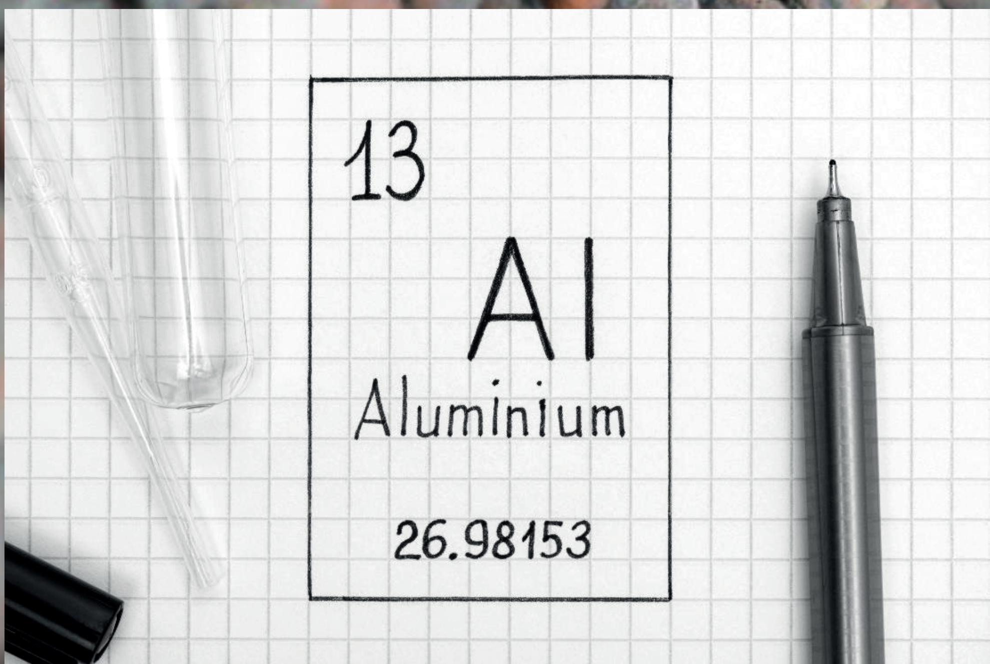
Toolbox for the Minimization of Aluminium in Cocoa and Chocolate Products



Preface

Aluminium as contaminant in food is under debate since many years. Over time, there have been different assessments of the influence of food on the human intake of Aluminium in general. National and international organizations for risk assessment have dealt with the topic, with different results. Without discussing the details and differences at this point, everyone comes to the conclusion that food makes up a considerable proportion of human Aluminium intake and that this should therefore be reduced. In this context, cocoa and chocolate products have repeatedly been mentioned as one source of human nutrition.

Confectionery industry has followed this process closely and initiated manifold activities to understand and quantify the Aluminium content in its products with the goal to identify mitigation measures. The distant countries of origin of cocoa across different continents followed by a long transport route through different climatic zones represent a complex starting point for a comprehensive analysis of the entry paths of Aluminium. Industrial processing in Europe adds another dimension to this complexity. Finally, competition law is an additional hurdle for a cross-industry, transparent exchange of research results.

The topic Aluminium is already worked on sponsored by the Joint Research Fund of the European Association of Chocolate, Biscuits & Confectionery (CAOBISCO), the European Cocoa Association (ECA) and the Federation of Cocoa Commerce (FCC) since a few years. The Association of the German Confectionary Industries (BDSI) in 2019 initiated an additional project in order to speed up the process and answer the still open questions in a targeted manner. A working group with all interested stakeholders connected in BDSI transparently accompanies all activities of this project. The possibility to quickly share anonymized results and more importantly findings derived therefrom is seen as an unbeatable advantage of this industry project.

The toolbox presented herewith summarizes the background to the topic, describes identified Aluminium sources and the results of the BDSI industry project. The identified potential entry sources are listed as the most important content and compared with possible minimization measures. Of course, this is generally valid knowledge that can only serve as an aid for checking and evaluating your own production process. They do not claim to be complete or fully applicable unreservedly in every case.

We would like to express our thanks to the company Alfred Ritter GmbH & Co. KG (Waldenbuch) for the great and tireless support in this project. The same applies to the company Olam Cocoa Deutschland GmbH (Mannheim). Our thanks also goes to the Foundation of the German Cocoa and Chocolate Industry (Hamburg).

Cologne, in November 2021

Food Chemistry Institute (LCI)
of the Association of the German Confectionery Industry (BDSI)

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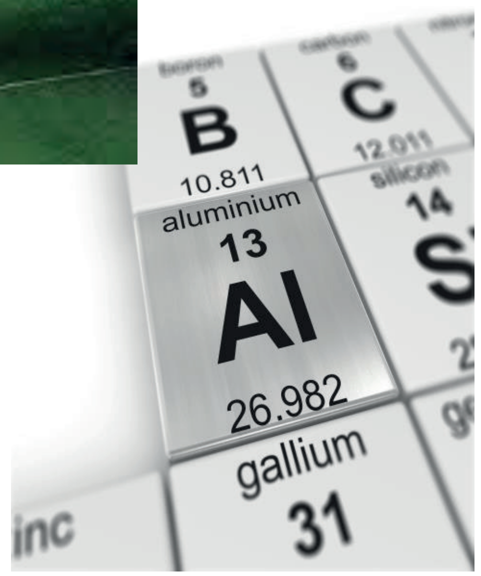


Background

As the most frequently occurring metal and third most frequently occurring element in the Earth's crust, Aluminium is a natural component of nearly all foodstuffs and is also found in drinking water. Migration from food contact materials is judged to have a low contribution to human Aluminium uptake if used under customary conditions. In addition, Aluminium is released into the environment e.g. by industrial processes or via the oxidation of Aluminium components. Humans only take up Aluminium in the form of Aluminium compounds and this mainly occurs via the ingestion of food or drinking water [1].

The lowering of the tolerable weekly intake (TWI) of Aluminium from 7 mg/kg to 1 mg/kg by the European Food Safety Authority (EFSA) in 2008 [2] brought Aluminium in foodstuff back into the public debate. In 2014, the Federal Institute for Risk Assessment (BfR) highlighted the occurrence of Aluminium in cocoa and chocolate. They presented research results on Aluminium content in cocoa and chocolate products [3]. The opinion on the safety of Aluminium in cosmetic products published by the Scientific Committee on Consumer Safety (SCCS) of the European Commission convincingly concluded antitranspirants to be a negligible source for Aluminium uptake in humans [4]. This moved foodstuffs back into the primary focus of mitigation measures for Aluminium as requested by official risk managers.

According to the findings of the BfR, Aluminium occurs in cocoa powder, cocoa masses, and chocolate products in considerably higher concentrations compared to other foodstuffs. For this reason, the Association of the German Confectionery Industry (BDSI) initiated research activities to understand the occurrence and to trigger avoidance of Aluminium in cocoa and chocolate products, supported by a working group together with industry stakeholders. Still following the approach of the international project (see preface), the working group advocated for an additional activity designed to concretely answer the open questions on potential Aluminium sources in the food group cocoa and chocolate products. The efforts should encompass both the possibilities in the countries of origin and further processing of cocoa in Europe. Of course avoiding Aluminium transfer on cocoa beans in the first place sounds to be the easiest solution to lower its content in the respective processing products, but the actors particularly wanted to take into account the feasibility of the potential minimization measures. In any case it was clear from the very beginning, that the results of the study can only list basic findings on Aluminium entry paths and possible countermeasures, which the cocoa and chocolate manufacturers then have to check against their specific production conditions. The association's patronage allows cross-sector and authorities communication of the results in accordance with antitrust law on the basis of pre-competitive research.

Aluminium in food

Food is unquestionably the main source of Aluminium intake for humans, whereby it is considered either primary or secondary. The primary content is the natural content of food caused by uptake from the geologic surrounding during growth and is for all practical purposes unavoidable. The secondary content is the primary content plus any possible contamination from Aluminium articles that come into contact with food and additives as well as veterinary drugs, fertilizers and the environment [5].

Foods with a high Aluminium content are spices and tea leaves. Also in other foods such as fresh vegetables, vegetable products, fresh fruit, cheese, nutrients, potatoes and cocoa products as well as meat and sausage products, high Aluminium contents are possible. In addition, a transfer of Aluminium from consumer goods to food is known, e.g. by heating acidic foods in Aluminium cooking pots, by using Aluminium foil and acidic beverages in Aluminium cans. The Aluminium concentration in drinking water is generally < 1 mg/L. In addition to its natural occurring, Aluminium-containing food additives can make a contribution to Aluminium absorption through food. Aluminium or its salts are used either as a coloring agent for coatings on sugar confectionery, as a firming agent for egg products, as a filler in chewing gum or as a raising agent for fine bakery wares. As a consequence, the European Commission has significantly restricted the approval of food additives containing Aluminium in terms of conditions and quantities of use for reasons of consumer protection [6]. Very high Aluminium uptakes are also conceivable when taking certain medications, especially antacids [7].

In general, the nutritional intake of Aluminium is still not fully understood. In particular, data on the amounts of different foodstuffs that must be ingested to reach the toxicologically tolerable intake of Aluminium is lacking [5]. Against this background, various national and international authorities for the safety assessment of food have dealt with the issue of Aluminium. The results of their considerations are briefly summarized below.

EFSA-Opinion

Since Aluminium is a natural component of soils, food naturally contains Aluminium. In its Scientific Opinion from 2008, EFSA evaluated EU-wide test data on Aluminium in food. Most unprocessed foods contain less than 5 mg Aluminium per kilogram. Higher concentrations (on average 5–10 mg/kg) occur in cereal products, baked goods, dairy products and in some vegetables, offal and seafood. Average concentrations of over 10 mg/kg were measured in cocoa, tea and herbs. Under normal and typical conditions, the contribution of migration from food contact materials would represent only a small fraction of the total dietary intake. However, it is likely that the oral absorption of Aluminium from food can vary at least 10-fold depending on the chemical forms present. Although the degree of water solubility of an Aluminium compound appears to increase the bioavailability of the Aluminium ion, the presence or absence in the intestines of dietary ligands may either increase (e.g. citrate, lactate, and other organic carboxylic acid complexing agents, fluoride), or decrease the absorption (e.g. phosphate, silicon, polyphenols) [2]. However, the bioavailability of Aluminium compounds taken up by food is low, i.e. only 0.1% of the Aluminium content is absorbed from food and 0.3% from drinking water [1].

After absorption, Aluminium distributes to all tissues in animals and humans and accumulates in some, in particular bone. The main carrier of the Aluminium ion in plasma is the iron binding protein, transferrin. Aluminium can enter the brain and reach the placenta and fetus. Aluminium may persist for a very long time in various organs and tissues before it is excreted in the urine. While retention times for Aluminium appear to be longer in humans than in rodents, there is little information allowing extrapolation from rodents to the humans. Although at high levels of exposure, some Aluminium compounds may produce DNA damage in vitro and in vivo via indirect mechanisms, the Panel considered this unlikely to be of relevance for humans exposed to Aluminium via the diet. The database on carcinogenicity of Aluminium compounds is limited. In the most recent study no indication of any carcinogenic potential was obtained in mice given Aluminium potassium sulfate at high levels in the diet. Overall, the EFSA concluded that Aluminium is unlikely to be a human carcinogen at dietary relevant doses. Aluminium has shown neurotoxicity in patients undergoing dialysis and thereby chronically exposed parenterally to high concentrations of Aluminium. It has been suggested that Aluminium is implicated in the aetiology of Alzheimer's disease and associated with other

neurodegenerative diseases in humans. However, these hypotheses remain controversial. Based on the available scientific data, the EFSA does not consider exposure to Aluminium via food to constitute a risk for developing Alzheimer's disease [2].

EFSA noted that several compounds containing Aluminium have the potential to produce neurotoxicity (mice, rats) and to affect the male reproductive system (dogs). In addition, after maternal exposure they have shown embryotoxicity (mice) and have affected the developing nervous system in the offspring (mice, rats). EFSA also noted that there are very few specific toxicological data for food additives containing Aluminium. Thus EFSA considered it prudent to take these effects into account when setting a tolerable intake for all dietary sources. The available studies have a number of limitations and do not allow any dose-response relationships to be established. The Panel therefore based its evaluation on the combined evidence from several studies in mice, rats and dogs that used dietary administration of Aluminium compounds [2].

In view of the cumulative nature of Aluminium in the organism after dietary exposure, EFSA considered it more appropriate to establish a tolerable weekly intake (TWI) for Aluminium rather than a tolerable daily intake (TDI). Based on the combined evidence from the abovementioned studies, EFSA established a TWI of 1 mg Aluminium/kg bw/week. The estimated daily dietary exposure to Aluminium in the general population, assessed in several European countries, varied from 0.2 to 1.5 mg/kg bw/week at the mean and was up to 2.3 mg/kg bw/week in highly exposed consumers. The TWI of 1 mg/kg bw/week is therefore likely to be exceeded in a significant part of the European population. Due to the design of the human dietary studies and the analytical methods used, which only determine the total Aluminium content in food and not the individual Aluminium compounds or species present, it is not possible to conclude on the specific sources contributing to the Aluminium content of a particular food. Research is needed to better understand factors such as the amount inherently present, the contributions from use of food additives and the amounts released to the food during processing and storage from Aluminium-containing foils, containers or utensils. Thus, a detailed breakdown by exposure source is not possible according to EFSA [2].

BfR Recommendation

The topic Aluminium is dealt with by the German Federal Institut for Risk Assessment (BfR) for many years. The latest assessment form 2019 covers the health risks resulting from total consumer exposure towards Aluminium and various Aluminium compounds, including contributions from foodstuffs, food additives, food contact materials (FCM) and cosmetic products. For the estimation of Aluminium contents in foodstuff, data from the German "Pilot Total Diet Study" were used, which was conducted as part of the European TDS-Exposure project. These were combined with consumption data from the German National Consumption Survey (NVS II) to yield Aluminium exposure via food for adults. It was found that the average weekly Aluminium exposure resulting from food intake amounts to approximately 50% of the tolerable weekly intake (TWI) of 1 mg/kg body weight (bw)/week, derived by EFSA. For children, data from the French "Infant Total Diet Study" and the "Second French Total Diet Study" were used to estimate Aluminium exposure via food. As a result, the TWI can be exhausted or slightly exceeded – particularly for infants who are not exclusively breastfed and young children relying on specially adapted diets (e.g. soy-based, lactose free, hypoallergenic). The study gives recommendations on how to reduce overall Aluminium exposure [8].

Based on the above mentioned publication, the BfR statement 045/2019 postulates the possibility to reduce health risks by the minimization of Aluminium uptake. The BfR assessment shows that Aluminium intake from food is lower than in previous studies. Food is still a relevant, but no longer the main source of intake for the population. If other relevant sources of Aluminium intake are taken into account, such as cosmetic products containing Aluminium and uncoated food contact materials, the total intake in all age groups can exhaust or even exceed the TWI. Consumers can influence the amount of Aluminium they consume. If you want to reduce your Aluminium intake, you should use Aluminium-containing antiperspirants and toothpastes that contain Aluminium sparingly. For food, the BfR recommends eating a varied diet and changing products and brands. This can help to reduce the risk of permanently high Aluminium uptake by individual highly stressed products. For other reasons, the BfR recommends, if possible, the exclusive breastfeeding of infants in the first six months of life. The BfR generally advises against the preparation and storage of acidic and salty foods in particular in uncoated Aluminium containers or Aluminium foil. If the named and avoidable inputs are reduced, health impairments are not to be expected for most consumers. The BfR recommends manufacturers to reduce the Aluminium input in food through suitable measures. This can include, for example, the use of low-Aluminium raw materials or low-Aluminium or coated materials for processing and packaging food. There are still great uncertainties in the BfR's risk assessment, as important data are still missing or can be interpreted in different ways. This concerns, for example, the question of how much Aluminium is actually absorbed through the skin, as well as the possible occurrence of certain long-term consequences of chronic Aluminium exposure [9].

In 2020, new scientific findings regarding the Aluminium transfer through the skin after the use of respective antitranspirants were published and evaluated by the European Commission Scientific Committee on Consumer Safety (SCCS). In light of the new data provided, the SCCS considers that Aluminium compounds are safe in antiperspirants and other cosmetic products. The SCCS considers that the systemic exposure to aluminium via daily applications of cosmetic products does not add significantly to the systemic body burden of Aluminium from other sources. Exposure to Aluminium may also occur from sources other than cosmetic products, and a major source of Aluminium in the population is the diet [4]. The BfR adopted its opinion in the light of such new results with statement 030/2020. Actually, the BfR had requested exactly such research already in 2014. Aluminium salts are an important ingredient in antiperspirants. They temporarily block the sweat pores so that there is no sweating under the armpits. They also have an antibacterial effect, so that the bacteria that normally decompose sweat do not come into play and the sweat odor is reduced. Aluminium chlorohydrate (ACH) is primarily used in antiperspirants. With the new studies, there are currently three human studies on the dermal bioavailability of Aluminium from ACH-containing antiperspirants. All three studies are based on measuring the concentration of Aluminium in the blood and / or urine. One difficulty in determining the dermal bioavailability of Aluminium is to distinguish which proportion of the amount of Aluminium in the body is due to absorption through the skin and which is due to the general background exposure to Aluminium from other sources (e.g. from food). Therefore, ACH-containing formulations were used in all three studies, which were marked with the extremely rare radionuclide aluminium-26. The most resilient value for the bioavailability provided the study from 2019. The absorption of Aluminium through the skin was found to have a bioavailability of 0.00192% of the amount of Aluminium applied. According to current scientific knowledge, adverse health effects from a regular use of ACH-containing antiperspirants are therefore unlikely. When assessing the risk of Aluminium, however, it is fundamentally important to consider the total intake via the various entry pathways such as food or products containing Aluminium for food contact. However, the contribution of Aluminium-containing antiperspirants to the overall exposure to Aluminium is significantly lower than previously assumed [10].

As a consequence of the latest findings, foodstuff has returned into the public debate to be the major contributor of Aluminium uptake by humans. BfR refers to the German "Pilot Total Diet Study", according to which in the ranking of the highly contaminated foodstuffs dark chocolate took second place, cocoa-containing beverage powder and cocoa powder took place 5, pralines took 6th place and nut nougat creams took 10th place [9]. This result makes the confectionery industry a main point of contact for the BfR and increases the pressure on the industry enormously.

Other risk assessors´ positions

The study by the National Institute for Public Health and the Environment of the Dutch Ministry of Health, Social Affairs and Sport comes to a different toxicity assessment of Aluminium than the EFSA and like the JECFA, states the provisional tolerable weekly intake, PTWI, as 2 mg/kg body weight/week. It is emphasized that a possible risk can only exist for certain vulnerable groups such as infants, young children and pregnant women [11].

As early as 2011, the WHO defined a TWI based on a NOAEL for Aluminium of 30 mg kg bw/day, which is classified as reliable from 2 mg/kg bw. It is also pointed out here that this value must also be adhered to when using food additives containing Aluminium [12].

The Belgian Scientific Committee of the Federal Agency for the Safety of the Food Chain (SciCom) took a different approach and calculated estimated acceptable concentrations (EAC) on the basis of scientific data. An EAC is a risk-based concentration limit that corresponds to the concentration of a substance that can be present in food without resulting in an appreciable risk or concern for public health. EACs can be used as a basis for the risk manager to set an action limit. An EAC for Aluminium is calculated for each identified food category by dividing the TWI of Aluminium by the 95th percentile consumption data of each food category considered. For example, the EAC for Aluminium in dark chocolate is 150 mg/kg, for milk chocolate 60 mg/kg, respectively [13].

Database for toolbox

The data on which this toolbox is based originate from an industrial project that encompasses the entire value chain from the cocoa harvest to chocolate production. The project comprised two parts: firstly, sampling in the country of origin and secondly, further processing of the cocoa in Europe. Specifically, the samples were taken directly on the cocoa farms in collaboration with a cocoa producer in Africa (Nigeria). The fermentation and drying process was also monitored directly on the cocoa farms. Finally, samples were taken from pre-cleaning and storage to transport to the ocean-going ship. Arriving in Europe (Netherlands), the sampling continued to cover potential Aluminium contamination whilst overseas transport. Interim storage and onward transport on a barge were also part of the sampling procedure. The further processing of the dried cocoa beans was then accompanied with a very large number of samples taken in a cocoa production plant in Germany. All steps of the pre-cleaning, debacterization, alkalization, roasting, de-shelling, crushing and winnowing, grinding and pressing as well as the resulting products press cake and cocoa butter were sampled. All samples were then analyzed for their Aluminium content in an accredited laboratory and the data were evaluated in the project consortium made up of cocoa and chocolate industry and the confectionery association.

Chemical analysis

The qualitative and quantitative determination of Aluminium in food is usually carried out using AAS (atomic absorption spectroscopy) or ICP-OES or -MS (inductively coupled plasma connected to optical emission spectroscopy or mass spectrometry). For this purpose, the sample must first be digested thermally or with acid. The determination is run in routine and judged to be dependably performed in accredited laboratories. Successful proficiency tests confirm the reliability of the analytical technique.

Cocoa farming

Cocoa is usually cultivated by small-scale farmers in addition to other commercially useful plants on areas of land sized 5 to 17 acres, yet it is frequently the main source of income. The majority of cocoa growers have families of 5 to 8 to feed. The cocoa growing regions are mostly remote and poorly developed or not developed at all.

Pods containing cocoa beans grow from the trunk and branches of the cocoa tree. Harvesting involves removing ripe pods from the trees and opening them to extract the wet beans. The pods are harvested manually by making a clean cut through the stalk with a well sharpened blade, often on the ground. The pods are opened to remove the beans within a week to 10 days after harvesting. In general, the harvested pods are grouped together and split either in or at the edge of the plantation. Sometimes the pods are transported to a fermentary before splitting. If the pods are opened in the planting areas, the discarded husks can be distributed throughout the fields to return nutrients to the soil. Some machinery has been developed for pod opening, but smallholders in general carry out the process manually on the ground. After extraction from the pod, the beans undergo a fermentation and drying process before being bagged for delivery [14].

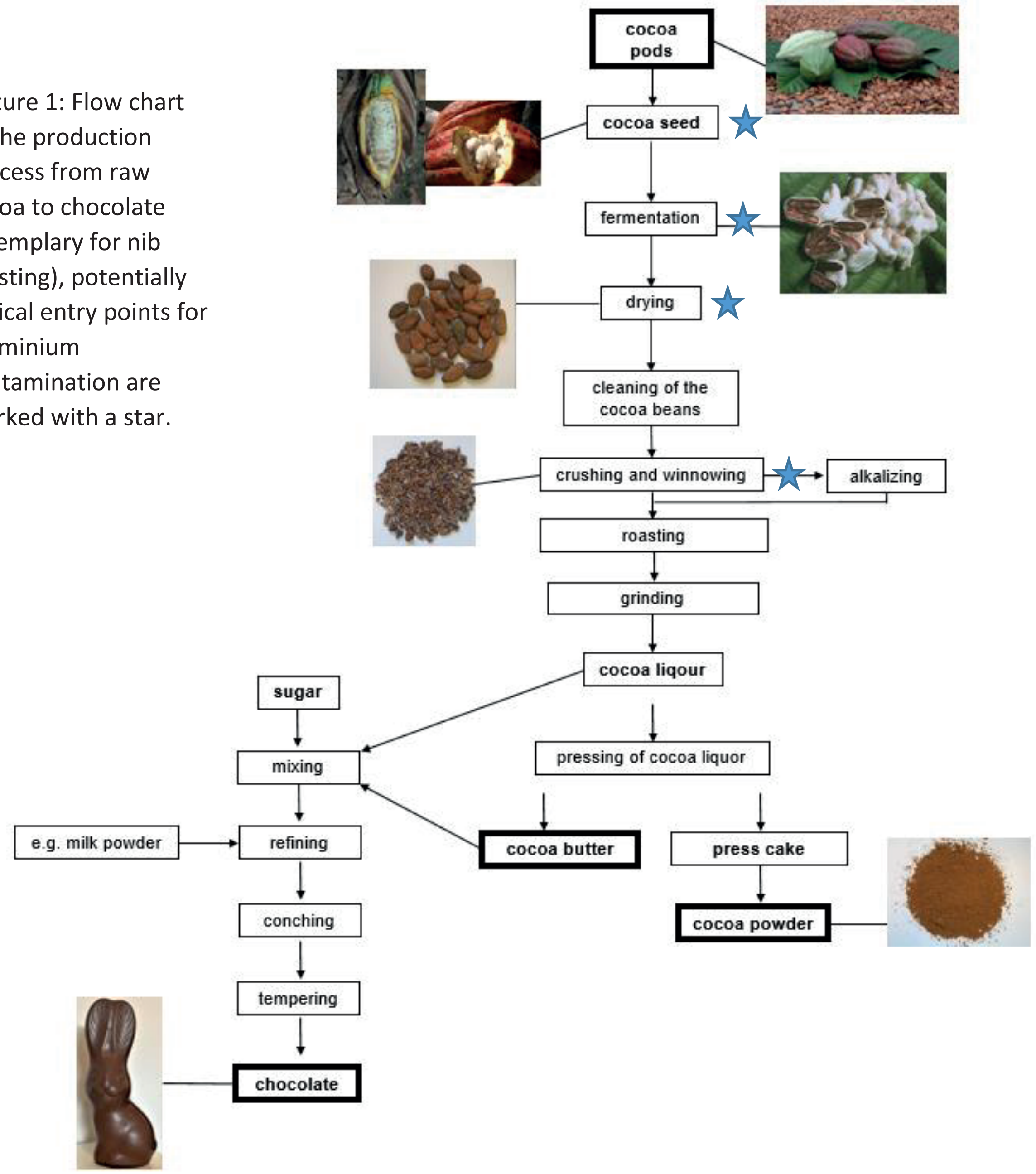
Fermentation can be carried out in a variety of ways, but all methods depend on removing the beans from the pods and piling them together or in a box to allow micro-organisms to develop and initiate the fermentation of the pulp surrounding the beans. The piles stored on the ground are covered by banana leaves. In the majority of cocoa growing regions piling on banana leaves is the most common method. The fermentation process begins with the growth of micro-organisms. In particular, yeasts grow on the pulp surrounding the beans. Insects, such as the Drosophila melanogaster or vinegar-fly, are probably responsible for the transfer of micro-organisms to the heaps of beans. The yeasts convert the sugars in the pulp surrounding the beans to ethanol. Bacteria then start to oxidise the ethanol to acetic acid and then to carbon dioxide and water, producing more heat and raising the temperature. The pulp starts to break down and drain away during the second day. In anaerobic conditions, the alcohol converts to lactic acid but, as the acetic acid more actively oxidises the alcohol to acetic acid, conditions become more aerobic and halt the activity of lactic acid. The temperature is raised to 40 °C–45 °C during the first 48 hours of fermentation. In the remaining days, bacterial activity continues under increasing aeration conditions, as the pulp drains away and the temperature is maintained. The process of turning or mixing the beans increases aeration and consequently bacterial activity. The acetic acid and high temperatures kill the cocoa bean by the second day. The death of the bean causes cell walls to break down and previously segregated substances to mix. This allows complex chemical changes to take place in the bean such as enzyme activity, oxidation and the breakdown of proteins into amino acids. These chemical reactions cause the chocolate flavour and colour to develop. The length of fermentation varies depending on the bean type, Forastero beans require about 5 days and Criollo beans 2–3 days [14].

Cocoa beans are dried after fermentation in order to reduce the moisture content from about 60% to about 7.5%. Drying must be carried out carefully to ensure that off-flavorous are not developed. Drying should take place slowly. If the beans are dried too quickly some of the chemical reactions started in

the fermentation process are not allowed to complete their work and the beans are acidic, with a bitter flavour. However, if the drying is too slow, moulds and off flavours can develop. Various research studies indicate that bean temperatures during drying should not exceed 65°C [14]. There are two methods for drying beans – sun drying and artificial drying using wood and fuel dryers. Sun drying is the oldest, cheapest, most popular, and freely available method that can be applied using the most rudimentary to highly sophisticated and scientific procedures, especially in the tropics and subtropics where solar radiation is abundant. Open sun drying is widely carried out by spreading the beans predominantly on the ground, on raised wooden mats and plastic sheets or on concrete floors during sunshine [15].

Production process

The flow chart below (picture 1) shows the production process from raw cocoa to finished chocolate. It provides an overview of the various production processes starting with the harvest in the countries of origin, the processing and finishing of the raw cocoa as well as the finalizing steps in industrial chocolate production.



Picture 1: Flow chart of the production process from raw cocoa to chocolate (exemplary for nib roasting), potentially critical entry points for Aluminium contamination are marked with a star.

Aluminium sources

The goal of the Aluminium industry project was to specifically look into the chocolate production process in detail to identify potential entry points for Aluminium. This should allow to close the knowledge gap on the reason for Aluminium contamination in chocolate taking into account, that the freshly harvested cocoa beans do not contain Aluminium as endogenous ingredient. Potential Aluminium sources identified from the project results are listed tabular in the next chapter. It is important to note that the entry sources do not have to occur either individually or in their entirety in the specific production process. Rather, the sources identified represent a list of possible critical process steps that can be used by the producers as a starting point for checking and evaluating their own process.

Tools

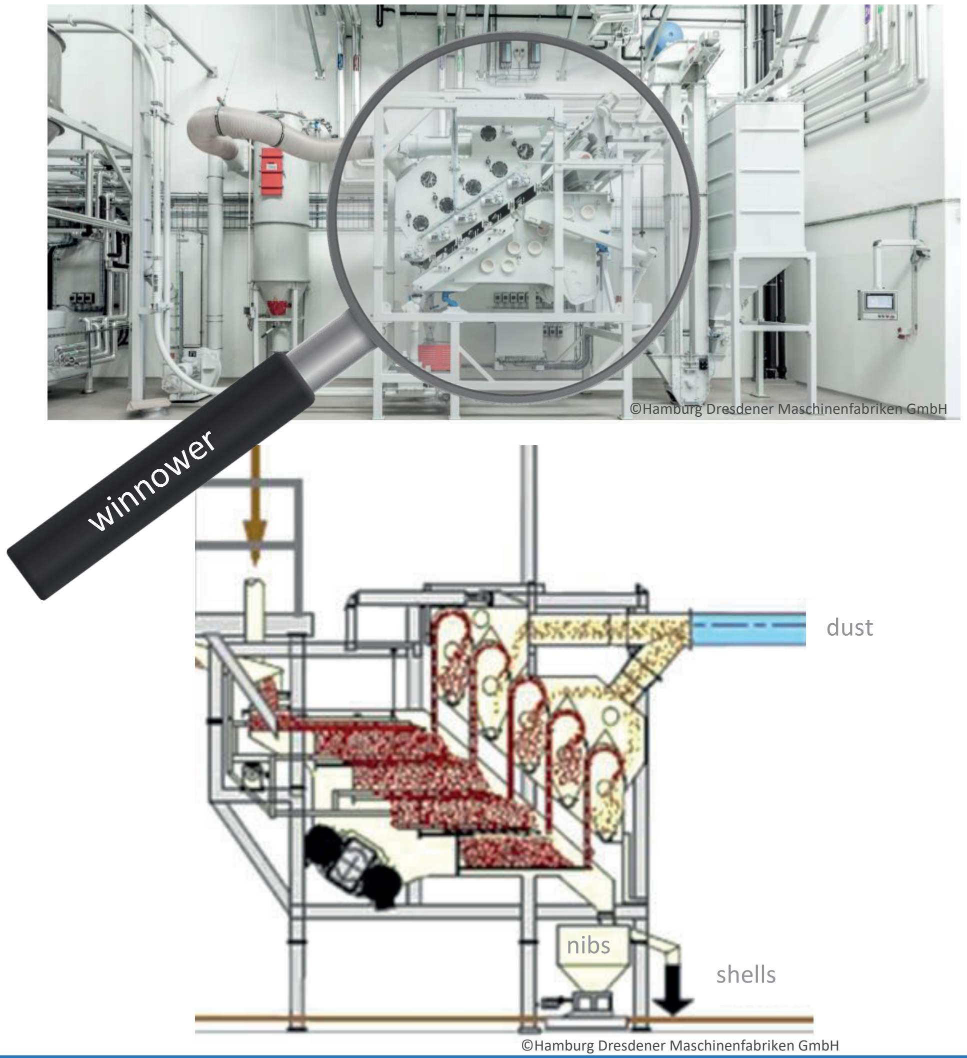
The compilation in table 1 summarizes the results of the industry project when it comes to identified Aluminium entry sources which are split in two sections: the country of origin and the subsequent cocoa converting process. For the latter, special attention is paid to the winnowing process. The pictures afterwards contrast widespread agricultural practice with alternative options. The proposed tools are intended to describe ways of reducing the Aluminium load at the specific point of entry. They cannot be generalized, but must be checked for applicability, practicability and prospect of success in the own supply chain and production processes. Since Aluminium is not detectable in the native cocoa fruit, the denomination "contamination" is used to describe the basic nature of Aluminium content in cocoa.

Table 1: Toolbox summarizing sources of Aluminium contamination and potential minimizing measures including a short substantiation

Toolbox Aluminium potential reduction of the contamination of Aluminium in chocolate		
source of contamination	**tool**	**reasoning**
country of origin avoid source of contamination, minimize introduction of dust (e. g. sand and soil) into the process		
harvesting procedure	move harvesting activities (e.g. opening of the fruits) from the ground	avoid transfer soil and sand on beans natively free of Aluminium in the fruit
environment	use of fermentation boxes	banana leaf fermentation on the ground increases environmental influence
environment	use drying tables / tents	raising drying process from the ground and shielding (still ensuring effective drying) reduces dust transfer by wind
organizational	centralize processing steps in cooperatives	controlled processing allows higher quality adjustment options
organizational	perform trainings following the rules of Good Agricultural Practice	optimized and standardized handling procedures reduce contamination
processing of cocoa liquor remove contamination on the shell, fast implementation of reduction measure independent from origin		
cocoa shell	effective cleaning of the beans prior to further processing	remove more dust, sand, soil, stones, foreign bodies (e.g. metal) to reduce potential transfer on the nibs
production procedure	optimization of bean humidity prior to roasting / processing	effective / technological achievable separation of shell from nibs
production procedure	optimize shell separation process (e.g. winnowing)	prevent Aluminium-containing dust entering the nibs fraction

Winnowing process

Winnowing refers to a mechanical separation process in which particles are separated based on their ratio of inertia and / or gravity to flow resistance in a gas flow. It is a sizing process and uses the principle of gravity or centrifugal separation. Fine particles follow the flow, coarse particles follow the inertia force. In practice, unavoidable random influences such as spatial and temporal fluctuations in the flow field, mutual particle collision, fluctuations in the infeed quantity, speed and direction affect the separation limit and accuracy [16]. As a result, the theoretical separation parameters can never be achieved to 100%. The different separation fractions always contain proportions of smaller and larger particles.



Explanatory pictures

The pictures show a comparison of current practice in cocoa processing (left) and possibilities to reduce Aluminium content on cocoa shell (right).


opening cocoa pods on the ground


opening cocoa pods on tables / in boxes


fermentation in banana leaves on the ground


use of fermentation boxes


conventional drying on the ground


shielded drying on tables

This toolbox was developed by the Food Chemistry Institute in Cologne, belonging to the Association of the German Confectionery Industry with the strong support of stakeholders along the complete cocoa production chain.

In case of questions and suggestions, feel free to contact:

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Abbreviations

AAS	atomic absorption spectroscopy
BDSI	Association of the German Confectionery Industry e. V.
BfR	German Federal Institute for Risk Assessment
CAOBISCO	Association of Chocolate, Biscuit and Confectionery Industries of Europe
EAC	estimated acceptable concentration
ECA	European Cocoa Association
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organization of the United Nations
FCC	Federation of Cocoa Commerce
ICP-MS	inductively coupled plasma connected to mass spectrometry
ICP-OES	inductively coupled plasma connected to optical emission spectroscopy
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LCI	Food Chemistry Institute of BDSI
NOAEL	no observed adverse effect level
SciCom	Belgian Scientific Committee of the Federal Agency for the Safety of the Food Chain
SCCS	Scientific Committee of Consumer Safety of the European Commission
TWI	tolerable weekly intake
WHO	World Health Organization

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