The CCE Sustainable Cocoa Trainers' Manual Ghana Version 2.1 - June 2016 (Dohmen, Helberg, & Asiedu, 2016), the Guidelines on Best Known Practices in the Cocoa Value Chain (CS-16-2-Rev 1) (ICCO, 2009), Gap recommendations to achieve the characteristics of good quality cocoa (Gilmour, 2009) and the information available from www.cocoasafe.org (CocoaSafe, 2015).

1. Pre-harvest

a) Environmental aspects.

Some physical characteristics of cocoa beans are influenced by the climate during the period of development of the pod. The major climatic factor is rainfall, though factors such as temperature and light conditions are also likely to affect pod and bean characteristics. Pods developing during the dry season will tend to contain smaller beans than pods developing during a wet season. Studies have shown that rainfall during the first 2-3 months of pod development is correlated with mean bean weight. Apart from bean weight, rainfall also influences fat content, the fat percentage being reduced by dry conditions.

The ambient temperature affects the composition of the cocoa butter, and thus its hardness. Evidence from Brazil indicates that the cocoa butter from beans which develop during cooler months contains a higher proportion of unsaturated fatty acids and is therefore softer (Lehrian, Keeney & Butler, 1980). Ambient temperature around the fermentation could also affect the initial progress of fermentation micro-flora activity. The climate in a cocoa growing area will also affect the choice of the methods of drying and may have some effect on storage. These matters are discussed later.

b) Methods of cultivation

i). Planting Material

Effects of planting materials on flavour have already been noted in Part 1: Section 1. Selection of planting material affects also yield, colour, bean size, cocoa butter content and, to some extent, cocoa butter hardness/fatty acid composition (*e.g.* Mustiga et al. 2019). There is fundamental choice between Criollo and Trinitario trees to produce "fine flavour" grades, or "Forastero" or Amazonian types and their hybrids to produce mainstream cocoa. For most growers this choice is not open to them as their planting material will be dictated by what is available locally, though growers are strongly encouraged to obtain recommended varieties (seed or clonal materials) from a reputable source rather than use materials from their own or neighbouring farms. If production of significant quantities of "fine flavour" grades are being considered, it is important that due consideration is given to the potential market for such cocoas. Where "fine flavour" grades are grown in areas where mainstream cocoas are also grown, it is important that the types can be segregated and marketed separately.

Within the "Forastero" populations, particularly within the Amazon hybrids planted widely today, there are appreciable differences in bean weight and it is prudent to avoid planting selections which tend to produce small beans.

There are significant effects of pollen donors on colour and bean size. It is important not to have stands of trees for "fine flavour" and mainstream cocoa production in close proximity, especially if pale colour is a critical characteristic of the "fine flavour" cocoa. Pods resulting from cross pollination will contain a higher proportion of darker beans. The much darker colour of beans from the Amazon type trees is dominant. The maternal parent has the strongest effect on the flavour of the beans (Clapperton, 1994, Sukha et al., 2017) though the pollen donor may have some effect on certain flavour characteristics (Sukha et al., 2017)

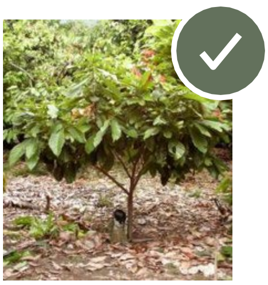
KEY POINTS

- ✓ Plant varieties that are recommended for the local area and which have been confirmed as having the quality and flavour characteristics desired by the intended buyers.

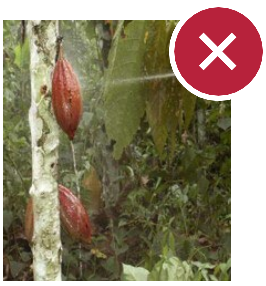
ii). Pest and disease control

Integrated Crop and Pest Management (ICPM) should be implemented in order to achieve sustainable good yields and ensure the cocoa produced complies with regulatory limits for pesticide residues. The key elements of ICPM are the prevention of conditions on the farm that favour pests and diseases, quick identification of the pest or disease and assessment of the level of infestation. Control methods can then be used which are appropriate for the infestation level. Such control methods may include the responsible and effective use of crop protection products in cases where if left untreated, the infestation would cause unacceptable financial losses. Detailed information on Responsible Pesticide Use (RPU) and ICPM practices for cocoa can be found in a number of sources. The recommendations will vary according to the pests endemic to a particular region. However, improved planting materials, coupled with good farm sanitation and the use of agronomic techniques to create ecosystems favouring the cocoa tree and the natural enemies of its pests rather than the pests themselves, will help to ensure that there is a continual reduction in the use of agrochemicals for crop production, and that where pesticides are used they are applied based on sound knowledge of the pest and good practices.

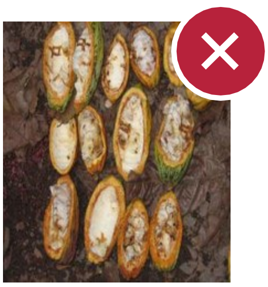
It is essential that only pesticides that are registered and approved for use on cocoa are used and that they are obtained from reputable sources to avoid counterfeit or contaminated products. They must only be used in full accordance with Good Agricultural Practice (GAP) which will include aspects such as dosage/timing of application, appropriate application technology and personal protective equipment. Particular attention should be paid to the Pre-Harvest Interval (PHI) which is the minimum permitted time between the last spray and harvest. The CAOBISCO/ECA/JRF/ICCO "Pesticide Use in Cocoa: Practical Manual 4th Edition" (Bateman and Crozier, 2023) available from https://www.icco.org/icco-documentation/pesticide-use-in-cocoa-practial-manual-fourth-edition// provides detailed information including the selection of appropriate control strategies, Good Agricultural and Storage Practices,
and annexes which list strategic/recorded pesticides for cocoa, compounds which should only be used with great caution (compounds with an uncertain future and a history of issues, such as with (eco)toxicology or frequent exceeding of MRLs) and those that MUST NOT be used on cocoa.



Tree pruned to enable effective monitoring for pest problems and spraying where necessary.



Inappropriate spray technique is wasteful and ineffective due to run off.



CPB infestation makes beans difficult to separate and leads to poor quality.

Fertilisers should be applied according to recommendations and checked for cadmium level, especially where soil levels are known to be high.

Photos: R. Bateman, M. Gilmour.

KEY POINTS: IMPLEMENT INTEGRATED CROP & PEST MANAGEMENT (ICPM)

- ✓ Implement good farm sanitation and agronomic practices which promote healthy growth of the cocoa trees and favour the natural enemies of its pests, rather than the pests themselves.
- ✓ Where pesticides are used as part of ICPM, usage must comply with all national and international regulations.
- ✓ Identify the pest and ensure that the recommended pesticide is used at the right time in the pest lifecycle/crop season. Make sure that the last application of pesticide is before the Pre-Harvest Interval.
- ✓ Ensure appropriate application and personal protective equipment are used and that all equipment is well-maintained.
- ✓ Manage tree architecture and adopt spraying patterns to ensure the crop can be treated evenly and effectively.
- ✓ Dispose of containers correctly.
- ✓ Avoid pesticide cross-contamination (drying table, storage areas, etc.).

iii). Cadmium uptake mitigation

Some cocoa-growing areas, particularly in certain regions of countries in Latin America and the Caribbean, have soils which naturally contain high levels of cadmium (Cd). However, levels in the cocoa beans produced in such areas are not necessarily highly correlated with total soil Cd levels as Cd availability in soil and its uptake by cacao plants depends on a number of factors including soil pH and organic matter (low soil pH and low organic matter increase Cd availability), salinity/chlorinity, availability of other nutrients such as zinc (Zn) and manganese (Mn), the variety of cocoa grown, and post-harvest treatments.

Codex Alimentarius adopted a code of practice for the prevention and reduction of cadmium contamination (CAC CXC 81-2022) which provides details on a various measures, though a nuanced approach is recommended to take account of local soil conditions and varieties grown. However, guidance will continue to be adapted to take account of results from the research currently underway (see for example “Mitigation of Cadmium Bioaccumulation” project on https://jointcocoaresearchfund.eu/ and the Clima-LoCa project https://climaloca.org. The following suggestions and recommendations for further research are made based on current knowledge of Cd uptake in cocoa and experience from other crops (See the Further Reading: Cadmium section for further information)

- Carry out a physical-chemical analysis of the soil to include assessment of levels of Cd and micro-nutrients, organic matter content, CEC, pH and chlorinity
- Analyse levels of Cd and micronutrients in leaves and cacao beans, when available
- Avoid flooded soils if the water sources are contaminated with Cd, and ensure water used for irrigation is not contaminated
- Where soils are low in Zn, application of foliar or soil micronutrients may be beneficial
- In some situations where soil conditions are acidic (pH < 5.5), increase soil pH, for example by liming, to reduce the availability of Cd (but take care to ensure that the availability of essential micronutrients such as Zn does not become a problem);
- Addition of biochar and other sources of organic carbon such as compost may reduce the availability of Cd though the effectiveness will depend on the type of

amendment and application method used

- Only use phosphate fertilizers and/or manure which has been checked to ensure it meets national norms for Cd content. In Europe, only products with less than 20 mg kg^{-1} P_2O_5 can be labelled as “low cadmium content” (EU Reg 2019/1009).
- In areas where foliar levels of Cd are high, removing pruned material and decaying pod husks from the ground may reduce recycling of Cd back into plant biomass. However, it should be noted that this will also reduce the recycling of nutrients and have a negative impact on soil organic matter content unless another nutrient-rich organic amendment is added, which has been tested to ensure it has low Cd. Moreover, it may be difficult to ensure the safe disposal of the pruned material/husks elsewhere. In most cases this is unlikely to be an effective strategy.
- Avoid post-harvest contamination, particularly by protecting drying/stored beans from dust and traffic fumes.

Key research areas include:

- ➢ Development of post-harvest procedures to reduce Cd in cocoa nibs. Fine-tuning of fermentation conditions, possibly including pulp drainage and addition of cultures to enhance populations of certain microbes, show promise in reducing Cd in beans whilst maintaining flavour quality attributes.
- ➢ Development of cocoa varieties, and/or root stocks, with low accumulation levels.
- ➢ Development of improved application methods for soil amendments to ensure they are efficient, practical and economical for farmers to implement.

KEY POINTS: MITIGATING CADMIUM

- ✓ Carry out physical-chemical analysis of soils and leaves/beans (if available) to ensure mitigation approach is appropriate to local conditions.
- ✓ Check local water sources (flood water/irrigation) for Cd contamination.
- ✓ Ensure levels of available micronutrients are adequate.
- ✓ Reduce availability of Cd in acid soils through liming.
- ✓ Biochar and other organic soil amendments may reduce availability of Cd.
- ✓ Check Cd levels of any soil amendments (including organic and inorganic fertilisers).

2. Harvesting

Fully mature and undamaged pods should be harvested as soon as they ripen. Care should be taken to minimise damage to the tree and flower cushions, and to prevent the introduction and spread of disease, by using clean, well-maintained tools. It is important that only beans from just-ripe, healthy pods are used in the fermentation since the beans from immature, overripe or damaged/diseased pods will be of lower quality and may give rise to food safety issues. Immature pods (often fully or partly green, but sometimes purple or red depending on the variety) contain beans which are generally smaller and contain less cocoa butter than pods which are fully ripe (often yellow, or orange-red depending on the variety). Moreover, since there is little or no liquid pulp (mucilage) in unripe pods, the beans are often hard to remove and do not separate easily from each other and the placenta. Since the pulp contains lower levels of sugars, the beans do not ferment well, leading to poor flavour. Moreover, if beans remain stuck together in clusters, they dry more slowly and this can give rise to problems with mould development, and therefore potentially Free Fatty Acids (FFA) and Ochratoxin A (OTA) formation.

Conversely, if harvesting is done too late, the pods become over-ripe and the beans may germinate within the pod. The beans may stick together leading to the problems of poor drying and mould development, as mentioned above, and there is also the risk that damage to the seed coat (shell) during germination,
or the subsequent loss of the radical during drying or storage, may allow the entry of moulds, insects and contaminants into the beans.

Damaged pods are more likely to be infected with microorganisms, regardless of whether the wound is caused by disease, insect pests or rodents whilst on the tree or inflicted by tools during harvesting and transporting the pods. It is therefore important that any wounded or damaged pods are not stored for longer than one day before opening and fermenting since they may already be infected with microorganisms which could lead to flavour deterioration, FFA and OTA formation during post-harvest processing.

The interval between harvesting and opening the pods has been found to influence fermentation. An interval of 3-4 days will result in a more rapid rise in temperature during fermentation. Such an interval should be adopted for undamaged pods wherever practical. Storage for more than 7 days is not recommended due to the risk of proliferation of ochratoxigenic fungi. Whereas different cocoa genotypes all show the more rapid rise in fermentation temperature following pod storage, the extent of the flavour improvement differs markedly between genotypes. These flavour differences relate to differences in the composition and biochemistry of the cotyledons rather than to changes in pulp composition that result from post harvest storage. Post harvest storage of unbroken pods is also impractical on large estate scale production because of the amount of extra handling involved, and in parts of Southeast Asia where the Cocoa Pod Borer (CPB) is prevalent.

Those involved in manually removing beans from pods should maintain an appropriate degree of personnel hygiene. It is preferable to open pods by striking them with a wooden mallet or baton, or a mechanical device designed to minimize damage to the beans. The use of a machete can result in damage to the shell of some of the beans thereby allowing mould and insects to enter and increase the proportion of broken beans, as well as increasing the risk of injury to the farmer/operator.

During the opening process any defective parts of the cocoa pod, mouldy beans, diseased beans, and damaged beans should be removed and appropriately disposed of. Good quality beans should be placed in a suitable container during transport.

Transport of fresh/wet beans from pod opening sites to on-farm fermentation facilities should be done under conditions that will prevent contamination *e.g.* spilled beans must be free of soil before being fermented.

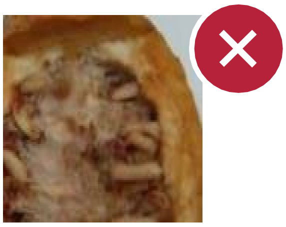
For some varieties a pre-drying or de-pulping stage is advocated before fermentation starts to reduce acidity and/or improve the expression of desirable flavour notes.


Ripe pod: seeds are fully developed, but not germinated, and easily separated.


Immature pod: seeds are not fully developed and are difficult to separate.


Open pods with a wooden baton to minimise damage to beans.


Beans have been damaged by opening pod with a machete.


Over-ripe pod: seeds are germinating and pulp is dry.


Diseased pod.

Photos: D. Sukha.


Diseased pods should be discarded and damaged pods must not be stored.


Fermentation should not include black, diseased or clumped beans.

Photos: D. Sukha, M. Gilmour.

KEY POINTS: POD HARVESTING, OPENING & STORAGE

- ✓ Keep tools and equipment clean and well-maintained.
- ✓ Harvest pods as soon as they ripen: generally, harvest every week during peak periods and every two weeks in non-peak periods.
- ✓ Carry out a separate weekly sanitation check and remove diseased, insect damaged and mummified pods using tools that are only used for this purpose.
- ✓ Avoid damaging the flower cushions and other parts of the tree when cutting the pods.
- ✓ Avoid unnecessary cutting or wounding of the pods: do not use a machete to pick up pods from the ground.
- ✓ Do not store wounded or damaged pods for longer than one day before they are opened and fermented.
- ✓ Undamaged pods should normally be opened within a week of harvest.
- ✓ Keep tools and equipment for opening pods clean and well-maintained.
- ✓ Break open the pods without causing any damage to the beans.
- ✓ Discard any beans which are mouldy, diseased, discoloured, damaged or germinated.
- ✓ Keep good quality beans free from contamination as they are moved to the fermentation area.

3. Post-harvest

a). Fermentation

Fermentation is normally carried out in heaps or boxes and is a crucial stage in the development of the cocoa flavour precursors. Moreover, fermentation is recommended to avoid ochratoxigenic fungal growth and OTA production because acetic, lactic and citric acid produced by bacteria during fermentation can inhibit these undesirable fungal species. Research has shown that OTA production can increase if wet beans, or partially depulped beans, are allowed to ferment during drying on a drying mat.

The fermentation process can be influenced by factors such as the variety of cocoa, addition of starter cultures of micro-organisms, altering the pulp:bean ratio, aeration and frequency of turning though in most cases good quality beans can be obtained by simply allowing the fermentation to proceed for between three to five days with a single turn after 24 and 36 hours to ensure uniformity. Lack of fermentation or under-fermentation will give rise to slaty and purple beans with consequent increases in bitterness and astringency. Although fermentation over 5 to 6 days is quite common in West Africa, extending fermentation beyond 120 hours in some situations brings a danger of over-fermentation with loss of cocoa flavour and development of off- flavours from putrefaction. Traditionally, some “fine flavour” cocoas require shorter periods of fermentation. Although modern cocoa estates may carefully control the fermentation conditions, in smallholder production systems it is more of an art than a science. Farmers often assess the progress of fermentation by cutting a few beans at intervals to observe the colour changes and judge the end-point on the smell and the external appearance of the beans, together with well defined internal ridging on cut beans, which through experience will indicate that they are ready to be dried.

Fermentation heaps or boxes should include wet beans from sound pods that are sufficiently ripe to allow the individual beans to be separated easily by hand from the placenta and husk. Damaged and diseased beans, pieces of husk and placenta should be separated and discarded.

Any baskets, trays or platforms used for the fermentation, and any tools such as paddles and shovels, should be maintained reasonably clean and dry between fermentations. Care should be taken to prevent cocoa beans from coming into contact with water during fermentation. A covered and/or sheltered space should be chosen to provide adequate protection against rain, wind and direct sunlight.

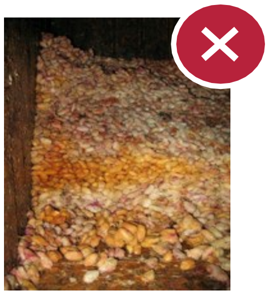
The fermentation process generates a considerable heat and temperatures close to 50˚C can be reached within the mass of beans during fermentation. The fermentation of very small quantities of beans will allow the heat to dissipate and the fermentation will be unsatisfactory. The minimum quantity of wet beans for a normal fermentation is considered to be about 100kg, although, as described in Appendix B, there are methods for fermenting smaller quantities of cocoa which are suitable for experimental purposes. Heaps of between 250 and 500kg are typical in West Africa, while in Southeast Asia and Brazil where box fermentation is practised, bed depths of between 40 and 100cm are normal with quantities being between 500 and 2,000kg of wet beans.

Ferments very much larger than 2,000kg are difficult to manage in order to achieve uniform and effective fermentation. For practical reasons, therefore, about 2,000kg wet beans is considered to be the upper limit for a single fermentation.

Fermentation heap typical of West Africa.

Fermentation should not include black, diseased or clumped beans.

Box fermentation.



Do not add beans to a fermentation already in progress.

Photos: E. Cros, D. Sukha, M. Gilmour.

KEY POINTS: FERMENTATION

- ✓ Ensure fermentation method is appropriate to the variety, climate, quantity of beans and locally available technology.
- ✓ Discard any pieces of husk, placenta, black beans, germinated beans.
- ✓ Ensure basket, platforms and any equipment is kept reasonably clean between fermentations.
- ✓ Site fermentation in a space with adequate protection from rain, wind and direct sunlight.

b). Drying

The drying process must be carried out carefully to ensure the beans are adequately prepared for storage and transport without becoming contaminated by moulds, *Salmonella* bacteria, PAH and other contaminants. Drying should be started immediately after the fermentation period to stop the beans from over-fermenting with consequent loss of cocoa flavour. Although drying under direct, natural sunlight is preferable, it may be necessary to use artificial drying to complement or replace sun-drying depending on climatic conditions. Amoa-Awua has reviewed the different drying techniques, including solar and artificial dryers (Amoah-Awua, 2014). Drying by whatever means must be thorough, with the moisture content being reduced below 8% over an appropriate time period. This period will vary according to local conditions and/or whether artificial drying is used, but for sun-drying it should ideally be 6-10 days. Prolonged drying periods and re-wetting should be avoided since moisture contents over 8% can lead to secondary mould development, and thus mouldy/ musty off-flavours and the possibility of OTA production, inside the beans during subsequent storage and transport.

Care should be taken to control the rate at which drying occurs when using artificial dryers since when beans are dried quickly at elevated temperatures the rate of water loss from the shells is faster than the rate of migration of acids from the beans to the shells. Consequently, water is evaporated and lost in preference to the acids which are concentrated in the cotyledons or nibs where they not only give rise to an excessively acidic taste but also, they inhibit the cocoa flavour forming reactions during subsequent drying and roasting. Moreover, excessive drying will result in cocoa beans that are brittle and break easily, causing a high proportion of waste and fostering lipolysis and FFA development.
In order to dry the beans effectively, with minimum exposure to contaminants, the following recommendations are made:

Drying surfaces/equipment should be located away from sources of contaminants and drying platforms should be elevated (ie the cocoa beans should not be spread out in direct contact with bare ground, tarmac or concrete floors) and protected from rodents, birds and livestock which can be a source of biological contamination.

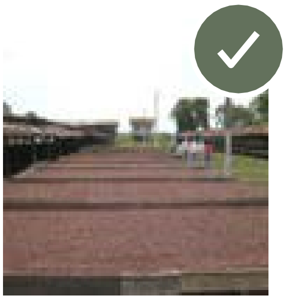
Platforms for sun-drying should be sited so that they receive maximum sun exposure and air circulation during most times of the day, to speed up the drying process.

The layer of drying cocoa beans should not exceed 6cm thick, (40 kg of wet cocoa beans per square meter of drying area) to avoid slow or inadequate drying and the beans should be turned several times each day (about every two hours during daylight period with a resting or tempering period at night) to ensure uniformly dried beans. This also provides an opportunity for defective beans to be removed.

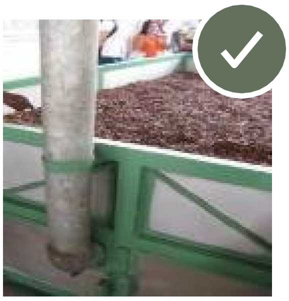
The beans should be protected from rain or dew, by heaping and covering the beans at night and when rain threatens, and re-spreading once the drying surface has dried. There should be no mixing of cocoa beans at different drying stages and specific identification methods should be used in order to distinguish and identify each drying stage.

Where artificial drying is necessary, it is essential that wood fires and other forms of direct fuel burners are not used since these will result in smoky off-flavours and PAH contamination. Fuel-burning dryers must incorporate heat exchangers and be designed, operated and maintained so that combustion gas and smoke does not come into contact with the beans during drying or while the dried beans are being stored to prevent off-flavours and contamination by PAH and other mineral oil hydrocarbons.

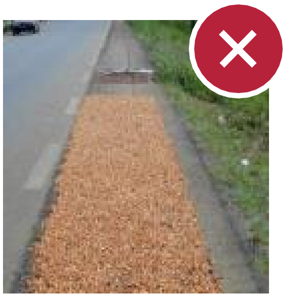
Smoke contamination and related PAH contamination are very obvious when beans are dried by wood fuelled kiln dryers. When direct fuel burners are used it may be less obvious that contamination has occurred, since there may not be the distinctive smoky aroma, but the beans may well be contaminated with PAH.



Sun drying on raised platforms.



Indirect fired artificial dryer.



Drying by roadside on tarmac.

Livestock feeding in and around cocoa drying on the ground.

Exposure to smoke during drying

No chimney and beans coming into contact with smoke

Photos: D. Sukha, M. Kokken.

KEY POINTS: DRYING

- ✓ Sun-dry where possible, but complement or replace with well designed and maintained artificial dryers where necessary.
- ✓ Dry cocoa beans off the ground so that they are not in direct contact with soil, tarmac or concrete and are inaccessible to animals.
- ✓ Ensure beans cannot be contaminated by smoke, fumes from dryers or vehicles.
- ✓ Protect beans from rain and dew (including covering at night).
- ✓ Turn the beans frequently but do not mix beans at different stages of drying.
- ✓ Dry for minimum of 6 days in the sun (<8% moisture).
- ✓ Control rate and length of drying period carefully when using artificial dryers to avoid high acidity levels and/or over-drying.

c) Storage

Before the cocoa beans are stored they should be sorted to remove any defective beans including those that are flat, shrivelled, black, mouldy, germinated, insect damaged, small and/or fused together. The cocoa beans should then be properly identified by lots, either at the farm level or in out-of-farm warehouses. Any bags used to store the cocoa should be labelled to indicate that they are suitable for food contact use, new, unused, clean and sufficiently strong and properly sewn or sealed to withstand transport and storage and discourage pest infestation. Moreover, in regions where cocoa production overlaps with allergenic crops (*e.g.* peanuts or sesame), new or cocoa dedicated bags must be used to avoid cross-contamination. Maintaining the correct storage conditions for cocoa beans in the tropics can be challenging, mainly because of high temperature and relative humidity, and therefore storage periods should not exceed three months unless special precautions are taken. The hazards to quality arising from storage in the tropics are re-humidification and subsequent secondary mould development, both internally and on the shell, fat degradation, infestation and possible contamination from other stored products.

i) Mould development

Dried cocoa beans can absorb moisture if the humidity is high. At 8% moisture content, cocoa beans are in equilibrium with the ambient relative humidity (about 70%) and normal temperatures in the tropics. Where the relative humidity exceeds this level for prolonged periods there is danger of re-humidification with secondary external and internal mould development.

ii) Fat degradation

Prolonged storage under humid conditions can also lead to a rise in FFA concentration. The normal FFA in the cocoa butter from beans which have been prepared correctly and exported without undue delay will be less than 1%. This compares with an EU limit for FFA in cocoa butter of 1.75%.

iii) Infestation

Wherever cocoa is stored in the tropics it is liable to become infested with various types of moths, beetles and mites. Some of these pests have a life cycle of only a few weeks in the tropics and can rapidly increase in numbers. Pest monitoring and reporting by the workforce and the timely use of approved insecticides is an important part of an in- store integrated crop and pest management strategy. Cleanliness and good stock control are essential, but in some cases this will need to be supplemented by the careful use of approved insecticides and in the last resort by approved methods of fumigation. In the latter case, appropriate documentation accompanying the cargo should state in clear and correct terms the fumigants and the quantities that were used.

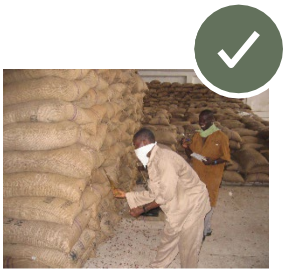
The construction and operation of a cocoa store helps to minimise the hazards that have been described. Such stores should be well-maintained to ensure they are kept clean, properly ventilated and weatherproof. They should have a concrete floor and walls of brick or concrete blocks. A wooden floor or walls should not be used because the spaces between the joints offer places where pests can breed. The doors and windows should provide adequate light and ventilation but exclude pests (birds, rodents, etc.). However, the cocoa should not be stored in direct sunlight nor near heating sources to avoid the possibility of temperature differentials, condensation and water migration.

Sacks should be stored on pallets off the floor. Wooden pallets should have a layer of protective polythene or plastic between the surfaces of the pallet and the first layer of sacks if the pallets have been treated with wood preservative containing phenols.

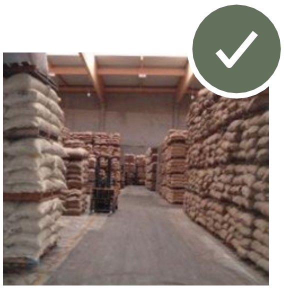
Extra care is required if such sheeting is used as condensation may occur on the plastic thereby damaging the cocoa. The stacks should not exceed 30 tons and should be separated from the walls to allow free access for inspection and sampling.

The use of battery powered or liquified petroleum gas (LPG) fueled forklift trucks rather than diesel oil in stores will reduce the risk of contamination from spillages of fuel and from fumes.

If and when fumigation is performed it should be carried out under expert supervision according to national requirements using well maintained gas proof sheeting of appropriately low permeability. Sufficient fumigant must be added and maintained for a sufficiently long period of exposure (at least 5 days for phosphine) commensurate to eradicate the particular pest species targeted. This is not only to ensure that the infestation is eradicated completely but also to minimise the amount of fumigant used and reduce the risk that the insect species develops resistance to the fumigant.



Quality testing in a warehouse at origin.



Warehouse in Europe.

Pheromone trap to monitor pest population.

Secondary mould due to excess moisture during shipping/storage.

Photos: M. Gilmour, D. Sukha.

KEY POINTS: STORAGE

- ✓ Sort and remove any defective beans.
- ✓ Identify bean lots and manage stocks carefully.
- ✓ Use new, clean bags suitable for food contact use and do not use bags which have been used for other foods such as peanuts or sesame.
- ✓ Seal bags carefully to prevent infestation.
- ✓ Stores should be clean, weatherproof and well ventilated.
- ✓ Store sacks off the ground but protected from contact with wooden pallets that have been treated with wood preservatives.
- ✓ Ensure stacks are clear of walls to allow access for inspection.
- ✓ Ensure stores are not contaminated by fuel spills, exhaust fumes or smoke.
- ✓ Monitor pest levels and if necessary, treat with approved pesticides, or fumigate as a last resort, following GAP.

4. Quality Control

The quality of the cocoa beans in the bags must be checked before the cocoa is sold. This process is a crucial one as it can considerably affect the final price paid to the farmer. At this stage, the cocoa beans must fulfil certain criteria agreed in the contract, including the following: the cocoa must be properly fermented and dried; the cocoa must be free from any foreign odours; the beans must comply with limits in contents of slaty, flat, clusters, broken, mouldy, insect-damage, foreign matter and germinated beans; the cocoa must conform to the required moisture level; and there have to be a number of cocoa beans per unit weight (100 or 1000 grammes) (See Appendix A).

In many cocoa growing countries, quality control is currently performed by the officials of cooperatives and local buyers, rather than by the farmers themselves. However, farmers who are enabled to take on more responsibility for quality control and actively involved in marketing their cocoa are key to modern sustainable production. Farmers who are aware of quality standards and well-informed on GAP will be better able to take appropriate action to address any quality deficiencies in their cocoa, or indeed any measures needed to meet the more stringent requirements for premium products, in order to command better marketing opportunities.

KEY POINTS: QUALITY CONTROL

Check that the cocoa fulfils the criteria agreed in the contract. The cocoa must:

- ✓ Be properly fermented and dried;
- ✓ Be free from any foreign odours;
- ✓ Comply with limits in contents of slaty, flat, clusters, broken, mouldy, insect-damage, foreign matter and germinated beans;
- ✓ Conform to the required moisture level; and
- ✓ Comply with bean count requirements.

5. Transportation & Shipping Practices

Whenever cocoa is transported, it is important to ensure that the beans do not become wet and are not contaminated by other materials. Precautions that can be taken include:

- Covering cocoa bean loading and unloading areas to protect against rain;
- Ensuring that vehicles are cleaned from residues of previous cargos before they are loaded with cocoa (especially with regards to allergenic crops);
- Checking that vehicles are well-maintained and the floor, sidewalls and ceilings (in closed vehicles) do not have points where exhaust fumes or rainwater could be channelled into the cocoa cargo. Tarpaulins and plastic canvas used to cover the cargo should also be regularly checked to ensure that they are clean and without holes; and
- Reliable transport service-providers, which adopt the recommended good transportation practices, should be selected by operators.

a). Cargo Ship Loading & Transport

Cocoa beans are transported from producing to consuming countries in bags or in bulk, usually in 12.5 to 25 tonnes capacity containers. To avoid mould growth and therefore possible OTA formation, it is essential that precautions are taken to minimise the risk that moisture levels exceed 8% at any point from where the cocoa beans leave the loading area to the point at which the cocoa is unloaded, stored and/or subjected to other processing procedures such as roasting. Temperature fluctuations during shipping can cause condensation to form even within consignments of well-dried cocoa and so precautions are needed to prevent re-wetting and mould growth. The recommended practices during transportation in the port are:

1. Cover cocoa loading and unloading areas to protect against rain;

2. Check cocoa lots to ensure that they are uniformly dried and below 8% moisture content, free of foreign matter and conforming to the established defect levels;

3. Check containers before loading to ensure they are clean and free from residue of previous cargo. They should be well- ventilated, dry and without structural damage that could allow water to enter into the container. They should not have been used previously to carry chemicals or other materials giving off strong odours;

4. Bags should be well stacked and crossed over for mutual support in order to avoid the formation of empty vertical columns (chimneys). The top layer and sides of the container should be covered with materials that can absorb condensed water, *e.g.* cardboard, for protection against the growth of fungi that could result in OTA production. Additionally, a sufficient number of water-absorbing bags should be placed along the walls of the container. For cocoa in bulk, a sealable plastic liner (*e.g.* big bag which allows aeration) is desirable and this should be kept away from the roof of the container;

5. If possible, choose an appropriate place to site the cocoa aboard the ship so that the risk of temperature fluctuation and contamination is minimised (*e.g.* avoid unprotected stowage on the deck (top layer) and stow away from boilers and heated tanks or bulkheads). Ideally cocoa beans should be stored, segregated from other cargoes in one location of the cargo vessel. High-fire-risk materials, hazardous or poisonous chemicals, should never be stored with cocoa beans; and

6. Keep the ventilation holes in the containers free from clogging.

To avoid mould growth and therefore possible OTA formation, it is essential that precautions are taken to minimise the risk that moisture levels exceed 8% at any point.

KEY POINTS: SHIPPING & TRANSPORT

- ✓ Protect cocoa from becoming wet and contamination from other materials:
- ✓ Cover loading/unloading areas to protect from rain.
- ✓ Ensure vehicles are well maintained and thoroughly cleaned.
- ✓ Ensure tarpaulins/covers are clean and free from damage.
- ✓ Ensure containers have not been used for chemicals or noxious substances, are well-maintained and clean.
- ✓ Ensure humidity levels are as low as possible by using ventilated containers if available and cardboard/kraft paper lining, with silica gel bags.
- ✓ For bagged cocoa: load bags carefully and cover with materials to absorb condensation.
- ✓ For cocoa in bulk: use a sealable plastic liner if possible and ensure it is kept clear of the roof of the container.
- ✓ Ensure ventilation holes in containers are free from clogging.
- ✓ Try to ensure cocoa is not exposed to temperature fluctuations or stored near to noxious materials.

Appendix A

FCC Definitions &

Specification of Quality Requirements & Standards as Used in Trade Contracts

FCC Definitions

Various standards have been developed to ensure that cocoa consignments can be assessed and classified using an agreed terminology and set of methods. Progress continues to be made in clarifying and harmonising these standards. The Federation of Cocoa Commerce (FCC) has updated its Quality Rules in order to take account of changes in the 2014 revision of ISO 2451, harmonise with the standards used by Conseil Café-Cacao and clarify some of the terminology used. The information on definitions and methods presented below has been extracted from the FCC Quality Rules (Applicable to contracts concluded on or after 01 June 2015)[3].

Adulteration
Means alteration of the composition of a parcel of cocoa beans by any means whatsoever.

Bean Cluster
Means two or more beans joined together which cannot easily be separated by using the finger and thumb of both hands.

Bean Count
Means the total number of whole beans per 100g derived from a test sample (a method is provided - see below for further information).

Bean Size Standards:
a) standard beans - means bean count ≤ 100
b) medium beans - means bean count 101-110
c) small beans - means bean count 111-120
d) very small beans - means bean count >120

Broken Bean
Means a cocoa bean of which a fragment is missing, the remaining part being more than half of a whole bean.

Cocoa Bean
Means a raw cocoa bean, which is the whole seed of the cocoa tree (*Theobroma cacao* L.)

Cocoa Related Matter
Means bean clusters, broken beans and associated fragments and pieces of shell which do not pass through the sieve.

Contamination
Means the presence of a smoky, hammy or other smell not typical to cocoa, or a substance not natural to cocoa which is revealed during the Cut Test or physical inspection of an Arbitration Sample.

Cut Test
Means the procedure by which the cotyledons of cocoa beans are exposed for the purpose of determining the incidence of defective and/or slaty cocoa beans, and/or violet or purple beans and/or the presence of contamination within an Arbitration Sample [a method is provided - see below for further information].

Defective Bean
Means an internally mouldy or insect-damaged bean.

Fair Average Quality
Means the quality specification for that season applicable to the cocoa origin referred to in the contract when the terms Good Fermented and Fair Fermented are not customarily applicable to that origin.

Fair Fermented
Means cocoa beans that are not more than 10% slaty and 10% defective by count.

Flat Bean
Means a cocoa bean which is too thin to be cut to give a complete surface of the cotyledons.

Foreign Matter
Means any substance other than Cocoa Beans, Cocoa Related Matter, Flat Beans and Sievings (Husk and placenta are to be considered as Foreign Matter).

Fragment
Means a piece of cocoa bean equal to or less than half a bean.

Germinated Bean
Means a cocoa bean, the seed germ of which has pierced the shell as evidenced either by the physical presence of the seed germ or by a hole in the shell following its detachment.

Good Fermented
Means cocoa beans that are not more than 5% slaty and 5% defective by count.

Insect Damaged/Infested Bean
Means a cocoa bean the internal parts of which are found to contain insects or mites at any stage of development, or to show signs of damage caused thereby, which are visible to the naked eye.

Main Crop
Means a cocoa parcel with a bean count consistent with that of beans normally produced during the main harvest period of that particular origin.

Mouldy Bean
Means a cocoa bean on the internal parts of which mould is visible to the naked eye.
(Mould is not to be confused with WHITE SPOT which is a concentration of theobromine or cocoa fat).

Sieve
Means a screen with round holes the diameter of which shall be 5.0mm min./max.

Sievings
Means the matter which passes through the Sieve.

Slaty Bean
Means a cocoa bean which shows a slaty colour on at least half of the surface of the cotyledons exposed by the Cut Test irrespective of texture.

Violet or Purple Bean
Means a cocoa bean which shows a violet or purple colour on at least half of the surface of the cotyledons exposed by the cut test.

Specification of Quality Requirements & Standards

Bean Count Allowances
For Main Crop, the following shall apply:

1. If the bean count is 100 or less, then the parcel shall not be subject to an allowance;
2. If the bean count is between 101 and 120 inclusive, the parcel shall be subject to an allowance;
3. If the bean count exceeds 120, then the parcel shall be replaceable or subject to an allowance.

Cocoa Related Matter
If the combined weight of the Cocoa Related Matter exceeds 3.5% of the weight of the whole arbitration sample the arbitrators may award an allowance.

Flat Beans
If the weight of the Flat Beans exceeds 1.5% of the weight of the whole arbitration sample the arbitrators may award an allowance.

3.5 Foreign Matter
If the weight of the Foreign Matter exceeds 0.75% of the weight of the whole arbitration sample the arbitrators may award an allowance.

Sievings Standards
If the weight of the Sievings exceeds 1.5% of the weight of the whole arbitration sample the arbitrators may award an allowance.

[3]Included with kind permission from FCC, see http://www.cocoafederation.com/ or contact fcc@cocoafederation.com for further information.

QUALITY ASSESSMENT

The quality of the parcel will be assessed in accordance with the following procedure:

1. A sample shall be drawn in accordance with the FCC Sampling Rules.
2. The Assessment of Sievings shall be conducted according to the methodology set out in Rule 5.
3. The Assessment of Cocoa Related Matter, Flat Beans and Foreign Matter shall be conducted according to the methodology set out in Rule 6.
4. The Assessment of Bean Count shall be conducted according to the methodology set out in Rule 7.
5. The Assessment of Defective and/or Slaty Beans and/or Violet or Purple Beans shall be conducted by a Cut Test according to the methodology set out in Rule 8.
6. The Assessment of Contamination shall be conducted during the Cut Test or physical inspection of the Arbitration Sample according to the methodology set out in Rule 8.

Quality tests for the Optional Quality Clauses must be conducted in accordance with the relevant methodology set out in Part 4 of these Quality Rules.

The Cut Test

The cut-test is the most common form of quality test used for cocoa beans. It is based on a visual observation of the cut surfaces of a sample of beans and an assessment of the numbers of defective beans. It is quick and easy to carry out, requiring little equipment or training, and can be used to infer some quality characteristics. It is important to note that these inferred quality characteristics can only provide an indication of the quality of the sample, with further checks needed to measure the characteristics more directly. Dand (Dand, 2010) provides further details of the procedure, the definition of the faults and the variations between the methods stated by the ISO 2451-2017 and that used by the FDA (FDA, 1968).

In summary the cut test method given in ISO 2451:2017 states that a sample should be taken, following the ISO standard 2292-2017 for sampling and 300 beans shall be opened or cut lengthwise through the middle, so as to expose the maximum cut surface of cotyledons. Both halves of each bean shall be visually examined in full daylight or equivalent artificial light. Each defective type of bean shall be counted separately, and the result for each kind of defect shall be expressed as a percentage of the 300 beans examined. ISO defines nine categories of bean defects, including those which may infer poor fermentation (slaty and violet/purple beans) or be indicators of high FFA levels, poor flavour and/or other contaminants (bean clusters, broken beans, smoky beans, mouldy beans, germinated beans, flat beans, insect-damaged/infested beans). However, only five of these are used in the grade standards (ISO 2451:2017 for cocoa bean specification), namely mouldy, slaty, insect-damaged, germinated and flat (with these last three grouped together).
The FDA method involves the examination of samples of 100 beans which have been broken to expose their internal surfaces. Only three categories of fault are recognised; mouldy, infested, or both infested and mouldy

The FCC has developed definitions for defective beans (insect and/or mouldy), slaty beans and germinated beans though the latter category is not used in standard contracts. Both ICE Futures Europe and CME Europe futures contracts adopt the same categories for mould and/or insect damage and slaty beans identified by the cut-test.

Bean Count

Another commonly used quality test is the bean count which determines the average number of whole cocoa beans that weigh 100 g. The recently revised ISO 2451 cocoa bean – specification standard (ISO, 2014) ie provides methods to assess the bean count of a test sub-sample of at least 600 g that has been prepared according ISO 2292 cocoa bean – sampling (ISO, 1973) and sieved through a screen with 5 mm diameter round holes. Any residue, foreign matter, flat beans and bean clusters are then removed and weighed, and an equivalent mass of whole beans taken from the whole sample is added. Here “residue” refers to any cocoa element other than whole cocoa beans, flat beans, and clusters which does not pass through the sieve (broken beans, fragments and pieces of shell) with the exception of husk or placenta which is considered as “foreign matter”. The total number of beans is then counted and the result expressed using the formula:

$$\text{Bean Count} = \frac{\text{Number of whole beans x 100}}{\text{Mass of whole beans (g)}}$$

Appendix B

Protocols for the preparation and flavour evaluation of samples and small-scale fermentation techniques.

Contributed by D. Sukha and E. Seguine

With Glossary of Terms for Flavour Evaluations from the Guide for the Assessment of Cacao Quality and Flavour (Cacao of Excellence, 2023)

Introduction

Chocolate manufacturers and users of other cocoa products will each have their own criteria to assess flavour quality and there are ISO standards for some aspects of quality assessment (ISO 2451:2017 and ISO 2292:2017). Procedures for detecting specific off-flavours in cocoa mass, such as smoke, mould and excessive acidity have been published by IOCCC (now ICA) (IOCCC, 1996). However, at that time, there was little agreement within the industry on how flavour notes (other than off-flavours) could be assessed due to the different terminologies and interpretations in use. Moreover, many of these flavour notes would be lost if the high temperature roasting conditions advocated in the IOCCC method were used to prepare the samples.

There has been a growing awareness of intrinsic flavour attributes as well as the need to confirm the absence of flavour defects in cocoa samples. To this end, there have been a number of international initiatives to identify interesting flavours and gain an understanding of the influences of genetic, environmental and post-harvest processing on core and complementary flavour attributes. The recently published "Guide for the Assessment of Cacao Quality and Flavour" (Cacao of Excellence, 2023) aims to establish a common language for a clear communication throughout the cocoa value chain. The protocols presented in this section summarise information in the Cacao of Excellence Guide and are designed to enable flavour assessments to be made using small-scale or basic laboratory equipment. The detailed protocols, glossary of terms and flavour wheel have recently been published in the "Guide for the Assessment of Cacao Quality and Flavour" (Cacao of Excellence, 2023). Although the summary information presented in this Appendix has been updated for consistency with the current version of the guide (as at September 2023), it should be noted that the protocols and terminology are expected to continue to evolve and readers are advised to consult the website https://www.cacaoofexcellence.org for any updates and revisions to the "Guide for the Assessment of Cacao Quality and Flavour" which may supersede the information presented here.

Guidance is also included on appropriate post-harvest methods to use when only limited quantities of fresh cocoa beans are available, for example in breeding programmes and other research and development activities and on how to train sensory panels.

These protocols adopted by Cacao of Excellence and Heirloom Cacao Preservation Initiative (HCP) have been the basis for a number of peer-reviewed journal articles and have been adopted by a number of country research groups to facilitate international harmonization. The protocols could also be adopted by those looking to introduce flavour quality assessment for research or monitoring purposes at larger cooperatives and estates, government offices, research stations/ institutes in producing countries and, of course, by manufacturers.

1. Guidance on post-harvesting processing techniques suitable for use where limited quantities of beans are available.

Both the Cacao of Excellence Programme and HCP recommend that commercial samples are harvested, fermented and dried according to best local practices.

Both the Cacao of Excellence Programme and HCP recommend that commercial samples are harvested, fermented and dried according to best local practices. The methods used will depend on the genetics of the planting material, local environmental conditions, technologies and facilities available. Further information on some of these factors can be found in Part III. Typically, fermentations require in the order of 50kg of wet beans, but the following guidelines can be used to prepare samples for flavour evaluation where more limited quantities of beans are available.

Harvesting, Pod-breaking and Bean Extraction for Small-Scale Fermentations.

The guidelines provided in Part III Section 2 should be followed to ensure that only fully mature, ripe but not over ripe, non-diseased pods are harvested. Where the Batch insert micro fermentation method is to be used, to ferment a sample of beans enclosed within a mesh bag within a larger fermentation mass, it is important to ensure that the pods to provide beans for the surrounding fermentation mass are harvested on the same day as the sample pods.

Fermentation.

Fermentations of samples for flavour testing can be achieved in different ways but regardless of method used, should be carried out in a covered and sheltered space providing adequate protection against rain, wind and direct sunlight and should start immediately or within six hours of the time that the beans are extracted from their pods as detailed in Part III Section 3a.

The timing of turning(s) or mixing of the fermentation mass, and the optimal endpoint of the fermentation will vary according to the variety. For most “Forastero” and Trinitario types the first turning will be at 48 hours, with a second turning at 96 hours, and the optimal end point is likely to be between 120 – 168 hours. Fermentation times for Criollo varieties could be as short as 48 hours with no turning or one turning after 24 hours. Regardless of variety, optimal end point can be assessed visually by cutting a few beans and looking for well defined internal ridging (Figure B.1).

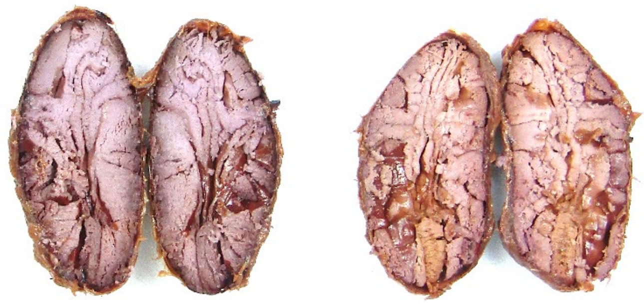


Figure B.1 Beans at the end of fermentation showing well defined internal ridging.
Photo: D. Sukha.

Batch insert micro fermentations.

This technique can be used to ferment samples of beans contained within a mesh bag (also referred to as a “net” bag) within a larger fermentation mass, The size of the mesh bag can be adapted according to the amount of beans available, and the technique has been used successfully for samples ranging from approximately 200g to 3000g, though samples of approximately 750g to 1000g are typical. It is important to keep the surface area to volume ratio of the fermentation mass constant and this can be achieved with heaps, baskets or fermentation boxes of at least 50 kg capacity. Baskets made of woven rattan with dimensions of approximately 38-50 cm diameter by 48 cm deep, can be used for this purpose. Good results have also been obtained using inverted plastic laundry baskets of similar dimensions which have had their bases removed and been strengthened with rattan hoops. Fermentation boxes 60 x 60 x 60 cm (170 kg capacity) or 90 x 90 x 90 cm (600 – 800 kg capacity) can also be used. These should be made of suitable non-resinous, hardwood with slats with gaps large enough to allow drainage of the fermentation exudates (known as “sweatings”) whilst small enough to prevent beans from passing through.

The bean sample for evaluation must be placed in labelled bags, made of an inert material such as nylon or polyethylene with no metal parts, and are of approximate size 20 x 35 cm to allow a layer 2-3 beans thick when spread flat in the fermentation box.

A mesh size opening of 10 mm allows good contact between the sample and the fermentation mass and the thread diameter should be 0.7 mm or greater for strength.

As a cautionary point, there could be a risk of flavour transfer from the fermenting mass to the micro fermentation in the mesh bag. This possible fermenting mass effect could be overcome by using similar varieties for the fermenting mass as the sample in the mesh bag and/or by using a finer (<10 mm) mesh size opening.

It is important that each mesh bag is not overfilled and that there is enough spare capacity to allow the bag to be held at each end to facilitate turning. The label on each mesh bag must contain information relevant to the sample such as (but not limited to) the clone name, the date of the start of fermentation etc.

Mesh bags should be buried in the top 15–30cm of the fermenting mass ensuring that each bag is at least 5 cm from the wall of the box and separated from other bags by at least 3 cm. A maximum of two layers of bags, with four bags per layer, can be included but there must be at least 3 cm of fermentation mass between the layers and the top layer must be covered by at least 5 cm of beans. The top of the fermentation must be covered by at least two layers of banana leaves and then two layers of food grade jute bags for insulation.

The first turning is done after 48 hours by removing the jute bags and leaves, then transferring the top of fermentation mass into a food grade plastic box or bucket. Each layer of fermentation mass and mesh bags as well as the bottom layer of the fermentation mass are placed into separate plastic boxes or buckets and are thoroughly mixed. The beans in the mesh bags are mixed by holding the ends of individual bags in each hand, shaking them from left to right a few times. The layers of beans and mesh bags are replaced in reverse order so that the top layer moves to the bottom and the bottom layer is at the top, whilst the central layer remains in its original place, and the mass is re-covered with the banana leaves and jute bags. The second turning is done after 96 hours by repeating the process and the optimal end point determined by visual assessment of the beans as described above.

Figure B.2 Small scale fermentation using adapted laundry baskets.
Photo: M. Gilmour.

Figure B.3 Small scale fermentation using baskets.
Photo: D. Sukha.

Figure B.4 Beans enclosed in a mesh bag for batch insert fermentation.
Photo: D. Sukha.

Styro-cooler Fermentation.

Styrofoam coolers of dimensions 27 cm (L) x 26 cm (W) x 17 cm (D) or 44 cm (L) x 28 cm(W) x 29 cm (D) respectively are a convenient way to ferment small (between 15 – 30 kg) bean quantities from the same variety or a defined mixture of varieties. Styrofoam coolers are relatively cheap and easily available in most countries. Six to eight holes evenly spaced at 4 cm and of diameter 1.5 cm are made on the underside to facilitate the drainage and aeration of the fermenting mass. It is recommended that the coolers (regardless of size) are placed off the ground (on small blocks of wood) to allow for optimal drainage and aeration.

New coolers can be inoculated artificially with a defined micro-floral matrix at particular time intervals, scrapings from a used fermentation box (preferred) or left to be naturally inoculated by fruit flies. Inoculation from a used fermentation box is achieved by taking scrapings from the inside top and bottom surfaces and mixing in double the volume of water (distilled water is best) to create a paste. This paste is thoroughly mixed into the wet beans when they are filled into the cooler at the start of fermentation to evenly distribute the inoculum from the used fermentation box throughout the fresh wet bean matrix. This is then covered with banana leaves and the matching Styrofoam lid to retain the heat given off during fermentation. The beans are generally turned by mixing well after 48 hours and 96 hours and the optimal end point is determined by visual inspection.

Figure B.5 Styrofoam box microfermentation.
Photo: N. Ali.

Single Pod Micro Fermentation.

There are currently a number of patented ways to achieve single pod micro fermentation which allows for preparation of samples from an individual tree and for working with wet bean samples weighing less than 1 kg. Almost all use a starter culture mixture of some sort, either obtained from a previous fermentation (for example, from scrapings taken from a fermentation container or sweatings) or using a pre-defined inoculum matrix, and added at different times. One method adds aromatic substances during fermentation whilst another physically pierces the beans before fermentation. Each will be briefly mentioned citing the appropriate Patent publication number reference for further reading:

Single pod micro fermentation processes:

WO2013025621 A1 (Seguine, E; Mills, D.; Marelli, J-P.; Motomayor-Arias, J-C. and Silvia Coelho, I.)

Starter cultures and fermentation method:

WO2007 031186 A1 (De Vuyst, L. and Camu, N.)

i. Microbial composition for the fermentation of cocoa material: EP 2459699 A2 (Camu,N.; Bernaert, H. and Lohmueller, T.)

ii. Method for fermenting cacao beans: WO 2014087816 A1 (Kawabata, Y.)

iii. Augmentation de la qualité et de l'arôme du cacao en utilisant une culture starter de levure pichia kluyveri pour la fermentation du cacao: WO 2013064678 A1 (Saerens, S. and Swiegers, J.H.)

Processing cocoa beans and other seeds:

US 20120282371 A1 (Robert Miller, C.)

Process for the fermentation of cocoa beans to modify their aromatic profile:

WO 2009103137 A2 (Dario, A. and Eskes, A.B.)

Improved cocoa fermentation via de-pulping:

EP 0442421 B1 (Bangerter, U.; Beh, B.H.; Callis, A.B. and Pilkington, I.J.)

Plant for the fermentation of vegetable or agricultural products such as cacao beans, and process for carrying out such a fermentation:

EP 0343078 B1 (Barel, M.).

Recommended application of fermentation methods.

The method chosen from the options provided above should be appropriate to both the quantities of wet bean available as well as the objectives of the study. The Styro-cooler method is used for homogenous or defined bean masses and takes more beans than the batch insert micro fermentation method. The batch insert micro fermentation allows more samples to be processed but requires larger fermentation masses (mother heaps/boxes) to insert the mesh bags into. There is also the potential risk of some flavour transfer from the larger fermentation mass. Single pod micro fermentations handle small quantities without contamination but suffer from the lack of averaging a larger number of pods. Each method used therefore has advantages and disadvantages which must be considered and weighed against the benefits derived from using a particular method.

Drying:

The beans should be carefully and thoroughly dried. Further guidance on best drying practices is provided in Part III Section 3b. Where the batch insert micro fermentation method has been used, the samples can be dried in their mesh bags though care should be taken that the beans are not spread in a one bean thick layer on a drying tray, since this would result in drying at too fast a rate due to full exposure of all beans both to air as well as to the sun. Samples from Styrofoam container fermentations should be dried in small heaps. All samples, including those in mesh bags, should be heaped up at night in a tempering phase to allow moisture to migrate from inside the bean to the surface.

It is essential that when many samples are being prepared at the same time (such as with multiple batch insert micro fermentations) they are not mixed up during drying and trays with individual labelled cells or separations can be used to minimise this risk. The optimal end point of drying should be between 6.5 – 8% moisture content as assessed by a suitably calibrated moisture meter.

Figure B.6 Beans from microfermentations drying in a compartmentalised tray.
Photo: D. Sukha.

2. Flavour Evaluation.

The flavour evaluation protocols described here are applicable whether the samples have been processed using one of the small-scale fermentation methods described above or have been produced commercially.

Aging and storage of beans.

Freshly fermented and dried beans usually have: a) very strong fruit notes that are very volatile, b) lower cocoa flavour notes, c) higher acidity (especially acetic acid), and d) a range of possible off notes (such as yeasty, musty and other odd notes). Therefore it is recommended that the bean samples are stored for a period of time to “age” before they are transformed into cocoa mass.

Aging for between 6 – 12 weeks improves stability, makes the samples more representative of commercial shipments and facilitates optimal expression of the true flavour potential of the beans. Beans should be stored in a new, clean bag suitable for food use and made from a breathable material. It is important that any bags used to store the beans are odour-free to ensure that the material used does not impart any off-odour or flavour to the beans as a result of storage.

It is important that the beans are stored carefully under conditions where they will not suffer from mould damage, infestation by pests or contamination from other samples or substances which could cause taints or pose health risks (See Part III Section 3c).

Physical quality assessment via cut test can be carried out during this time to visually assess fermentation progression and bean fissuring using appropriate representative sampling protocols and assessment charts (See Appendix A).

i) Roasters

There are many options available for roasting samples for flavour testing. These include:

- Static oven tray roasters such as table top toaster ovens and home ovens.
- Converted small scale rotary type coffee roasters and rotisserie ovens.
- Lab scale non ventilated box ovens.
- Mechanically ventilated convention ovens.
- High efficiency convection ovens.

The heating systems in these various roasting options vary from electric elements to infrared heaters with or without air or ventilation control and temperature or timer settings. At the very least, there should be some form of either temperature or timer control.

Critical factors for the most optimal roasting method to prepare samples for flavour testing include:

- Thermal uniformity of the air flow throughout the oven cavity unloaded and loaded.
- Thermal recovery time from door opening to set point.
- Air volume movement through a circulating fan.

ii) Roasting trays

Roasting trays should be a wide mesh stainless steel (preferred) or non-treated, mild steel wire mesh tray with mesh size small enough to prevent beans from falling through but large enough to promote optimal air flow across the beans. Galvanized or plastic coated screens should not be used to construct roasting trays. Rotary type ovens should have either mesh screen or evenly perforated drums. Solid drums are not recommended. Loading and unloading should also be uncomplicated and allow for complete discharge and cleaning which is always necessary to ensure uniformity of air flow.

Ideally, static tray ovens should be loaded with a single, wide mesh screen tray. Beans should be loaded as a single bean depth across the loading area. Where there is insufficient sample to fill the tray, filler beans should be used so that all roasts are carried out with the same bean loading. It is important to note that filler beans cannot be used to ensure uniform charge size for rotary drum roasters and so these are limited to applications where sufficient beans are always available.

iii) Roasting conditions

Roasting conditions should be chosen to maximize the flavour potential for each type of cocoa bean and would need to be mapped according to temperature, time and loading capacity for each variety and for the specific type of roaster used.

Typically the following temperature and time combinations are suggested as a starting guide for individual roast mapping using a convection tray roaster according to aromas identified in the cut test and dominant genetic type of cocoa beans (if known):

- Low roast - 112˚C for 25 minutes
- Medium roast - 120˚C for 25 minutes
- High roast - 130˚C for 25 minutes

Time is measured starting from 2˚C below the set point. Note that these times are based on an oven recovery time of 5 – 7 minutes from the time that the door is closed to 2˚C below the set point.

Although a low roast would commonly be used for traditional Criollo types, most modern Criollo types will usually be roasted following the Medium roast conditions. This is because they are generally much closer genetically and in terms of processing requirements to traditional Trinitario beans which are normally given a Medium roast.

Roasting conditions should be selected that will promote the expression of the intrinsic fruity and floral complementary flavours whilst preserving any delicate nutty/ caramel notes of Criollo types. The high roasting conditions may be best suited for "Forastero" to bring out any complementary flavours as well as the maximum cacao intensity inherent in these types.

Both bean size and moisture content of the beans prior to roasting are important considerations and samples with very low moisture contents (<6.5%) or very high moisture contents (≥ 8.5%) may require adjustment to be made to the roasting conditions to ensure a standardized roast for flavour evaluation. Similarly, beans may need to be sorted for size consistency before roasting. As long as bean size is in the range of 70 – 130 beans/100 g, the roasting conditions should not need adjustment for bean size.

Roasting Adjustment for both moisture content and bean size to ensure optimum roasting of beans are provided in Table 49 of the Guide for the Assessment of Cacao Quality and Flavour (Cacao of Excellence, 2023) (see www.cacaoofexcellence.org/)

Breaking and Winnowing.

Optimal fermentation and roasting have a direct impact on breaking and winnowing performance. Under-fermented and low-roasted beans tend to have shell that adheres tightly to the nib and makes efficient breaking and winnowing difficult.

Breaking and winnowing should occur immediately following cooling of the beans after roasting (usually between 20 – 60 minutes) for efficient breaking and to ensure that no off-flavours are picked up from the environment. Cooling to room temperature can be done on an elevated rack or by using a small fan to accelerate the cooling process. The area where sample preparation is done should be neutral smelling.

Note: prior to roasting, the beans are considered to be a raw agricultural product that is likely to be contaminated with large numbers of microbes, potentially including pathogens. Roasting conditions should ensure the killing of pathogens, though samples should be checked for presence of pathogens prior to sensory analysis. It is essential that precautions are taken to prevent cross-contamination between raw and roasted beans as part of an active HACCP programme to ensure the wholesomeness of any products which will be tasted.

Where only a few samples are to be processed, breaking and winnowing can be done most simply by placing cooled beans in a high quality snap seal bag, removing as much of the air as possible and using a rolling pin to lightly break the beans. Afterwards a home use hand-held hairdryer can be used to blow off the free shell from the nibs in a flat tray in a well ventilated area. Higher throughput sample preparation for flavour evaluation will require at least a mechanised winnowing system. Industrial winnowing systems include mechanisms to adjust airflow to the size of the nib/shell particles (a process known as “sizing”) to optimise shell separation. Laboratory scale mechanised individual cocoa breakers and winnowers are available but since the broken nibs/shells are not “sized”, separation is less efficient with nib yields frequently as low as 62 – 78% of the starting raw beans. This is an important point in planning the sample size of beans needed for the roasting process in order to meet the volume needs for flavour evaluation.

It is recommended that the residual shell in the winnowed nibs (including both loose shell fragments and pieces of shell adhering to a piece of nib) be manually removed with tweezers to take the shell content to effectively zero. This ensures low contamination from residual shell with an additional benefit of producing cocoa mass samples which have much lower levels of microbiological contamination (i.e. extremely low Standard Plate Counts/Total Plate Counts) since most of the microbes reside on the shell.

Nibs will pick up both environmental humidity as well as off flavours if they are present in the environment, therefore storage of nibs following winnowing and before hand picking as well as after hand picking should be in airtight storage containers or in high quality snap seal bags suitable for food use.
Nib samples deteriorate quickly and every effort should be made to convert them to cocoa mass within 48 hours of roasting. Where necessary nib samples can be stored for a maximum of seven days at 10-24°C in sealed bags.

More details are provided in Chapter 12 - Breaking and winnowing cacao beans in “Guide for the Assessment of Cacao Quality and Flavour” (Cacao of Excellence, 2023) https://www.cacaoofexcellence.org/

Cocoa Mass Milling.

There a number of options available for milling nibs into cocoa mass and these include:

- Table top liquidizers for coarse grinding and coarse milling (up to 100g of nibs).
- Table top and free standing mortar and pestle mills of varying capacities (100 – 500g of nibs).
- Laboratory scale melangeurs capable of handling from 200g up to 2.5 kg of nibs.

It is important that the nibs should be gently warmed (not more than 40˚C) before milling and equipment such as bowls, pestles, and the stones from melangeurs should be pre-warmed to ensure that the cocoa butter in the sample melts and facilitates grinding.

The temperature of the milling mass can be measured using an infrared thermometer and should remain below 55˚C. Above this temperature, volatiles are lost at a substantially higher rate—similar to what would occur in full conching. By holding the temperature below 55˚C the cocoa mass displays the inherent flavour of the beans without being stripped or reduced as it would be in conching. Should the temperature of the mass rise above this value, the room can be ventilated (cooled) or the mill can be turned off to allow the sample to cool off.

Regardless of the milling equipment used, particle size, as determined by a micrometer, is a critical parameter in determining milling end point. A particle size range between 14 – 25 microns is optimal for effective flavour evaluation since it ensures that all the volatiles in the sample will have been released and that there is no grittiness in the sample which would distract the taster during the flavour evaluation.

More details can be found in Chapter 13 - Processing cacao nibs into mass in “ Guide for the Assessment of Cacao Quality and Flavour” (Cacao of Excellence, 2023) www.cacaoofexcellence.org

The temperature of the milling mass can be measured using an infrared thermometer and should remain below 55ºC. Above this temperature, volatiles are lost at a substantially higher rate.

Chocolate Making.

It is often desirable to evaluate how cocoa mass flavour potential translates into chocolate where the interplay of sugar and other ingredients in the matrix is important in holistically assessing the full potential of a bean sample. Additionally, cocoa mass tasting is more technically challenging to perform compared to chocolate evaluation since acidity, bitterness and astringency are sometimes dominant attributes. Often the cocoa mass alone does not display the full flavour potential that will be present in the chocolate and sometimes flavours that are present in the cocoa mass are not present in the chocolate and vice versa.

The recipe used in chocolate making for this purpose is important and standard formulations range between 65 – 70% cocoa mass with 2 – 10% added deodorized cocoa butter used. The recipe shown below, which does not require the addition of lecithin, has now been adopted by the Cacao of Excellence Programme.

The cocoa butter, sugar and any soya lecithin used must be neutral tasting to avoid influencing the flavour inherent in the cocoa mass. Sugar can be evaluated by placing a 50 – 120 g sample in a jar large enough to hold at least twice that amount, securely capping the jar and warming it to 50˚C. It should be held for at least 1 hour at 50˚C then uncapped and immediately smelled. An acceptable result is a sugar that has no inherent odour.

The chocolate should be refined to less than 20 microns measured using a micrometer. Conching at a low temperature (not more than 55˚C) should be kept to a minimum, if used at all, to retain the intrinsic flavour potential of the bean whilst gauging its performance as a chocolate.

More details can be found in Chapter 14 - Processing cacao mass into dark chocolate in the Guide for the Assessment of Cacao Quality and Flavour” (Cacao of Excellence, 2023)

Ingredients	
Cocoa mass	63%
Deodorized cocoa butter	7%
Sugar	30%

Tempering.

Chocolate samples for flavour evaluation can be assessed as either un-tempered or tempered pieces. Tempering produces a uniform sheen, sharp 'snap' and crisp 'bite' in the chocolate pieces and results from consistently small/dense cocoa butter crystals in the product.

The fats in cocoa butter can crystallize in six different forms (identified using Roman numerals I to VI) at different temperatures and each of the six different crystal forms has different properties. Well tempered chocolate has the largest number of the smallest sized type V crystals possible which provides the best appearance and texture. Type V crystals are also stable so texture and appearance will not degrade over time.

The careful manipulation of temperature during the cocoa butter crystallization process to accomplish tempering can be achieved by a) manually using a marble slab, b) using a double boiler c) using a small table top tempering machine or d) using pre-crystallized cocoa butter.

Regardless of the process and equipment used, the chocolate must first be heated to 45 ˚C to melt all six forms of crystals. Next, the chocolate is cooled to about 27 ˚C which will allow crystal types IV and V to form. At this temperature, the chocolate is agitated to create many small crystal "seeds" which will serve as nuclei to create small crystals in the chocolate. The chocolate is then heated to about 31 ˚C to eliminate any type IV crystals, leaving just type V. After this point, any excessive heating of the chocolate will destroy the temper and this process will have to be repeated. Moulding and cooling into small bars or pieces immediately follows tempering.

Refrigerators and air conditioned rooms are often used to cool filled chocolate moulds but both need to be checked prior to use to ensure they are neutral smelling and do not contain any off odours.

Chocolate (particularly semi-sweet chocolate) will change its flavour profile over time, particularly mellowing with long term storage. While this is recognized, it may not be practical to hold the chocolate 2-4 months following creation to allow this to happen before assessment.

More details can be found in Sections 14.4.4 – Tempering the chocolate and 14.4.5 Moulding of chocolate in the Guide for the Assessment of Cacao Quality and Flavour" (Cacao of Excellence, 2023) www.cacaoofexcellence.org

Flavour Testing.

Flavour testing or sensory evaluation is defined by the Institute of Food Technologists (IFT) as "…a scientific method used to (1) Evoke, (2) Measure, (3) Analyse, and (4) Interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing" . From this definition one can infer that the same rigour and attention to detail placed on sample preparation must be extended to the flavour evaluation process for both cocoa mass and chocolates.

Flavour Testing - "A scientific method used to (1) Evoke, (2) Measure, (3) Analyse, and (4) Interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing".

Flavour assessment of both cocoa mass and chocolate take the following formats:

- Evaluation by a panel of trained tasters for presence or absence of defects.
- Evaluation by a panel of unskilled tasters using Hedonic preference indicators.
- Evaluation by a panel of skilled tasters providing both quantitative and qualitative assessment (including presence or absence of defects), as well as an overall global quality or preference score.
- Evaluation by a single or few highly skilled tasters providing both quantitative and qualitative assessment (including presence or absence of defects), as well as an overall global quality or preference score.

Each flavour assessment format identified above has a direct implication on the amount of sample needed, the size of the panel and number of repetitions of tasting required for a robust dataset based on the inherent purpose and need of the evaluation exercise. Critical elements in this process therefore include:

- Tasting area and layout
- Panellist training or experience
- The use of physical reference samples in training
- Tasting design and/or sample randomization
- Sample presentation
- The evaluation process
- Flavour descriptors - interpreting the results

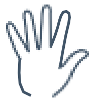
Tasting area and layout.

Ideally, flavour testing should be carried out in tasting booths with appropriate light and temperature control etc. This set up could be prohibitively expensive and a simple air-conditioned room that is clean, free from distractions and strong odours with a large enough table for the panellists is often sufficient. There should however, be easy access to a sink.

Panellists should not be distracted when tasting so the layout of the room (location of samples, water and expectorant cups, scoring sheets and pencils, or computer for digital tasting forms etc.) should be the same each time.

Panellists should also consider the following guidelines carefully and try to put them into practice whenever they participate in a tasting session:

Panellists should neither smoke nor drink alcohol or coffee, nor eat food which will alter their sense of taste, nor undertake prolonged periods of strenuous exercise within 60 minutes prior to a tasting session.



The use of strong scents, perfumes and aftershaves should be avoided by panellists and anyone else involved in the setup of the tasting area or sample handling. Hands should be washed prior to tasting using perfume-free soap.

Any instructions handed out at tasting sessions should be read carefully and understood before commencing. Panellists should feel free to ask any questions if they are unsure about the instructions.

Any persons suffering from colds should not attend or participate in tasting sessions or set up.

Panellists should avoid talking until everyone has finished tasting.

Panellists should strive to be independent tasters by following their first instinct about a particular flavour attribute and trust in their ability.

Panellist training or experience.

Some form of intensive training is required for cocoa mass assessments whilst training for chocolate assessment is very desirable. Only Hedonic (preference tasting) can be done with an untrained panel.

A detailed guide for panellist training and selection for flavour testing is given in Sukha et al (2008). As a summary, sensory panellists can be trained in identification of basic tastes using aqueous solutions such as sweet (sucrose at 5.0g/500 mL), bitter (quinine chloride at 0.072g/500 mL), salt (sodium chloride at 0.8g/500 mL), acid (citric acid at 0.25g/500 mL), astringent (maleic acid at 0.25g/500 mL) as well as flavour attributes associated with cocoa mass (fruity and floral at a concentration of 2 mL/500 mL of kola flavour and orange blossom water, respectively). This can be followed by identification of acid, bitter and astringent tastes at threshold level concentration using citric acid, quinone chloride and maleic acid (at 0.1, 0.009 and 0.15g/500 mL, respectively) in solutions to gauge the sensitivity of individuals to these attributes.

A critical element of panel training is flavour association to flavour descriptors. In this regard, physical reference cocoa mass standards play a crucial role in sensory evaluation training. These should be used after the initial taste identification part of training to associate specific flavour descriptions for cocoa mass samples together with previous taste experiences so that all panellists gain agreement on the same sensory language. These physical cocoa mass flavour reference standards should be obtained from recognized sources (such as the Cacao of Excellence Programme) to cover the nine core flavour attributes considered viz. cacao, acid, astringent, bitter, fruity, floral, nutty, woody and spicy flavours, as well as, identifiable off-flavours such as smoky, hammy, mouldy and unfermented. Panellists should also be encouraged to identify any other complementary flavours or defects that are apparent in the cocoa mass samples, (recorded under 'other' flavours).

Training for chocolate tasting should include an exposure to a wide variety of different origin chocolates to build a mental library of associations linked to key chocolate flavour descriptors
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Tasting design, sample randomization and presentation.

Cocoa mass samples should be assessed by a panel of between six to eight trained individuals using a factorial statistical design that incorporates hidden reference samples. Cocoa mass samples should be coded with three-digit numbers and randomised over three repetitions to minimise carry- over effects. Prior to panelling, bring the samples to room temperature. Label small plastic soufflé cups with random 3-4 digit numbers to ensure that all flavour evaluations are blind. Cover the cups with the matching tight-fitting lids. Prepare three replicates of each sample and assemble into sets of 18 samples for each panellist. It is important that samples are only held in a molten state for a short period of time before evaluation since delicate volatile notes can be lost and, if samples are held in a molten state for longer than 30 minutes, cacao intensity scores can also be affected. Place randomly ordered samples in a dry-bath incubator or clean box or convection oven set at 55-60˚C for 20 minutes prior to flavour evaluation and taste with a timer marking 10 minutes between flavour evaluations. No two panellists should receive samples in the same order for any given evaluation session and a maximum of six cocoa mass samples should be tasted in any one session to prevent panellist fatigue.

Chocolates can be evaluated in the same way as either solid blocks or pieces melted at 45^{o}C. Evaluation using solid blocks is recommended unless an assessment of the melting performance on the palate is not important.

The evaluation process.

Place about 1 ml of cocoa mass on a small spatula and place directly on the tongue and keep it there for 20 seconds. During this time the different attributes making up the flavour profile become apparent at three contiguous time intervals viz. initial front flavour notes, middle flavour notes and residual end flavour notes. Panellists should note that some flavours either appear or disappear very quickly or are easily masked whilst other flavours could linger for a longer time with distinct after tastes. Score the intensity of the flavour attributes for each flavour descriptor using 10-cm line scales with a possible range of scores from 0 to 10 where the higher numbers denoted stronger flavour intensities. After sample evaluation, the following clearing procedure is used:

- Expectorate the sample
- Rinse with warm water, expectorate rinse water
- Chew 1/8 – 1/6th of a Table Water Cracker Wafer (non yeast based) with the front incisors and not the molars and swallow
- Rinse with warm water, expectorate rinse water
- Rinse again with warm water this time swallowing the rinse water

The performance of the sensory panel can be optimised during evaluations by including a hidden reference samples to check panellist consistency between repetitions during training and evaluation sessions.

Flavour descriptors - Interpreting the results.

One of the most difficult parts of flavour testing of both cocoa mass and chocolates is finding the right words to describe the perceived flavours, especially since this relies heavily on a mental association to the flavour descriptors. Glossaries of flavour descriptors with comments and flavour wheels have been developed to group terms used to describe the flavours and can be used by panellists to ensure they use a common language when describing their perceptions and to aid in the interpretation of results (The Glossary developed by Cacao of Excellence is attached on the next page).

Having a Global Quality indicator in the flavour testing for both cocoa mass and chocolate is very useful as it goes beyond simple attributes of the sample but is intended to reflect an overall attribute standing. It should not be a score derived using a formula or calculation from the attributes but stands on its own for each evaluator to indicate their impression of overall quality.

More details can be found in the Guide for the Assessment of Cacao Quality and Flavour (Cacao of Excellence. 2023). Readers are advised to check the website www.cacaoofexcellence.org for any updates to this guide including the protocols, glossary of terms and flavour wheel.

Glossary of Terms for Flavour Evaluations

Glossary of terms for flavour evaluations (for both cocoa mass and chocolates) with kind permission from the Guide for the Assessment of Cacao Quality and Flavour (Cacao of Excellence, September 2023). These flavour attributes and sub-attributes are grouped into core attributes, complementary attributes and off-flavours, Each of these attributes is assessed using an intensity scale ranging from 0 to 10. The glossary also includes examples of intensity scores (references) to assist evaluators in understanding and applying the scale accurately, Furthermore a global quality score is defined, providing a comprehensive assessment of the overall quality of the sample, Readers are advised to check the Guide for the Assessment of Cacao Quality and Flavour for further details and the website www.cacaoofexcellence.org for any updates to this glossary of terms

Attribute intensity scale and meanings:

Intensity	Meaning
0	Absent.
1	Just a trace and may not be found if tasted again.
2	Present in the sample but at low intensity.
3 to 5	Clearly characterising the sample.
6 to 8	Dominant characterisation of the sample.
9 to 10	Maximum. Strong intensity. Overpowers some other flavour notes in the sample.

The flavour attributes are divided into three groups:

1. **Core attributes:** cacao, acidity, bitterness, astringency and roast degree expected to be present in every sample and scored.
2. **Complementary attributes:** characteristics that may or may not be perceived in cacao samples.
3. **Off-flavours:** resulting from defects that may or may not be perceived in cacao samples.

Descriptor	Description	Intensity level / Reference notes	
Cacao	Typical flavour of roasted cacao beans that are well fermented, dried, free of defects.	0–2	Under-fermented cacao, ancient Criollos.
		3–5	Appropriately fermented "Nacional" and Papua New Guinean lots.
		6–8	Appropriately fermented cacao, some West African and some Dominican Republic Hispaniolan lots.
		9–10	Some West African lots.
Acidity	**Total acidity** is the sum of the following individual acidities: • **Fruit:** citric or other fruit acids. • **Acetic:** vinegar (can be smelled in the sample). • **Lactic:** typically occurring in sour milk and yogurt • **Mineral and butyric:** harsh metallic tasting (mineral) and rancid butter (butyric). Perception of acidity intensity is particularly dependent on the amount of sample in the mouth.	0–2	Some well-prepared West African lots.
		3–5	Some Ecuadorian, Peruvian and Central American lots.
		6–8	Some Dominican Republic Hispaniolan, Papua New Guinean and Malaysian lots.
Bitterness	Basic taste, typically perceived in caffeine, coffee, kola nut, some beers and grapefruit. Perception of acidity intensity is particularly dependent on the amount of sample in the mouth.	1–2	Some ancient Criollos.
		3–5	Well-prepared West African lots.
		6–8	Severely under- and un-fermented cacao.

Descriptor	Description	Intensity level	Reference notes
Astringency	Astringency could be perceived in two ways: • **Sharp mouth-drying effect**, sharp, perceived between tongue and palate and /or at the back of the front teeth and inside lips and gums – typical of raw nut skins and green banana skins. • **Velvety sensation** on the sides of mouth and tongue. Typical of tannins in some wines or beers. Perception of astringency intensity is particularly dependent on the amount of sample in the mouth.	INTENSITY 1–2	Some ancient Criollos.
		3–5	Normal intensity for most cacao.
		6–8	-
		9–10	-
		TYPE Sharp-mouth drying	Typical of under-fermented cacao.
		Velvety	Typical of appropriately fermented "Nacional".
Fresh fruit	**Total fresh fruit** is composed of the following sub-attributes: • **Berry:** red or black currant, strawberry, raspberry, blackberry, acai berry. • **Citrus:** orange, lemon, lime, grapefruit or generic sensation of citrus-like fruit. • **Dark:** cherry, plum. • **Yellow / orange / white flesh:** apricot, peach, pear, banana. • **Tropical:** passion fruit, pineapple, mango or soursop.	0–2	Many West African lots.
		3–5	Some Central and South American, well fermented Asia and Pacific country lots.
		6–7	Madagascar, some Central and South American country lots, some Papua New Guinean lots.
Browned fruit	**Total browned fruit** is composed of the following sub-attributes: • **Dried:** dried apricot, banana, yellow raisin, fig that has undergone an un sulphured drying process. • **Browned:** dark raisin, dates, prune. • **Over ripe:** No longer fresh and severely over-ripe fruit, turning brown inside and outside, as a step towards over-fermentation.	0–2	Many West African lots.
		3–5	Fully fermented Indonesian and some Caribbean country lots.
		6–8	Some Papua New Guinean and some Caribbean country lots.
Vegetal	**Total vegetal** is composed of the following sub-attributes: • **Grassy / Green vegetal / herbal:** » Grassy – freshly cut grass, young green leaves. » Green vegetal – crushed mature leaves. » Herbal – hay, straw or herbal / dried green, herbs like thyme and rosemary. • **Earthy / mushroom / moss / woodsy:** » Earthy – smell of dampness rising from soil after rain. » Mushroom – smell of fresh mushrooms. » Moss – damp moss often associated with earthiness. » Woodsy – leaves and wood on a forest floor.	0–2	West African lots.
		3–5	Appropriately fermented "Nacional" and some Caribbean country lots.
		6–8	Some Caribbean country lots and some Peruvian lots.

Descriptor	Description	Intensity level / Reference notes	
Floral	**Total floral** is composed of the following: • **Orange blossom:** orange blossom flavour. • **Flowers:** jasmine, honeysuckle, rose, lilac, lilies, etc.	0–2	West African lots.
		3–5	Appropriately fermented "Nacional" and some Caribbean country lots.
		6–8	Some Caribbean country lots and some Peruvian lots.
Woody	**Total woody** is composed of the following sub-attributes: • **Light wood:** freshly cut cacao wood, white pine wood, maple wood, ice-cream/popsicle wooden stick. • **Dark wood:** oak, walnut, teak, mahogany. • **Resin:** pitch of pine or other resinous wood.	0–2	-
		3–5	Some "Nacional" and many West African lots.
Spice	**Total spice** is composed of the following sub-attributes: • **Spices:** dried coconut, nutmeg, cinnamon, cloves, cacao mass, tonka, vanilla, black pepper. • **Tobacco:** dried tobacco leaves. • **Savoury/Umami:** sodium glutamate, umami.	0–2	In most origins.
		3–5	In some West African, Central and South American and Caribbean country lots.
Nutty	**Total nutty** is composed of the following sub-attributes: • **Nutty – nut flesh:** the edible kernel of a light roasted nut – hazelnut, macadamia, pecan, walnut, cashew, almond, brazil nut • **Nutty – nut skins:** the flavour of lightly roasted nut skins – hazelnut, macadamia, pecan, walnut, cashew, almond, brazil nut	0–2	In most origins.
		3–5	Some Central and South American and Caribbean countries' lots and ancient Criollos.
Caramel / Panela	Aromas reminiscent of caramel, brown sugar and panela (unrefined cane sugar)	0–2	In most origins
		3–5	Some Central and South American and Caribbean countries' lots and ancient Criollos
Sweetness (only for chocolate)	Basic taste of white sugar solutions, typically perceived in foods like candies and desserts that contain sugar (or other sweeteners such as aspartame) and also naturally found in other foods like fruits.		

Descriptor	Description	Intensity level / Reference notes
Roast degree	A measure of the extent of the roasting the beans. Significant under or over roasting alters many of the attribute values.	2–3: Low roast 4–6: Medium roast 7: High roast 8–10: Levels of burnt/over-roasted
Off-flavours	**Total Off-Flavours** is composed of any unpleasant characters from the following: • **Dirty/dusty:** not related to texture but to an off-flavour. • **Musty:** stale, damp, mildew, decaying. • **Mouldy:** characteristic of mould growth. • **Meaty/animal/leather:** » Meaty – cured meat, ham, rendered fat. » Animal – dirty animal / farmyard. » Leather – used old leather. • **Over-fermented/rotten fruit:** decomposing fruit. • **Putrid/manure:** » Putrid – wet decomposing vegetative matter. » Manure – farmyard animal manure. • **Smoky:** contamination from the smoke (any kind). • **Other off-flavours:** rancid, diesel, oil fumes, petroleum, tar, paint, tyres, chemicals, burnt, etc.	0: Absent – clean, well fermented, dried and stored cacao beans. 1–2: Low intensity. 3+: Clearly characterizing the sample as a defect.
Global Quality	The **Global Quality** score reflects the overall impression of the: • expressed flavour potential • uniqueness of the sample • balance of flavour and cleanliness of the finish It celebrates the expression of genetics and terroir diversity through the farmer's knowhow.	Global Quality scores and meaning below

Meaning of the global quality scores for the sensory analysis of cacao beans processed into cocoa mass (liquor) and chocolate. With kind permission from the Guide for the Assessment of Cacao Quality and Flavour (Cacao of Excellence, September 2023)

	Off-flavours	Core attributes	Complementary attributes	Notes
0 1 2 3	Serious off-flavours clearly characterizing the sample as defective	Masked by off-flavours	Masked by off-flavours	Be as specific as possible on the type of off-flavours as this is valuable feedback to the producers Depending on the type, number and intensity of off-flavours, 0 would be the worst case and 3 the least but still bad
4	In low intensity	Seriously unbalanced	Masked by off-flavours and unbalanced core attributes	
5	In low intensity	Unbalanced	Partially masked by unbalanced core attributes	
6	In low intensity or absent	Unbalanced	In low intensity, none outstanding, not in balance to core attributes	Overall plain flavour – mainly characterized by the core attributes and less by the complementary attributes
7	Absence of any	Balanced	One or more are outstanding but not in balance to core attributes	Overall plain flavour – mainly characterized by the core attributes and less by the complementary attributes
8	Absence of any	Well balanced with moderate base cacao flavour	One or more are outstanding, in balance to core attributes and to each other	Overall flavour presents some complexity
9	Absence of any	Well balanced, good base cacao flavour	Many outstanding, in balance to core attributes and to each other	Overall flavour presents a combination of complexity, uniqueness, harmony, brightness, clean finish
10	Absence of any	Well balanced, in low to moderate intensity, good base cacao flavour	Clearly recognizable, many outstanding, in balance to core attributes and to each other	Overall flavour presents a combination of complexity, uniqueness, harmony, brightness, clean finish The sample is of extraordinary quality, rarely seen

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Swiss Platform for Sustainable Cocoa

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