Organic Farming in the
Tropics and Subtropics

Exemplary Description of 20 Crops

Cocoa

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Franz Augstburger, Jörn Berger, Udo Censkowsky,
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The cultivation guidelines are available in English, Spanish and German for the following crops:

banana, brazil nut, cashew nut, cocoa, coconut, coffee,
cotton, hibiscus, macadamia, mango, papaya, peanut,
pepper, pineapple, sugar cane, sesame, tea, vanilla.

The cultivation guidelines for Bananas, Mangoes, Pineapples and Pepper were revised in 2001 for the United Nations Conference on Trade and Development (UNCTAD) by Udo Censkowsky and Friederike Höngen.

In 2002 two more guidelines, for rice and date palms, were published in English.

All the authors emphasize, that the cultivation recommendations at hand can just provide general information. They do not substitute technical assistance to the farmers with regard to the location.

All indications, data and results of this cultivation guidelines have been compiled and cross-checked most carefully by the authors. Yet mistakes with regard to the contents cannot be precluded. The indicated legal regulations are based on the state of the year 1999 and are subject to alterations in future. Consequently all information has to be given in exclusion of any obligation or guarantee by Naturland e.V. or the authors. Both Naturland e.V. and authors therefore do not accept any responsibility or liability.

Furthermore the authors kindly call upon for critical remarks, additions and other important information to be forwarded to the address below. The cultivation guidelines will be updated regularly by Naturland e.V.

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Organic cocoa cultivation

1. Introduction

Economically, *Theobroma cocoa L.* is the most important variety of the species Theobroma. In practice, the two subspecies Criollo and Forastero are differentiated, whereby the latter subspecies is present on over 80% of all plantations. It originates from the Amazon forests (the subspecies Forastero Amazónico) as well as the rainforests of central America (the white seed subspecies Criollo). The crop was already known to the Aztecs, who relished it as a "drink of the Gods". The cocoa seeds are highly rich in fat content, and therefore provide an energy-rich and delicious foodstuff. On traditional cocoa plantations in Mexico (Tabasco) the ground and dried cocoa is mixed together with maize flour, then stirred together with water, to provide a nourishing drink during the work. Cocoa arrived in Europe through the former colonial powers Portugal and Spain, and was later to be found in Africa. Today, cocoa is cultivated in all of the humid, tropical countries.

1.1. Botany

Theobroma cocoa belongs to the family of sterculiaceae. Cocoa trees attain a height of 8-10 m. The blossoms appear in the many year old wood of the leaf axil, on the trunk and on the branches (Kauliflorie). Blossoms can appear throughout the whole year, providing no extreme drought periods or seasonal temperature fluctuations occur. The berries develop within 5-6 months from blossoms that are pollinated by insects, mainly of the species *Forcipomyia* and *Lasioshelea*. The cocoa fruit has a cucumber-like shape, and is about 25 cm long, 8-10 cm thick and weighs 300-400 g. The shell, which can be up to 20 mm thick, surrounds the sugar-rich, bitter-sweet, acrid pulp. The fruit contains 25-50 almond-shaped, bitter tasting seeds, in 5-8 long rows: the cocoa beans.

1.2. Varieties and countries of origin

Up until the end of the 80's, the largest producing countries were the Ivory Coast, with an annual production of 775,000 t[1] and Brazil with 346,000 t[2]. Due to the huge reduction in price on the world market towards the end of the 80's, and massive phytosanitary problems on the plantations, cocoa cultivation in Brazil has been sharply

[1] REHM, S. AND ESPIG, G. (1996): KULTURPFLANZEN DER TROPEN AND SUBTROPEN, ULMER VERLAG.
[2] DTO.

reduced. Contrastingly, Asian countries such as Malaysia (ca. 226,000 t)[3] and Indonesia (ca. 220,000 t)[4] have significantly increased their production with the help of government subsidies.
The very first cocoa certified to have been produced on an organic plantation during the 80's was introduced onto the international market from Bolivia. During the 90's, other countries such as the Dominican Republic, Brazil, Mexico, Ghana and the Ivory Coast have joined in.

1.3. Uses and contents

The seeds of the cocoa plant are mainly used to manufacture chocolate, cocoa-based drinks and other sweet products. On the international market, raw cocoa (dried cocoa seeds) are the most usual product, which then need to be roasted before being processed further. More and more cocoa-producing countries are now beginning to process the raw cocoa in cocoa mills before they are exported, and to offer semi-manufactured goods, such as cocoa butter, cocoa powder as well as cocoa blocks.
In Brazil during the past few years, more *Theobroma grandiflora* (Copuazú) has been cultivated, to extract its fruit pulp in order to manufacture drinks. *Theobroma bicolor* also plays a certain role on local markets and for own-use in many regions of south and central America.
Fresh cocoa fruit juice from the seed pulp, which is produced during the process, can be fermented into alcoholic beverages and vinegar, or made into fruit jellies.

Main average constituents of pure, *shell-free* cocoa seeds:[5]

Water	5 - 6%
Nitrogen substances	14%
Fat	53%
Starch	7 - 10%
Tanning agents	5 - 6%
Organic acids	2 - 3%
Pentosane (Poly-sugar)	1.5%
Raw fibres	4%
Ash (Mineral substances)	3%
Phosphatide (fat-like substances)	0.3 – 0.5%
Theobromine	1 - 2%
Caffeine	0.2%

[3] DTO.
[4] DTO.
[5] CHEMIE IN LEBENSMITTELN (1988): KATALYSE INSTITUT FÜR ANGEWANDTE UMWELTFORSCHUNG E.V. ZWEITAUSENDEINS

2. Aspects of plant cultivation

Every single attempt to cultivate cocoa in a monocropping system, or in systems with only a little ecological diversity, have sooner or later encountered crises due to phytosanitary problems or through a loss of soil fertility. The problems could neither be solved by the selection of resistant plants, or with chemical regulation measures or by supplying additional mineral fertilisers. We would like to place special emphasis on the cocoa production in the formally largest cocoa plantations regions in the world: In the Brazilian state of Bahia during the last 15 years, cocoa plantations have been heavily reduced due to the plantations being infested with witches' broom disease (*Crinipellis perniciosa*), even though millions had been pumped into research. Attempts in Ecuador to counteract the witches' broom disease by developing resistant clones have also failed. During the 50's, witches' broom disease clones from the Scavina (SCA 6) group are now one of the clones most susceptible to this disease.

2.1. Site requirements

Cocoa grows in the primary forests in the so-called understorey and is associated with a variety of palm species, as well as a number of other different tree varieties. For example, with tree varieties stemming from the upper storey in rain forests, among them mainly single trees overtopping the forest canopy which lose their foliage during the months of shorter daylight hours. The resulting increase in light encourages the development of the cocoa blossoms, and the falling leaves an enrichment of organic material.

With an even annual spread of rainfall (100 mm per month), the plantations can survive on 1250 mm per year. Short drought periods can be compensated for by heavy clouds and high humidity. The average annual temperature should be around 25°C. In regions with extensive wet periods or large seasonal temperature fluctuations, the harvesting periods are reduced to only a few months per year. In with regions a balanced climate, and only slight temperature and rainfall fluctuations, cocoa produces fruit practically throughout the year.

The soil on cocoa plantations should be deep, well-drained, and have sufficient water-retaining capacity. The pH-value should lie between 4.0 and 7.5, whereby care must be taken that sufficient organic material is available.

Cocoa trees can live for over one hundred years. Naturally occurring cocoa crops propagate themselves through lateral shoots, which can occur at any height on the trunk. The natural vegetative proliferation occurs when the seeds are spread by small rodents and apes.

2.2. Seeds and seedlings

Many cocoa varieties are self-sterile, and need to be fertilised through allogamy, by relying on other varieties for fertilisation. These varieties belong mainly to the group of clones and hybrids of the group 'Trinitarios'. No general recommendations are available as to which seed and shoot material should be used, as this depends largely on the material available in the Region. So-called hybrid seeds can be used, as well as vegetatively developed material. Cocoa shoots are usually set out in polyethylene bags for 4-6 months, and then transplanted onto the site. With the vegetative method, the shoots are sorted after 3-5 months, according to the sturdiness of the rootstocks, and then the plants remain a further 4-6 months in the nursery. In regions with naturally occurring cocoa plants, or with self-fertilising varieties (comp. table), the seeds can be sown directly, whereby 3 seeds per hole are sown. In the course of the first 3-5 years, the plants should be thinned out to one or two per hole.

Self-fertilising cocoa varieties, suitable for direct sowing:

Africa	Brazil	Ecuador	Mexico	Bolivia	Asia
Cocoa of the Amelonado type	Cocoa común, type Amelonado	Cocoa nacional	Criollo (white seed superior cocoa)	Criollo (forastero amazónico)	No self-fertile varieties.

2.3. Cultivation method

2.3.1. Planting new plantations

When choosing the site for a new plantation, the natural site requirements of cocoa should be adhered to. Ideal sites are those with alluvial soils, which are not susceptible to water-logging. Other suitable sites are sites irrigated form wells, and in hollows. Unsuitable sites are steep and convex slopes.
When creating a new plantation, care should be taken to reproduce as closely as possible the natural structure of forests. This means that all of the varieties that are to be cultivated along with cocoa in the agro eco-system should be planted at the same time (or even beforehand) as the cocoa. The best method is to leave an area free for natural growth, and to plant tall-growing trees which will rapidly provide cover, such as bananas and manioc, and to plant the cocoa in-between them at a later date. In this way, the biological activity of the soil is maintained, and the mycorhiza of the cocoa can begin to develop immediately.

2.4. Diversification strategies

Rice as well as maize can be sown as a pioneer crop, depending on the starting conditions (soil fertility, market access, consumer habits etc.), simultaneously with manioc (*Manihot esculentum*), new cocojam (*Xanthosoma sagittifolium*), bush peas (*Cajanus cajan*), and, as ground coverage, *Canavalia ensiformis,* among others. Before a pioneer crop is sown, bananas should be planted, whereby the distances between each plant depends on the distances between the individual cocoa plants and the variety of banana (comp. organic banana cultivation). Along with standard commercial varieties of banana from the Cavendish group, other tall-growing local varieties which can tolerate shade should also be integrated into the plantation. The number of cocoa trees should lie between 600 and 1100 trees per ha.

Examples of setting up cocoa plantations

Example 1:

1. Year	2. Year	3. Year	5. - 10. Year	from 11. Year
Maize/dry rice	Sweet potato (Ipomoea batata)			
Papaya	Papaya	Papaya		
Bananas	Bananas	Bananas	Bananas	
Cocoa	Cocoa	Cocoa	Cocoa	Cocoa
Forest trees	Forest trees	Forest trees	Forest trees	Forest trees

Example 2:

1. Year	2. Year	3. Year	5. - 10. Year	from 11. Year
Maize-beans-Okra	Cocojam, Taro (Xanthosoma sagittifolium or Colocasia esculenta sp.)			
Bananas	Bananas	Bananas	Bananas	
Cocoa	Cocoa	Cocoa	Cocoa	Cocoa
Forest trees	Forest trees	Forest trees	Forest trees	Forest trees

Example 3:

1. Year	2. Year	3. Year	5. Year	6. to 10. Year	from 11. Year
Manioc	Okra (Hibiscus esculentus)				
Pineapple	Pineapple	Pineapple	Pineapple		
Bananas	Bananas	Bananas	Bananas	Bananas	
Cocoa	Cocoa	Cocoa	Cocoa	Cocoa	Cocoa
Forest trees	Forest trees	Forest trees	Forest trees	Forest trees	Forest trees

Example 4:

1. Year	2. Year	3. Year	5. Year	6. to 10. Year	from 11. Year
Maize					
Papaya	Papaya	Papaya			
Bananas	Bananas	Bananas	Bananas	Bananas	
Rubber	Rubber	Rubber	Rubber	Rubber	Rubber
Cocoa	Cocoa	Cocoa	Cocoa	Cocoa	Cocoa
Forest-/	Forest-/	Forest-/	Forest-/	Forest-/	Forest-/
Fruit trees	Fruit trees	Fruit trees	Fruit trees	Fruit trees	Fruit trees

During the first few years, on fertile soils, papaya (*Carica papaya*) can also be cultivated in addition to bananas within the system (2 x 2 m). Together with the papaya seeds or bananas, trees growing up to the middle storey (such as *Inga ssp.*, *Erytrina ssp.*, *Gliricida sepium*) as well as growing up to the upper storey must also be planted. This can be in seed form. Only in the cases of certain varieties (such as e.g. palm varieties that are old, or difficult to germinate), should the trees be first sown in a tree nursery. The choice of tree depends on which varieties are available in the region.
In addition to the varieties listed above, it is recommended to integrate palm species (e.g. *Bactris gasipaes*, *Euterpe ssp*., *Jessenia bataua*) at a density of 100-150 trees per ha in organic cultivation systems (comp. 2.5.).

Many combinations are possible, in which other fruit trees such as avocado, mangosteen, rambutan, Jackfruit and many more besides can be integrated.

Monoculture plantations that already exist, and which have only very few shading trees can be improved. The best method is to re-forest wrongly cultivated spots, and also spaces that become available after unproductive single plants have been removed.

2.5. Supplying nutrients and organic fertilisation management

This list has been compiled from results for conventional cultivation:

Annual nutrient demand on the soil in kg for 1000 kg/ha harvest yield[6]

	N [kg]	**P** [kg]	**K** [kg]
Seeds	23.2	6.0	19.6
Shells	19.6	2.0	44.5
Total[7]	42.8	8.0	64.1

Other sources for 1000 kg harvest came to these totals[8] (in kg)

	N	P	K
Harvest (1000 kg seeds)	20	4	10

It is not advisable to use fertiliser that has not originated from the site's production, also of organic origin, because the costs are simply too high. The creation of organic material through mulching and pruning activities is sufficient for an economically viable production – provided a stratified (multi-phase), diverse and densely planted system is in place.

Any shells that are left over after the harvest must remain on the plantation. This means that the fruits should be broken open on site, if possible, and the resulting shell material spread as evenly as possible. The cocoa fruits harvested on a plot are first plied into a heap, and then broken open to provide around 50 kg of fresh cocoa. The cocoa fruits should then be plied onto a different heap during the next harvest stage, and broken open there.

Many varieties of palms are capable of actively break down phosphorous through symbiosis with mycorhiza, as well as binding heavy metals in the soil, which thereby reduces the amounts absorbed by the cocoa plants. This can be useful, because the amount of heavy metals in the cocoa seeds can be problematic (comp. 3.1). It is therefore recommended to integrate suitable palm varieties into the plantation.

[6] Wood, G.A.R. (1975): COCOA. LONGMAN, LONDON AND NEW YORK

[7] DAS VERHÄLTNIS ZWISCHEN SCHALE AND FRISCHEM SEEDS BETRÄGT CA. 5 : 1, IS VON VARIETY AND DER WITTERUNG ABHÄNGIG

[8] Hille, T. AND Lems, G. (1989): COCOA. IN: HANDBUCH DER LANDWIRTSCHAFT AND ERNÄHRUNG IN DEN ENTWICKLUNGSLÄNDERN, BAND 4. ULMER

2.6. Biological methods of plant protection

2.6.1. Diseases

The most important diseases and the ways they appear:

Witches' broom (Crinipellis perniciosa)	**Late blight, Bark canker** (Phytophtora palmivora, P. capsici, P. citrophtora)	Trunk and branch canker (Ceratocystis fimbriata)	Pod-rot; Stem canker Moniliophtora roreri	Cocoa Swollen shoot Virus *(CSSV)*
South America, Trinidad, Tobago, Grenada	World-wide (still little in Malaysia)	South America, Trinidad, Costa Rica, Dom. Republic, Guatemala, Hawaii, Philippines, hardly at all in West Africa	Ecuador, Columbia, Panama, Venezuela	Only in Africa

Most diseases are caused by the following:

- Cultivation in monocropping systems with no or only very few varieties and number of shading trees (on conventional plantations, 25-40 trees of mostly one variety per ha recommended).
- Ignoring the natural rotation of the forest system. For example, cocoa plantations which grow beneath old shading trees from the secondary forest system (mostly *Inga ssp*., *Gliricidia sepium* etc.), are highly susceptible to diseases and pests. Cocoa, as a plant from the primary forest, can tolerate old primary forest trees above it, yet not trees from the secondary forest system.
- Too little distance between the different varieties in a system which have the same status; failure to thin out the agroforestry system.
- Degraded and poor soils, lack of organic material.
- Unsuitable site (water-logging, too dry, no possibility for deep root development).

Effective measures are often only possible in the form of improvements to the whole system. One possibility lies in radically cutting back the trees and subsequently replacing them with the correct varieties, or, with a complete renewal measure, whereby the trees are sawn down to a stump of around 40 cm. One to three of the resulting shoots which develop out of the stumps are left to develop. Opening up the plantation allows many new varieties to be included (comp. 2.4.).

A tolerable loss at harvest time, which is also heavily dependant on weather conditions, is often caused by late blight (*Phytophtora palmivora*). In addition to the measures described here, regular harvesting, which should then include diseased fruit, can reduce the infestation (many farmers only harvest the healthy fruits). In the case of a heavy infestation by *Phytophtora palmivora,* harvest losses can be alleviated with Bordeaux mixture[9], or other spray preparations containing copper, that

[9] ACCORDING TO THE EUROPEAN REGULATION FOR ORGANIC AGRICULTURE (EEC) 2092/91 THE USE OF COPPER PREPARATIONS FOR PLANT PROTECTION (E.G. BORDEAUX MIXTURE) IS ALLOWED FOR A TRANSITIONAL

are permitted on organic plantations. These methods should only be used in emergencies.

2.6.2. Pests

An infestation of pests in a cocoa plantation has the same causes as diseases which affect a system. The causes are listed under 2.6.1..

The most common pests are:

- Tarnished plant bugs (Sahlbergella singularis, Distantiella theobroma, Helopeltis varieties)
- So-called 'Cocoa bugs' *(Monalonium spp.)*
- Thrips (Selenothrips rubrocinatus, Heliothrips rubrocinctus)
- Leaf cutter ants (*Atta ssp*.)

The losses caused by these pests world-wide is enormous. They result from the cocoa fruits being sucked dry in all stages of growth, after which, the plant dies off, according to the amount of damage done.
Without losing sight of the need to combat the root causes, a solution which can be immediately utilised to save a harvest is by spraying with a 3% alkaline soap solution (potassium soap), which has proven itself in Bolivia in regulating different bug varieties[10]. In addition, other preparations being permitted on organic farms can also be used.

2.7. Crop cultivation and maintenance

During the first three years, the cultivation measures consist almost entirely of selective regulation of the weed growth, whereby grasses are removed, and flowering weeds cut down to be used as mulching material. Trees which do not loose their leaves, e.g. *Ingas ssp*., need to be radically trimmed during the blossoming period of the cocoa (ca. 6 months before the main harvest begins), in order to increase the amount of light. The resulting organic material should then be chopped and spread out over the soil. Diseased plant parts and fruits should be removed. The cocoa trees

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[10] 100 G LINSEED OIL OR EDIBLE OIL ARE MIXED TOGETHER WITH 70G FUEL ALCOHOL OR HIGH PERCENTAGE ALCOHOL. 20G PURE OF POTASSIUM HYDROXIDE (HIGHLY CAUSTIC!) ARE THEN DISSOLVED IN 33G OF LUKE WARM WATER (CAUTION, STRONG BUILD-UP OF HEAT!), AND THEN ADDED TO THE OIL AND ALCOHOL MIXTURE, THEN FINALLY THOROUGHLY STIRRED OR SHAKEN. THE SOAP IS READY AFTER CA. 5 MIN., AND CAN BE TESTED TO SEE WHETHER A SMALL AMOUNT MIXED IN WATER REMAINS TRANSPARENT OR NOT.

should also be lightly trimmed, and diseased of poorly developed trees removed (in cases of direct sowing), during these shading regulation tasks.

2.8. Harvesting and post harvest treatment

The most essential quality characteristics of cocoa are dependent on their being correctly processed, which begins with the harvesting process and ends with the storage method.
The harvest can begin when the fruits are completely ripe. In many Trinitario types, with their red and dark violet fruits, this can be recognised by an orange discolouring of the shell. Yet other varieties take on a yellow colouration when ripe. Depending on the region and weather conditions, there are usually one or two harvesting phases, which are spread out over several months. In order to achieve a uniform ripeness of the fruits harvested, it is wise to harvest all of the ripened fruits every 2-3 weeks. The best way to avoid harming the bark is to cut off the fruits at the base of the blossom with a sharp knife or other suitable instrument.
Cocoa seeds have no lull in germination. If the fruits are harvested when overripe, then germination can already have begun in the shell. A large number of already germinated cocoa seeds will not pass a quality control, for this reason, overripe and diseased fruits should not be mixed together with healthy cocoa fruits, but are to be processed separately.
Ripe cocoa fruits are split open with a large splitting knife or iron bar, taking care not to harm the seeds within, after being stored for around 24-35 hours.

3. Product specifications and quality norms

Quality characteristics for ***cocoa 1st quality*** that can be influenced by a farmer are:
Minimum of 70% of well fermented seeds
Moisture content under 8%
No foreign smells such as fungi or smoke

Tolerances for cocoa 1st quality:
max. 3% cocoa beans with visible fungus mould
max. 3% of beans without fermentation
max. 3% of beans infested by pests, germinated or too small

For ***cocoa 2nd quality*** the tolerances are:
5% cocoa beans with visible fungus mould
5% of beans without fermentation
5% of beans infested by pests, germinated or too small

The quality is examined with a so-called ‘cutting test’. Hereby, 300 cocoa beans are split open lengthways and graded according to the classification criteria.

Efforts are made to attain bean sizes of at least 1 g, with as few shell parts as possible, and a high cocoa fat content. The sizes are dependant on the variety, the soil and the climatic conditions. The following table gives an overview of the average bean weight, percentage of shell pieces and fat content for cocoa from a variety of producing countries.

Country	weight of 100 beans	Shell content in %	Fat content in %
Africa			
Ghana	105.8	13.3	56.9
Nigeria	113.8	12.3	57.3
Ivory Coast	112.8	12.6	58.2
Cameroon	101.8	12.9	56.3
Latin America			
Brazil	104.0	15.3	56.5
Ecuador	129.0	14.2	53.4
Trinidad	105.7	17.3	56.7
Mexico	113.4	9.0	53.2
Grenada	97.9	16.6	56.7
Asia			
New Guinea	120.4	16.4	56.9
Indonesia	0.3	9.9	53.6

3.1. Harmful substances

3.1.1. Heavy metals

Cocoa plants efficiently extract the naturally occurring heavy metals in the soil, and store these in the fat of the seeds. This leads to varying concentrations of heavy metals being enriched in the fat, according to where the beans originated from. Systematic examinations of the cadmium content of cocoa and cocoa products were first introduced in 1979. Results from1983 produced values of 0.06 and 0.16 ppm for edible varieties from Brazil (Bahia), Ghana, Ivory Coast, Cameroon and Nigeria. Yet some of the exclusive sorts produced results of between 0.66-2.60 ppm (Grenada, Malaysia, Trinidad, Venezuela, Ecuador).

The lead content of broken cocoa seeds lies between 0.10 and 0.85 ppm.

No legal regulations limiting the highest values allowed exist in Germany, merely recommendations, which are then 0.6 mg/kg for lead and cadmium.

3.1.2. Insecticides

In Germany, the highest permitted doses of individual harmful substances in cocoa powder of 0.02 mg/kg (ppm). The sum of pesticide residues is not allowed to exceed 0.04 mg/kg.
In many cocoa plantations regions during the 60's and 70's, insecticides, such as DDT, were used to deal with pests. This has resulted in several of the active substances still being discovered in cocoa samples from plantations where no DDT has been sprayed for years or even decades. Also, up until a few years ago (and is still carried out today in parts), DDT was used in many countries to combat malaria, meaning that the substances can be found in concentrations which still cause problems. The 'Health personnel' responsible for the sprayings pay no heed thereby to foodstuffs and storage depots. In these cases, organic producers need to be especially careful, and, if necessary, store their produce away from living areas – because in many regions, denying access for spraying is punishable.

3.1.3. Micro-organisms

Certain special measures need to be adhered to during the processing of cocoa products in order to prevent contamination by micro-organisms. According to the regulations from 26.06.1995 (Switzerland) regarding hygienic-microbiological requirements for foodstuffs, instruments, rooms, equipment and personnel, the tolerance levels for chocolate without fillings, chocolate powder and cocoa powder are:

aerobic mesophile germs	100,000/g
Enterobacteriaceae	100/g
Staphylococcus aureus	100/g
Yeasts	1,000/g
Mould	100/g

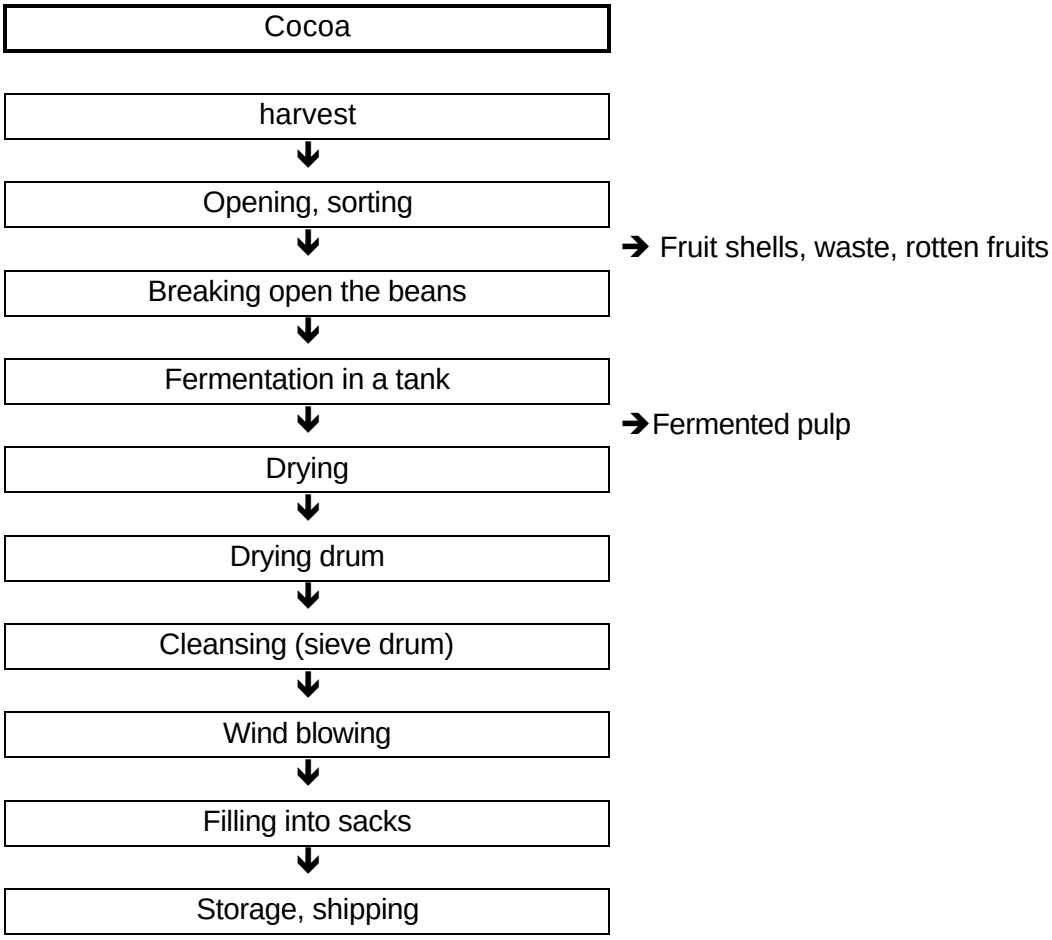
3.2. Processing

3.2.1. Processing

Cocoa powder is produced by grinding down the fermented, roasted and shelled cocoa beans. Cocoa butter is a by-product of processing cocoa, and is used, in addition to its utilisation in the confectionery industry, mainly as a raw material in the cosmetic and pharmaceutical trades.
Around 32-47 kg of fermented, dried, raw cocoa beans can be produced from 1000 kg of fresh cocoa fruits. The water content of the fresh beans increases from 30-35% during the fermentation process, up to around 60%, and should sink, after drying, to around 5-7%.

The following chart provides a schematic representation of the way cocoa beans are first prepared, and then processed into cocoa powder. A more detailed description follows afterwards

Steps in cocoa-processing:



Fermentation

The aim of fermentation is to remove the fruit pulp residues that remain, to kill off the seed, and to commence the development of aroma, taste and colour in the beans.

Fresh cocoa seeds are enveloped in a white, fruity-sweet pulp, that composes up 15-20% of the fruit's weight. They consist to 80% of water, 10-15% glucose and fructose, as well as 0.5% non-volatile acids (mainly citric acid) and pectin, and have a pH-value of 3.5. The seeds themselves have a strong, bitter taste, which is caused by the dark violet-coloured anthocyan

constituent in the seeds. It is only when the fermentation process has begun that these bitter parts are chemically transformed, when seeds begin to take on a chocolate brown colouring, and the first signs of the typical aroma begin to develop.

During the drying and roasting processes, the colour change and aroma development are increased again.
The fruit pulp of the cocoa seeds offers excellent living conditions for those micro-organisms that play an important role during the entire fermentation process. As the process commences, the fermentation is dominated by yeast fungi which produce alcohol. The fruit pulp begins to disintegrate, and flows away. The fermentation tanks therefore need to be constructed and set up so that the fruit pulp juices can drain away (comp. below). Large harvests also produce large quantities of juice, which is not allowed then to flow directly into the environment. It must either be processed, or disposed of in a soakage or sewage pit.
After ca. 24-36 hours in the fermentation tank, the cocoa needs to be aerated so that the aerobic acetic and lactic acid fermentation processes can be initiated, in order to transform the alcohol and remaining sugar. This usually performed manually, by tipping the contents into a different tank. The contents are then heated to 52°C. Acetic acid penetrates into the seeds, and during the third day of fermentation, the pH-value of the cotyledons (seed leaves) sinks down from an original value of 6.6 to 4.8. The strong development of heat, combined with the acetic acid penetration of the seeds causes the embryos to die off, and the beginning of an enzymatic process to further the aroma development. Depending on the cocoa type, fermentation tank and air temperature, this process takes between 96-120 hours, and requires regular aeration of the contents every 48 hours.

Overview of the fermentation process

Aeration ⇓ Aeration ⇓

1. day	3. - 4. day	5. - 7. day
fruit pulp strongly acidic (pH 3.5) Contents white in colour pH 6.5 in seed interior violet colour of seed interior no development of heat Smell sweet-sour. aromatic	Contents acidic (pH 4.5) Contents light brown in colour pH 4.5 in seed interior violet colour of seed interior. Edges brown Temperature increase of contents to 45-50°C Strong smell of acetic acid	Contents slightly acidic (pH 5.5) Contents brown in colour pH 5.5 in seed interior Brown colour of seed interior Temperature decrease of contents to 40°C Smell of acetic acid somewhat weakened

One indication that the fermentation process is coming to a close is that the temperature of the contents begins to fall. In order to precisely determine the correct time to stop the fermentation process, when the temperature has dropped to 40° C, a sample is cut from the contents. Cocoa beans are removed from several layers of the tank and cut open lengthways. Fresh or insufficiently fermented cocoa beans have a violet colouring inside, which turns into violet-brown as the fermentation progresses. When 75% of the beans have reached this stage, the fermentation process needs to be halted, as otherwise a rotting process would quickly begin.
Depending on the site and weather conditions, types of fermentation tanks, as well as the cocoa variety or type, the fermentation process is concluded after 5-7 days. The white bean Mexican Criollo cocoa only needs 1-3 days for the fermentation process, because it lacks the bitter-tasting anthocyan components.

Fermentation tanks

Fermentation of the cocoa seeds is carried out in wooden boxes, woven baskets, and in other suitable containers made of natural materials. Care should be taken to provide them with insulation, and protect them against the weather, in order to prevent the fermenting cocoa from loosing too much heat. The containers should not exceed a capacity required for 1 t of fresh cocoa, or a height of 0.75 m, because otherwise, the fermentation process cannot be carried out uniformly. Small amounts of cocoa also only ferment insufficiently, because the ratio of surface to volume is too large for the heating process to continue. Therefore, a minimum amount of 50 kg fresh cocoa is needed for fermentation.
Another, wide-spread, fermentation procedure is the step form, whereby 3-4 fermentation boxes are stacked on top of one another, and the cocoa falls, due to gravity, from one box down to the one below it, thereby providing enough air circulation. So that the fruit juice can drain out unhindered, the uppermost box should be constructed with ca. 0.5 cm slits, which will also facilitate cleaning.

Drying

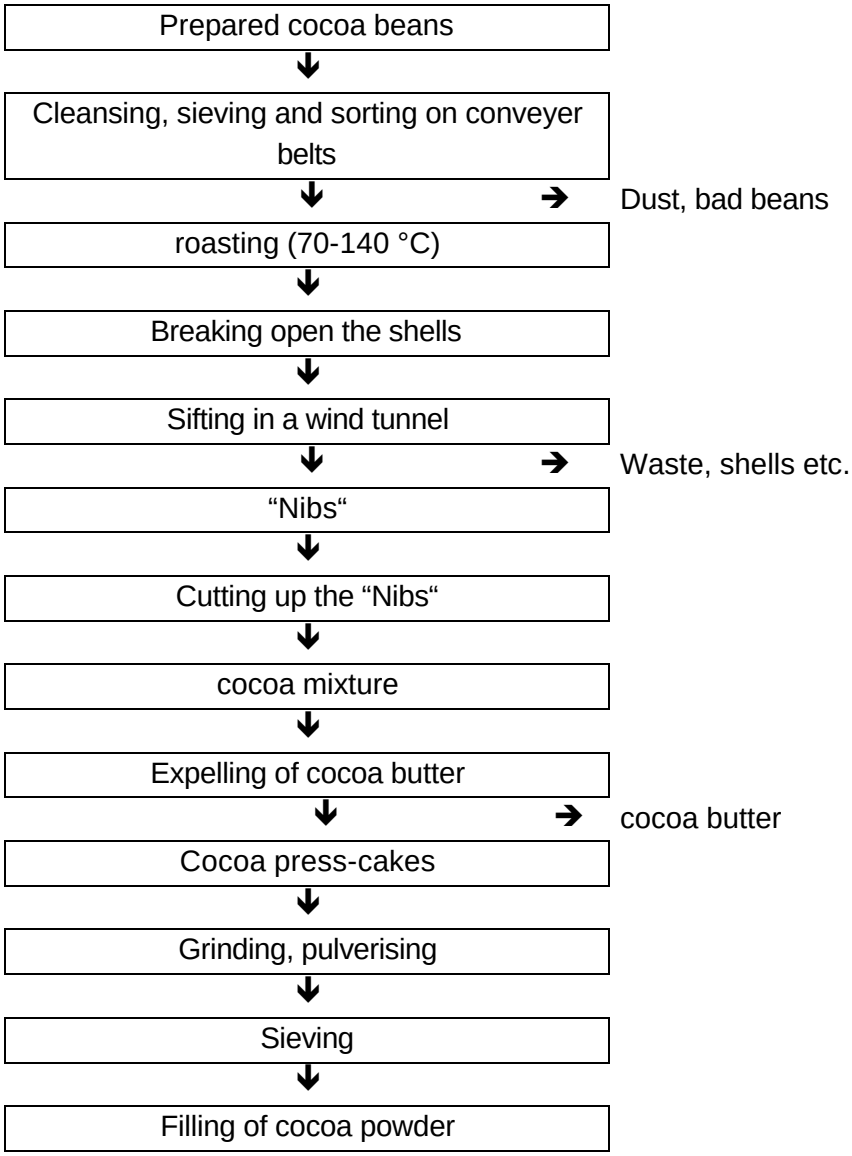
After the fermentation process is finished, any unripe or damaged beans are sorted out and the rest dried. The starting level of water content is around 55%, which must be reduced to around 6-7% before the beans are stored. Enzymatic transformation processes continue to take place during the drying process, whereby the contents are oxidised, and the cotyledon inside the seeds' shells turns a brown colour, and the typical aroma of chocolate develops. In addition, the surplus acetic acid evaporates.
It is important to dry the cocoa beans carefully, in order to maintain a certain stability and storability. The beans are dried on equipment especially created for this purpose; such as, e.g. reed mats, or wooden, plastic or metal racks, which then need to be placed high enough above the ground to prevent them becoming dirtied by animals or dust. Sunlight will increase the browning process and also the development of aroma. Slow, careful drying in the sun can take up to 7 days. Afterwards, the water content must be below 8%. It is important to turn the cocoa beans by often raking them through with a large rake – this will ensure that the beans are dried uniformly and

carefully. Drying apparatus that utilise warm air are recommended for use in those regions where it is often cloudy during the harvest season. Yet it is important to note that the cocoa should not come into contact with the fumes from the fuel – as this would adversely affect their taste and smell, and therefore, their quality.

3.2.2. Processing into cocoa powder

The processing of cocoa beans into cocoa powder is described below schematically, then in more detail later on.

Processing steps towards making cocoa powder:



In order to manufacture cocoa powder, the cocoa beans are first cleansed and sorted according to size. The beans are then scrubbed free of attached dirt particles and impurities by rotating brushes, which are then sucked away and disposed of.

Sieves then sort the seeds according to size, which is important to the roasting process afterwards. After being sieved, the cocoa is fed over conveyer belts, where it is sorted once more. Special care must be taken here to sort out the mouldy, bitten, rotten or damaged beans. The roasting can take up to 45 minutes in large drums at temperatures between 70°C and a maximum of 140°C, according to variety and origin of the cocoa. The roasting gives the cocoa its typical aroma and characteristic brown colouring. The shells and seeds are thereby loosened, and removed by a blower after the cocoa beans have been broken open. Only the nibs remain, the valuable part. Cocoa mills then grind the nibs down into a thick paste – the cocoa mixture. In order to extract fine, dry cocoa powder from this, the cocoa butter first needs to be expelled, and the press-cake ground down to produce extremely fine to give cocoa powder. Pressing out the cocoa butter should only be performed mechanically. According to how efficiently the cocoa butter has been pressed out, the products are then termed 'strong drained oil' or 'light drained oil' cocoa, and exhibit the following characteristics:

Normal trading varieties of cocoa powder:

Light drained oil cocoa/ cocoa powder: 20-24% cocoa butter
max. 5% water

Strong drained oil cocoa/ cocoa powder: 10-12% cocoa butter
max. 5% water

3.2.3. Quality requirements

The following is a list of quality characteristics with minimum and maximum values for 'light drained oil' cocoa that are usually required officially or by importers. Different minimum and maximum values can be agreed between importers and exporters, providing these do not clash with official regulations.

Quality characteristics	Minimum and maximum values
Taste and smell	Variety specific, aromatic, not musty
Purity	Free from foreign particles, such as e.g. sand. soil, insects
Cocoa butter	min. 20 % (in relation to the dry weight)
Water content	max. 5-9 %
Residues	
Pesticide	Not measurable
Bromide	Not measurable
Ethylene oxide	Not measurable

Micro organisms	
Aerobic mesophile germs	max. 100.000/g
Yeasts	max. 1.000/g
Mould fungi	max. 100/g
Enterobacteriaceae	max. 100/g
Staphylococcus aureus	max. 100/g
Salmonella	Not measurable in 20 g
Mycotoxins	
Aflatoxin B1	max. 2 µg/kg
Total aflatoxins B1. B2. G1. G2	max. 4 µg/kg

In order that the quality requirements are upheld, and no contamination of the cocoa beans occurs, preparation should take place under clean, hygienic and ideal conditions. The following aspects should be adhered to:
Equipment (tubs, knives etc.), as well as working and drying surfaces (racks, mats etc.) and preparing and storage rooms, should be cleaned regularly.
Personnel should be healthy, and have the possibility to wash themselves, or at least their hands (washrooms, toilets) and wear clean, washable overgarments.
Water used for cleansing purposes must be free from faeces and other contaminants.
Animals or animal faeces must not come into contact with the fruits. If the fruits are to be dried in the open, then fences must be erected to guard the racks against birds and nearby animals.
The following offers an explanation of the terms and descriptions of generally available cocoa products – in part, with the requisite minimum and maximum values:

Cocoa beans

Fermented and dried cocoa tree seeds (*Theobroma cocoa L.*).

Cocoa seeds

Cocoa beans in roasted or non-roasted form, after they have been cleaned, shelled and the germination roots removed, and contain only a maximum of 5% shell pieces or shoots and max 10% ash, in relation to the fat-free weight of the dry mixture.

Cocoa mixture

Cocoa seeds that have been mechanically processed into cocoa mixture which still contains all of the natural fat.

Cocoa press-cakes

Cocoa seeds that has been mechanically processed into cocoa press-cakes and which contains a minimum of 20% cocoa butter, and a maximum of 9% water, in relation to the weight of the dry mixture – excepting the definitions of lean or meagre cocoa press-cakes.

Lean (meagre) cocoa press-cakes, 'Strong drained oil' cocoa press-cakes
Cocoa press-cakes with a minimum cocoa butter content of 8%, in relation to the weight of the dry mixture.
Cocoa powder. ''Cocoa''
Cocoa press-cakes extracted hydraulically, which is then mechanically processed into cocoa powder, and – excepting the definitions of lean (meagre) cocoa powder - contains 20% cocoa butter, and a maximum of 9% water, in relation to the weight of the dry mixture.
Lean (meagre) cocoa powder, lean (meagre) Cocoa, 'Strong drained oil' cocoa powder, 'strong drained oil' cocoa
Cocoa powder which contains a minimum of 8% cocoa butter in relation to the weight of the dry mixture.
Sweetened cocoa powder, sweetened cocoa, chocolate powder
A product that derives from a mixture between cocoa powder and saccharose, with a minimum cocoa powder content of 32%.
Cocoa butter
Fat gleaned from cocoa beans:
a) Cocoa press-butter, cocoa butter
Cocoa butter that is produced by pressing it out of one of the following ingredients: cocoa seeds, cocoa mixture, cocoa press-cakes, lean (meagre) cocoa press-cakes.
It has the following characteristics:
Content of nonsaponifiable substances (measured with benzine): maximum 0.35%
Content of free fatty-acids (expressed in oleic acid): maximum 1.75%
b) Expeller cocoa butter
Cocoa butter extracted from cocoa beans with an expeller, or from a mixture of cocoa beans and cocoa seeds, cocoa mixture, cocoa press-cakes or lean cocoa press-cakes.
It has the following characteristics:
Content of nonsaponifiable substances (measured with benzine): maximum 0.50%
Content of free fatty-acids (expressed in oleic acid): maximum 1.75%
Cocoa fat
Fat gleaned from cocoa beans, or parts of them, that does not fulfil the quality specifications for cocoa butter.

3.2.4. Storage

Cocoa can be stored for years in temperate climates without fear. In the moist tropics on the other hand, the high temperatures and humidity cause a rapid infestation of storage pests and mould fungi. Because cocoa is strongly hygroscopic, even a product that has been well dried can rise in moisture content up to 10 % in regions

with 80-90% humidity, and thereby lose its capacity to be stored, the critical value for which is 8%.

Equilibrium moisture content of dried cocoa beans (%) in relation to humidity [11]

Relative humidity	Moisture content of the cocoa beans
75	7.3
80	7.7
85	8.7
90	11.6
95	15.5

The cocoa should be stored in air-permeable sacks on the production site for only a short time, whereby the sacks should be stacked on wooden planks or boards. The use of sacks made of organic material (jute) should be avoided, if these have been treated with pesticides. The cocoa butter part in the cocoa shell is an excellent solvent for chlorinated hydrocarbons which can diffuse through the outer shell when they come into contact with it, and into the cocoa seed. In such cases, tests have then shown limits for certain agricultural poisons being exceeded – although no pesticides had ever been used on the site.
The storage area should always be well-ventilated – the inside temperature should remain below the outside temperature.
On conventional plantations, it is quite usual to gas the cocoa with methyl bromide in order to protect them against storage pests. In addition, tetraline soap, hydrogen phosphide and prussic acid are also used. **On organic cocoa plantations, it is not permitted to use either insecticides against storage pests, or to gas the beans.**

3.2.5. Packaging

Bulk packaging
To be exported to Europe, the raw cocoa beans are usually filled into sacks of 60-70 kg.

Information printed on transport packaging
The transport packaging should display details of the following:
Name and address of the manufacturer/packer and country of origin
Description of the product and its quality class
Year harvested
Net weight, number
Batch number

[11] Wood, G.A.R. (1975): COCOA. LONGMAN, LONDON AND NEW YORK

Destination, with the trader's/importer's address
Visible indication of the organic source of the product[12]

Storage

Cocoa beans should be stored in dark, dry and well-ventilated rooms at low temperatures.
Short-term: ca. 16°C; relative humidity: 55%
Long-term: ca. 11°C; relative humidity: 55%

If the organic product is being stored in a single warehouse together with conventional cocoa products mixing of the different qualities must be avoided. This is best achieved using the following methods:
Training and informing of warehouse personnel
Explicit signs in the warehouse (silos, pallets, tanks etc.)
Colour differentiation (e.g. green for the organic product)
Incoming/dispatched goods separately documented (warehouse logbook)

It is prohibited to carry out chemical storage measures (e.g. gassing with methyl bromide) in mixed storage spaces. Wherever possible, storing both organic and conventional products together in the same warehouse should be avoided.

[12] ORGANIC PRODUCTS MUST BE PROTECTED FROM CONTAMINATION BY NON-COMPLIANT SUBSTANCES AT EACH STAGE IN THE PROCESS, I.E. PROCESSING, PACKAGING, SHIPPING. THEREFORE, PRODUCTS ORIGINATING FROM A CERTIFIED ORGANIC FARM MUST BE RECOGNISABLY DECLARED AS SUCH