



Drinking your Greens: Green Smoothies from a Nutritional and Toxicological Point of View

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Abstract

Green smoothies often contain beneficial ingredients (e.g. vitamins, minerals and fibers) and can enrich the daily diet. However, with regard to the selection of ingredients, some points should be considered in order to avoid health risks. First, it has to be kept in mind that a high fruit content may result in a considerably high energy intake. In principle, only plants or parts thereof should be used in smoothies which have also been used traditionally as foods and, therefore, are regarded as safe. Further, all ingredients should be used with as much variety as possible in order to avoid an unbalanced nutrient supply and to avoid a high long-term intake of potentially harmful substances. Special care should be taken when using self-collected wild herbs, since, among other things, confusion with poisonous plants may occur. It is also recommended to use ingredients as fresh as possible and to follow the general rules of kitchen hygiene.

Keywords: Green smoothies, health risks, plant toxins, contaminants, raw food

Introduction

A smoothie can be prepared quickly and is recognized as “natural and healthy”. Therefore, smoothies have become a real food trend. More than 15 million people in Germany consume smoothies once or several times a month [1]. The beverage has a notable role in the raw food diet, in which the consumption of raw and largely unprocessed plant food is of priority.

Freshly prepared green smoothies contain numerous nutrients – including vitamins, minerals and dietary fibers, and, therefore, can significantly contribute to a healthy diet. However, to avoid health risks, some points should be considered with regard to selecting ingredients and preparing the smoothie. For example, in addition to plants or parts thereof traditionally consumed as food, also ingredients that have not been eaten raw or at all in the past are used in smoothie recipes, and might pose a health risk.

This review should draw attention to the fact that the consumption of green smoothies may, in principle, also lead to health risks. In addition to the description of nutritional aspects and an overview of ingredients of potential health concern, recommendations for a safe preparation of smoothies are provided.

Nutritional aspects

The term “smoothie” is not legally protected and no binding definition exists. Therefore, there are no consistent rules which ingredients have to be added to the drink and at what quantities. Usually, a green smoothie consists of fruits as well as vegetables and/or greens that are mashed with water to a smooth purée. Hence the name “smoothie” – derived from the English word “smooth” [2].

Citation

Lietzow J: Drinking your Greens: Green Smoothies from a Nutritional and Toxicological Point of View. *Ernahrungs Umschau* 2022; 69(8): 126–35.

The English version of this article is available online:

DOI: 10.4455/eu.2022.024

Peer reviewed

Manuscript (original) submitted: 24. February 2022

Revision accepted: 02. May 2022

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Fruits	<ul style="list-style-type: none"> • Bananas • Apples, pears • Berries (including frozen foods) • Pineapple • Oranges • Oiwí • Grapefruit • etc.
Vegetables and leafy greens	<ul style="list-style-type: none"> • Salads (lettuces, rocket etc.) • Kale • Spinach, chard • Avocado • Chives, cress • Carrot green, radish leaves, kohlrabi leaves, beetroot leaves, celery leaves • Culinary herbs (parsley, basil, sage, etc.) • Wild herbs (dandelion, chickweed, nettle, sorrel, etc.) • Leaves of various trees and bushes (e.g. lime tree, blackberry, hibiscus)
Other Ingredients	<ul style="list-style-type: none"> • „Superfoods“ (goji berries, chia seeds, flaxseed) • Sweeteners (honey, stevia, dates, birch sugar) • Herbs and spices (culinary herbs, wild herbs, chilli, vanilla, cinnamon, cocoa, etc.) • Special water (coconut water, spring water, distilled water) • Matcha • Acerola • Ginseng • Activated charcoal • Medicinal herbs • Protein powder • Plant powder, e.g. wheatgrass powder

Tab. 1: Typical ingredients for the preparation of green smoothies [2], (Free web search)

Recipes often recommend the use of whole fruits, including the peel and the seeds. Some recipes also include other ingredients such as wild or culinary herbs, kernels, nuts, spices or so-called “superfoods” (table 1) [2]. “Superfoods” are not legally defined and are commonly understood as foods that have certain nutrient profiles, such as particularly high levels of vitamins, minerals or dietary fibers. However, the health-related claims associated with “superfoods” are often not scientifically proven [3].

Priority is often given to the health-promoting characteristics of smoothies, especially due to the high levels of vitamins, minerals, antioxidants and dietary fibers. As promised, smoothies, among other things, are intended to support, for example, the process of “detoxification” – a statement that has not been supported by scientific evidence [4].

In particular, green smoothies are also often used for weight-loss purposes due to their high proportion of vegetables, even if this is not always promising. The green juices can have a high energy content because of their high levels of naturally occurring sugars, especially through the added fruits. For example, a self-prepared smoothie with 200 g of leaf spinach, a banana and half an apple contains about 30 g sugar and more than 200 kilocalories [5] (table 2). Furthermore, “Stiftung Warentest” recently noted

that the content of natural sugars in green smoothies from retailers can vary between 5 and 11 g per 100 ml [6]. This is in the same order of magnitude as soft drinks, which usually contain 10 g sugar per 100 ml. The German Nutrition Society (DGE) recommends not to exceed a maximum intake of 50 grams of free sugars per day for adults (7). It makes little difference whether this is natural or added sugar.

In addition, energy-dense drinks such as fruit and vegetable juices result in a lower compensatory response to food intake than solid foods. For example, the satiating effect is less pronounced [8]. Fruits and vegetables contribute significantly to a healthy and diverse diet in daily life. The consumption of one glass of smoothie per day can supplement the diet. However, due to their high calorie content it is suggested not to consume fruit and vegetable smoothies in addition to the recommended five portions of fruit and vegetables per day, but to replace one portion occasionally [9].

Potential health risks resulting from the consumption of green smoothies

Plants naturally contain various ingredients, whose levels can also differ from plant part to plant part. As a result of this diversity, the plant ingredients are often not or insufficiently characterized toxicologically. Therefore, the safety of traditionally consumed foods is generally substantiated by the “history of safe use” [10]. On the other hand, for plants or parts thereof that have not been consumed so far, such information is usually not available. Thus, indications of harmful effects often arise only in relation to the occurrence of poisoning cases or intolerances. A particular problem: Potentially carcinogenic effects often remain undetected as such effects usually occur decades after the harmful substance was ingested.

Hence, a general estimation whether plants or parts thereof pose a health risk or not is usually not possible. In some cases, a bitter taste can be a simply perceptible indication for consumers concerning potentially toxic substances. However, this may not always be true-bitter-tasting compounds are not toxic per se, nor do all toxins have a bitter taste. Therefore, some points, that are described



Ingredients		1 banana		1/2 apple	Baby spinach	Lemon juice	Total*
Quantity		125 g		75 g	200 g	30 ml	
Water	g	94		64	185	28	370
Calories	kcal	123		46	54	6,6	229
Macronutrients							
Protein (total)	g	0,9		0,1	5,7	0,1	6,8
Fat (total)	g	0,4		0,1	1,2	0,1	1,8
Carbohydrates (total)	g	29		11	4,8	2,1	47
• Fiber	g	2,5		1,6	3,2	0,1	7,4
• Sugar (total)	g	20		8,9		0,8	30
of which sucrose	g	5,3		1,5		0,1	6,9
of which fructose	g	7,6		5,9		0,3	14
of which glucose	g	6,9		1,5		0,3	8,7
Minerals and vitamins							
Calcium	mg	6,3		5,3	136	1,8	149
Sodium	mg	4,0		0,5	222	0,3	227
Potassium	mg	408		80	1164	31	1682
Magnesium	mg	35		3,7	186	1,8	226
Phosphorus	mg	28		6,0	78	2,4	114
Vitamin C	mg	15		3,5	53	12	83
Iron	mg	0,4		< 0,1	2,5	< 0,1	3,0

Tab. 2: Nutritional profile of a green smoothie (sample recipe)

[source: U.S. Department of Agriculture, Agricultural Research Service. FoodData Central, 2019-2021]

* corresponds to about 2 servings (glasses), depending on the addition of liquids (e.g. 200 ml of water)

further below, should be taken into account when selecting the ingredients for green smoothies.

Toxicologically relevant substances in edible plants or parts thereof

Consumption of green smoothies can result in an intake of unusually large amounts of certain plant ingredients that are not taken up through the traditional consumption of plant-based food. In consequence, health risks may result from ingredients which are actually not a problem for healthy individuals if consumed in small quantities. Some of these examples are described below.

Oxalic acid

Plants belonging to the families Amaranthaceae (foxtail) and Polygonaceae (knotweed) are known for their high levels of oxalic acid. The best-known representatives are spinach, mangold, amaranth and quinoa, as well as sorrel and rhubarb. Some of these plants contain oxalic acid levels of more than 100, some have more than 500 mg per 100 g fresh weight [11].

Oxalic acid is an organic acid and its salts are called oxalates. While potassium and sodium salts are highly water-soluble, oxalic acid forms complexes of low solubility with some other minerals, such as calcium. Plant-based foods contain both soluble potassium oxalate and insoluble calcium oxalate [12].

In general, foods composed of vegetables rich in oxalic acid do not pose a health risk to healthy people when regularly consumed. However, when spinach, but also chard, is used in relatively large quantities (e.g. recipes with more than 200 g of leaf spinach per smoothie) as well as in unprocessed raw form in green smoothies, it can contribute to a very high intake of oxalic acid.

A high chronic intake of oxalic acid or its soluble salts can result, together with minerals, such as free calcium, in the formation of compounds with low solubility in the intestinal lumen which can lead to a deficiency of these minerals by the respective persons [11].

According to the European Food Safety Authority (EFSA), the dietary intake of more than 180 mg of oxalic acid per day significantly enhances the urinary oxalic acid excretion (hyperoxaluria) [13]. After systemic absorption, the oxalic acid can form calcium oxalate complexes with low-solubility, that may crystallize in the kidney at higher concentrations, which may in turn lead to an increase of the risk of kidney, urinary or bladder stones. A low urine volume and a low urine pH as well



as deficits in the supply of minerals can promote the formation of stones. The simultaneous intake of calcium-rich foods (e.g. dairy products or calcium-rich mineral water) counteracts the systemic absorption of oxalic acid as a consequence of the formation of low-soluble calcium oxalate complexes in the intestinal lumen, which are then eliminated via feces. However, as described above, this also reduces the absorption of calcium [12].

Acute poisonings caused by the intake of foods rich in oxalic acid are not widely known. However, the scientific literature describes cases in which a high consumption of oxalate-rich foods (more than 1 g oxalate intake per day), e.g. via green vegetables or juices, over an extended period of time caused kidney damage – in most cases in people with pre-existing renal damage [14–16].

Soaking or cooking vegetables markedly reduces the content of oxalic acid (30–87%) because the water-soluble oxalic acid passes into the cooking water [11]. However, smoothies are usually made with raw ingredients, and therefore, the intake of oxalic acid can be relatively high [17].

Nitrate and nitrite

Leafy greens such as spinach, chard or rocket belong to the nitrate-accumulating plants and may contain high levels of nitrate, depending on season and cultivation area [18]. Nitrate can be converted to nitrite either in the food itself or in the human body (by nitrate-reducing bacteria in the mouth or gastro-intestinal tract, or enzymatically). Nitrite reduces the ability to transport oxygen through the red blood cells, because it oxidizes hemoglobin to methemoglobin which is no longer capable to reversibly bind oxygen. This may result in an inadequate oxygen delivery to the tissues, which can be particularly dangerous for infants [19]. In addition, nitrite may contribute to the formation of a group of compounds known as nitrosamines, some of which are considered carcinogenic [20].

EFSA derived an acceptable daily intake for nitrate of 3.7 mg per kg of body weight and for nitrite of 0.07 mg per kg of body weight [20, 21]. A daily nitrate intake of 260 mg over a lifetime is therefore unlikely to cause adverse health effects in a person with a body weight of 70 kg. In order to protect consumers, EU-wide maximum levels are set for nitrate in various leafy vegetables such as spinach and fresh lettuce [22]. Nevertheless, these foods contribute to an overall high nitrate intake.

Nitrate levels in foods can vary depending on growing conditions and season. For example, depending on the sunlight exposure, field vegetables (leafy greens/lettuces) and vegetables harvested in summer have lower levels of nitrate compared to vegetables harvested in the greenhouse or in winter [23]. Analysis of lettuces and leafy greens grown in the greenhouse showed average nitrate concentration of 2,950 mg/kg. By comparison, open-field lettuces and leafy greens had up to 37% lower nitrate values – the average concentration was 1 865 mg/kg [24]. In addition, nitrogen fertilization also plays a major role in terms of nitrate accumulation in plants. In organic farming the use of mineral nitrogen fertilizer is not allowed, therefore organic vegetables usually have lower nitrate levels [25].

Non-digestible carbohydrates in raw cabbages

Cabbage varieties have always been used in meals such as stews and soups or to make sauerkraut. In addition to numerous vitamins and minerals, they contain lots of fibers and secondary plant ingredients such as the pungent mustard oil glycosides, also known as glucosinolates. Cabbages, e.g. kale, are also often used as an ingredient in green smoothies due to their high nutrient content [26]. It is generally known, that the consumption of cabbages may lead to gastrointestinal complaints such as flatulence, diarrhea and feeling of fullness up to abdominal pain, dependent on the intake level. The reason for these symptoms may be the non-digestible carbohydrates in cabbage (e.g. raffinose in kale) which are not or not completely enzymatically hydrolyzed and reach the colon undigested or not completely digested, and are then fermented by bacteria. Odorless gases such as carbon dioxide, hydrogen and methane can thereby be formed which can lead to severe flatulence and are thus the cause of the symptoms described [27, 28].

Traditionally, various cabbage meals are seasoned with ingredients such as savory, dill, fennel or caraway seeds to alleviate flatulence symptoms. In addition, soaking and cooking vegetables can reduce the level of non-digestible fibers [29, 30]. In general, the severity of gas production after intake of cabbages in healthy people is very different and depends, among other things, on the individual metabolic activity and the composition of the intestinal flora [31]. Therefore, the digestibility of (raw) cabbage differs individually and should be considered when using cabbages in smoothies.

Goitrogens

Various vegetables of the Brassica family, including cabbages, may contain goitrogenic substances. These compounds can impair the iodide uptake by the thyroid gland and the synthesis of thyroid hormones. This can especially occur when large quantities are consumed and in cases of simultaneous iodine deficiency. However, the presence of those substances varies between the different Brassica plants and is considerably dependent on the methods of processing and preparation [32, 33]. People with thyroid diseases (e.g. enlargement of the thyroid gland) and simultaneous iodine deficiency should therefore avoid frequent and excessive consumption of (raw) cabbages.



Interactions between plant ingredients and drugs

People taking drugs should consider that some plant ingredients may lead to interactions with certain drugs – either by reducing their effect or by enhancing the side effects. The consumption of green smoothies can lead to relatively high intakes of such plant ingredients.

An example of an interaction is vitamin K in leafy greens, which can reduce the effect of some anticoagulant drugs (e.g. phenprocoumon or warfarin). In addition, goji berries contain substances that may also interact with anticoagulant drugs such as phenprocoumon. Another example is the St John's Wort listed in different recipes, which may, among other things, interfere with the effect of oral contraceptives ("pill"). Further, furocoumarins occurring in citrus fruits can affect the bioavailability of drugs by inhibiting their enzymatic degradation and thus increase the risk of adverse reactions [34]. The relevance of such interactions in the context of the consumption of green smoothies has not been studied systematically. However, a clinically relevant interaction potential is realistic due to the potentially high intake of secondary plant ingredients via the consumption of green smoothies.

Use of parts of plants usually not consumed

General conclusions regarding possible health risks due to the use of plant parts that are usually not consumed, such as leaves, stems, rinds or pits, cannot be made. In many cases, the consumption of such parts does probably not pose a health risk – but this might not always be the case. Important to note: Parts of plants can contain harmful substances even if other parts are safe. Potatoes and tomatoes are given here as an example. Usually, the potato tuber or tomato regularly consumed contains low levels of toxic glycoalkaloids, like α -solanine, which protect the plant against harmful organisms (pests). However, higher levels can be found in the leaves. For example, the potato tuber usually has a glycoalkaloid content below 150 mg/kg, whereas the leaves can contain up to 1,000 mg/kg and flowers and sprouts can even reach several thousand mg/kg. Intake of 1 mg/kg body weight or more can lead to acute poisoning effects, such as gastrointestinal symptoms [35].

Risk to human health can also be related to the **kernels** of certain fruits. For example, while the seed kernels of the watermelon can be consumed without presenting an appreciable risk, the kernels of almost all stone fruit species (e.g. almond, apricot, plum, apple) contain so-called cyanogenic glycosides such as amygdalin, that can release cyanide upon consumption [36, 37]. As often, the dose makes the poison: The intake of few apple seeds, e.g. by eating a single apple, does usually not represent a health problem. On the other hand, it is not recommended to consciously consume larger quantities or larger kernels of stone fruits (e.g. apricot kernels, bitter almonds) because this might result in problematically high intake levels. For adults, the consumption of two bitter apricot kernels or one bitter almond is considered safe. In contrast, such quantities can already have serious consequences for young children and, dependent on the dose, can lead to clinical signs of toxicity including headache and dizziness,

up to dyspnea, convulsions, coma and death [38]. Beside stone fruit kernels, flax seeds contain cyanogenic glycosides, too. However, intake levels of 15 g per meal are considered safe because the amount of cyanide released can easily be detoxified by the body [39].

Avocado pits are also frequently claimed to be used as an ingredient in smoothies. A well-known ingredient in all over-ground plant parts of the avocado, including the fruit, is persin. It is known that persin can lead to poisonings in various domesticated species and livestock—for humans it is considered non-toxic [40]. However, the available data are not sufficient to conclusively assess potential risks. The authors have currently no evidence regarding the occurrence of adverse health effects in humans when eating avocado pits—poisoning cases have not yet been documented.

Moreover, it should be considered that leaves and stems used for smoothies can contain higher levels of pesticide residues or environmental contaminants than the parts of the plant usually consumed as food. According to the Federal Office of Consumer Protection and Food Safety (BVL), for example, multi-residues of pesticides were detected more frequently in the leaves of kohlrabi or radishes in 2020 than in the corresponding edible tubers [41].

In the European Union, maximum residue levels have been set for pesticides to ensure the safety of consumers. However, the levels often have only been set for plant parts usually consumed, and accordingly are monitored only for these parts [42]. Organic fruits and vegetables usually have lower levels of pesticide residues than conventional products [43].

Use of wild plants

Other ingredients that are often used for green smoothies are wild herbs, wildflowers or blossoms. In this case, it is very important to inform yourself beforehand about the used plants. In principle, there are two potential risks by using wild herbs and wildflowers:

- Some herbs, regarded as edible, contain harmful substances. For example, borage, coltsfoot and comfrey contain so-called pyrrolizidine alkaloids, which are mutagenic and carcinogenic. A safe level of intake cannot be identified for these



Edible wild herbs	Poisonous or inedible plants	Toxic ingredients	Adverse effects
Wild garlic (<i>Allium ursinum</i>)	Lily of the valley (<i>Convallaria majalis</i>)	Cardiac glycosides (e.g. convallatoxin)	Gastrointestinal symptoms, cardiac arrhythmia
	Meadow saffron (<i>Colchicum autumnale</i>)	Alkaloids (e.g. colchicine)	Painful swallowing, gastrointestinal symptoms, seizure, paralysis
Wild chervil (<i>Anthriscus sylvestris</i>), Yarrow (<i>Achillea millefolium</i>)	Hemlock (<i>Conium maculatum</i>)	Alkaloids (e.g. coniine)	Burning sensation in the mouth, gastrointestinal symptoms, seizure, paralysis
Comfrey (<i>Symphytum officinale</i>)	Foxglove (<i>Digitalis</i> spp.)	Cardiac glycosides (e.g. digoxin)	Gastrointestinal symptoms, cardiac arrhythmia, hallucinations
Corn mint (<i>Mentha arvensis</i>)	Pennyroyal mint (<i>Mentha pulegium</i>)	Essential Oil (e.g. pulegone)	Liver injury
Dandelion (<i>Taraxa- cum officinale</i>)	Ragwor (<i>Senecio</i> spp.)	Pyrrolizidine alkaloids	Liver injury, possibly carcinogenic

Tab. 3: Possibilities of confusion between edible wild plants and toxic or inedible plants [46]

substances according to the current state of knowledge. The intake of these substances should therefore be as low as possible [44, 45]. Accordingly, these herbs should only be exceptionally used in smoothies. Vulnerable population groups such as pregnant and breastfeeding women or young children should better avoid the use of these herbs.

- A further risk might exist with respect to the possibility of confusion between certain wild herbs and known poisonous plants (table 3). One example: Confusion of leaves of wild garlic with those of lily of the valley or meadow saffron. Both lily of the valley and meadow saffron contain strong toxins, which can also lead to fatal poisoning [46]. There is also a possibility of confusion between cows parsley and poison hemlock as well as yarrow and poison hemlock and many other wild herbs. The consumption of poison hemlock causes death by suffocation already after a short time [46]. Recently, a case of poisoning has been reported in which a 43-year-old woman showed symptoms of poisoning after drinking a smoothie prepared from collected wild plants, likely due to the confusion of common sorrel with the poisonous plant foxglove [47].

“Exotic” ingredients

Aloe vera leaves

The leaves of plants of the genus *Aloe* have been considered as remedy for centuries, e.g. for the treatment of sunburn and skin eczema, and, more recently, are also used as an ingredient in smoothies. With regard to consumption it should be noted that the juice of the leaf rind of plants of the genus *Aloe* contain anthranoids (syn. anthraquinones) which have a laxative effect at higher doses. In addition, there is some evidence that these substances could be carcinogenic. However, the gel obtained from the inner gel layer does not contain anthranoids [48].

Therefore, only the inside layer of the leaf, i.e. the plant gel, should be used for *Aloe vera* preparations. Nevertheless, anthranoids can pass from the leaf bark into the gel even when carefully prepared, thus, it is advisable not to use self-made *Aloe vera*

gels [49]. From a toxicological point of view, whole leaves of *Aloe vera* are generally not suitable for consumption. *Aloe vera* products from retailers have to comply with food law and should be preferred here.

Water lentils

An exotic ingredient for green smoothies are water lentils, commonly called duckweed. Originally and primarily consumed in Asian countries, the green flowering plants have also been included in various smoothie recipes for some time now. The small water lentils have a favorable amino acid and fatty acid composition, and otherwise consist of more than 90% water. In addition, they can efficiently absorb essential minerals from the water or culture medium. However, they also accumulate toxic substances, such as heavy metals, and therefore, are used for wastewater treatment or phytoremediation [50, 51].

Ideas for recipes with “self-harvested” or “self-cultured” water lentils are commonly found in online forums. However, usually it is not described what exact type of the five known genera should be used as an ingredient. Due to the characteristics described above, it is not advisable to culture water lentils on its own or to collect them from ponds because several environmental contaminants can be absorbed depending on the water quality.

In the EU, water lentils are considered as novel foods and, as such, require pre-market authorization. Recently, the water len-



til species *Wolffia globosa* and *Wolffia arrhiza* have been authorized in the EU and thus can be marketed in the future [52].

Black Smoothies

Another trend are “black smoothies”. They are intended to detoxify the body and have been reported to help, for example, against symptoms of excessive alcohol consumption [53]. In many recipes, the addition of 1/2 teaspoon of activated charcoal is suggested to prepare a “black smoothie”. This amount already corresponds to the dose used for pharmaceutical purposes, as activated charcoal is mainly used to treat diarrhea and certain kinds of intoxications [54]. Due to its large surface area, the charcoal can bind various (harmful) substances within the gastrointestinal tract which are then excreted with the feces [55].

Due to its very non-specific mode of action (adsorption of organic compounds by van der Waals forces) [56] it is assumed that large amounts of activated charcoal in smoothies can lead to nutrient deficiency (e.g. vitamins), albeit scientific studies regarding undesirable effects in relation to the intake of activated charcoal via foods are limited. Principally, charcoal can also affect the efficacy of drugs (including contraceptives or painkillers) and can lead to constipation [57].

Activated charcoal (vegetable carbon) is also used in the food industry as food colour E153 (carbo medicinalis vegetabilis) in some food categories [58]. However, the amounts of vegetable carbon used here are usually much lower compared to “black smoothie” recipes. In general, regular consumption of activated charcoal in larger quantities is not recommended due to the effects described.

Plant-based powder mixtures

Plant-based powder (mixtures) can also be part of green smoothie recipes and are promoted to some extent as “superfood” powder. Examples include moringa powder, barley and wheatgrass powder, spirulina powder or guarana or matcha powder.

It should be noticed that these herbal powders possibly can contain high levels of certain substances, such as caffeine from guarana seeds or matcha tea leaves. One teaspoon (about 1.5 g) guarana powder can contain as much caffeine as about a cup of coffee [59, 60].

It has been shown that matcha powder may contain high levels of aluminium and thus, can cause a relevant contribution to the already high dietary intake of aluminium. The European Rapid Alert System for Food and Feed RASFF also reported on contamination of moringa powder or spirulina powder with heavy metals, carcinogenic polycyclic aromatic hydrocarbons (PAH) and other toxins [41, 61].

Microbial risks

The preparation of green smoothies using fresh fruits and vegetables and other plants or parts thereof should in any case comply with the general rules of kitchen hygiene.

During cultivation as well as during further treatment and processing, plant-based ingredients can be contaminated with germs. For this reason, the plant-based foods should be washed thoroughly in fresh water before cutting. Freshly produced green

smoothies should also be stored at a maximum temperature of 7 °C until consumption and should be used on the day of manufacture. The addition of sour juices or citrus fruits (without peel) can reduce the proliferation of microorganisms [62].

Moreover, prepackaged frozen berries from retailers can also pose a risk for foodborne infections. Microorganisms associated with foods from frozen berry mixtures frequently cause serious diseases. For example, norovirus can cause severe diarrhea. Therefore, it is recommended not to use raw frozen berries in smoothies, and to heat them beforehand in order to inactivate potential microorganisms [63].

Furthermore, bacteria can convert nitrate contained in smoothies to nitrite in case of improper storage and/or neglect of common hygiene practice. A high nitrate or nitrite intake can be dangerous especially for young children, because of inadequate oxygen delivery (methemoglobinemia) [19, 64]. For this reason, the leftovers of smoothies containing vegetables rich in nitrate should be cooled down as quickly as possible in order to reduce nitrite formation by microorganisms.

Especially sensitive consumer groups, such as immunocompromised individuals, pregnant and breastfeeding women and (young) children should follow the general rules of kitchen hygiene [65].



Conclusion

Green smoothies represent a significant contribution to the overall intake of fruits and vegetables, and can enrich the daily diet. They often contain numerous beneficial ingredients – especially when prepared freshly. From a nutritional point of view, however, it should be noted that especially smoothies rich in fruits contain high levels of naturally occurring sugar resulting in a significant energy intake. Care should be taken regarding freshness and compliance with good kitchen hygiene when using the ingredients. It is recommended to restrict the choice on plants or parts thereof in smoothies, which are also traditionally consumed as food and can therefore be considered as safe. In this context, plant-based ingredients usually eaten raw are particularly suitable. Special caution is important when laypeople collect wild herbs, as there is a possibility of confusion between some wild herbs and poisonous plants. It is generally recommended to use varying kinds of fruits, vegetables and other plants or parts thereof in order to avoid an unbalanced nutrient supply on the one hand and to avoid a long-term high intake of potentially harmful substances on the other hand.

Conflict of interest

The authors declare that there is no conflict of interest.

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