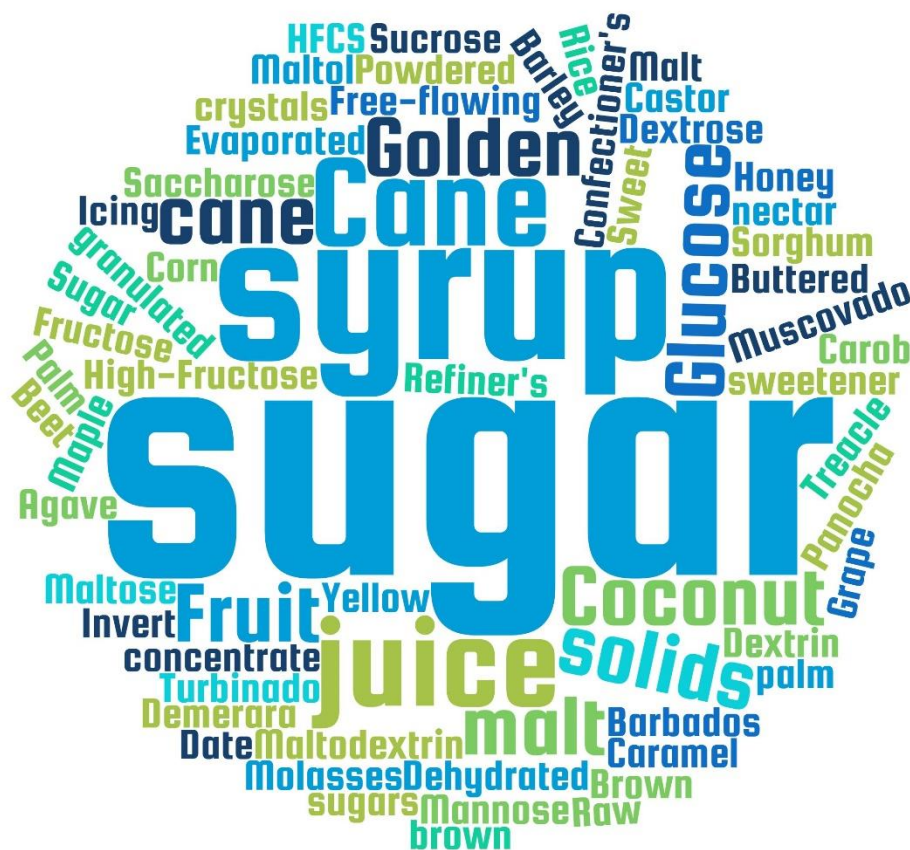


# The sugar debate: naturally occurring sugars vs free sugars



Debbie Tijsterman

Bachelor thesis

# The sugar debate: naturally occurring sugars vs free sugars

A literature research on Western dietary sugar consumption and the health effects on  
overweight and obesity

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This thesis is written for every individual who consumes a typical Western diet, who might be concerned with their current sugar consumption, who are looking for more insight into the subject. Using the skills that I developed over the last few years, putting these into practice and offering these people a report that could provide that insight, has made me work determinately on this thesis.

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The adventure of writing this thesis was mine, but the pleasure of reading it is all yours!

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## Content

Acknowledgement.....	2
Glossary .....	4
Abstract – English .....	5
Abstract – Dutch.....	6
1. Introduction.....	7
2. Study design .....	12
3. Results .....	16
3.1. How can overnutrition lead to overweight and obesity?.....	16
3.2. What happens to naturally occurring sugars and free sugars in the body? .....	18
Potential metabolic differences between naturally occurring sugars and free sugars.....	18
Glucose metabolism .....	19
Fructose metabolism .....	20
3.3. How does the consumption of fresh, dried, or juiced fruit affect overnutrition? .....	21
Fresh fruit consumption .....	21
Dried fruit consumption .....	23
Fruit juice consumption.....	23
3.4. How does the consumption of sugar sweetened beverages affect overnutrition?.....	24
4. Discussion .....	27
4.1. Overnutrition, overweight and obesity .....	27
4.2. Naturally occurring sugars and free sugars .....	28
4.3. Fresh, dried or juiced fruit and overnutrition .....	28
4.4. Sugar sweetened beverages and overnutrition .....	29
4.5. Study design .....	29
5. Conclusion .....	31
5.1. How can overnutrition lead to overweight and obesity?.....	31
5.2. What happens to naturally occurring sugars and free sugars in the body? .....	31
5.3. How does the consumption of fresh, dried, or juiced fruit affect overnutrition? .....	31
5.4. How does the consumption of sugar sweetened beverages affect overnutrition?.....	31
5.5. Relevance of results .....	32
6. Recommendations.....	33
References.....	34

## Glossary

5-a-day	Health program in countries such as the UK, USA, France and Germany to promote nation wide increase consumption of fruits and vegetables
Adipogenesis	Lipid accumulation; pre-adipocytes (fat cells) become adipocytes
Adipose tissue	Fat tissue
Ghrelin	'Hunger hormone'; when the stomach is empty, the secretion of ghrelin notifies the hypothalamus the body needs food
Glycemic index (GI)	An indication of how fast blood glucose rises, and glucose reaches the blood. Carbs that are metabolised faster, and reach the blood stream faster, have a high GI ( $\geq 70$ ); carbs that are metabolised slower have a lower GI ( $\leq 55$ ).
Hepatic	Liver
Insulin	Hormone that promotes the uptake of glucose into liver, fat and skeletal muscle tissue.
Iso caloric meal	A meal with similar caloric values [compared to another meal]
Leptin	'Satiety hormone'; regulates energy expenditure mainly by inhibiting hunger (antagonist to ghrelin).
Pancreas	Organ that secretes different hormones, such as insulin
Peer-reviewed	Evaluation of a written work by one or more people with similar competence to the writer of the work.
Postprandial	After consuming a meal

## Abstract – English

**Introduction** | The prevalence of obesity has almost tripled in the last four decades and is therefore an increasing threat to human health. Overnutrition – the excessive consumption of energy or nutrients, exceeding energy requirements – is believed to be one of the root causes of overweight and obesity. In literature, it is suggested that the type of sugar, either naturally occurring or free, can trigger different reactions in the human body and influence overnutrition. Therefore, this thesis aimed to answer the following research question: *How can the consumption of products high in naturally occurring sugars and the consumption of products high in free sugars affect overnutrition<sup>2</sup> in adults over 18 years old on a Western diet?*

**Study design** | The thesis followed a similar approach as that of a literature review. For each sub question, keywords and search combinations were prepared. Potential eligible data had to match a set of inclusion criteria. Literature deemed useful was analysed in a matrix format, assigned per sub question. The four sub questions formulated were: 1. How can overnutrition lead to overweight and obesity? 2. What happens to naturally occurring sugars and free sugars in the body? 3. How does the consumption of fresh, dried, or juiced fruit affect overnutrition? 4. How does the consumption of sugar sweetened beverages affect overnutrition?

**Results** | 1. Overnutrition can lead to overweight and obesity through a continues positive energy balance. 2. Naturally occurring sugars trigger a normal satiety response and stimulate insulin mediated processes, while free sugars do not and stimulate hepatic *de novo lipogenesis*, which results in accumulating adipose tissue 3. Fresh and dried fruit consumption can maintain weight status or induce weight loss, while fruit juice can result in weight gain. 4. Sugar sweetened beverages can positively affect weight gain.

**Conclusion** | Products high in naturally occurring sugars can balance or negatively affect overnutrition, while products high in free sugars are likely to positively affect overnutrition.

**Recommendations** | Add more fresh and dried fruit to your daily diet and make your own fruit juice by tossing fresh fruit in a blender. Try to track your total calorie intake for a few days to check if your energy intake is balanced and gradually decrease (excessive) sugar sweetened beverage intake.

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<sup>2</sup> Overnutrition can result in many different diseases; the focus of this thesis was on overweight and obesity.

## Abstract – Dutch

**Introductie** | De prevalentie van obesitas is in de afgelopen vier decennia bijna verdrievoudigd en is daarom een steeds grotere bedreiging voor de volksgezondheid. Overvoeding – overmatige consumptie van energie of voedingsstoffen, waarbij de energiebehoefte wordt overschreden – wordt verondersteld als een van de hoofdoorzaken van overgewicht en obesitas. In de literatuur wordt gesuggereerd dat verschillende type suikers, van nature aanwezige suikers of vrije suikers, verschillende effecten hebben op het menselijke lichaam en overvoeding. De hoofdvraag van deze scriptie luidt daarom als volgt: *Hoe kan de consumptie van producten met veel natuurlijke suikers en producten hoog in vrije suikers overvoeding<sup>3</sup> beïnvloeden in volwassenen boven de 18 jaar op een Westers dieet?*

**Onderzoeksopzet** | De opzet van deze scriptie was gelijkwaardig aan dat van een literatuuronderzoek. Voor elke deelvraag waren er zoektermen en combinaties opgesteld. Eventueel bruikbare data moest voldoen aan een aantal inclusiecriteria. Bruikbare data werd verwerkt in een matrix, die aangaf welke deelvraag de bron zou beantwoorden. De vier deelvragen luiden als volgt: 1. Hoe kan overvoeding leiden tot overgewicht en obesitas? 2. Wat gebeurt er met natuurlijke suikers en vrije suikers in het lichaam? 3. Hoe kan de consumptie van vers, gedroogd of fruitsap overvoeding beïnvloeden? 4. Hoe kan de consumptie van suikerhoudende dranken overvoeding beïnvloeden?

**Resultaten** | 1. Overvoeding kan leiden tot overgewicht en obesitas door een positieve energiebalans te creëren. 2. Natuurlijke suikers induceren een verzadigingsgevoel, evenals insuline gemedieerde reacties. Vrije suikers induceren deze reacties niet, echter induceren ze wel hepatische *de novo lipogenesis*, wat kan leiden tot overtollig vetweefsel. 3. Vers en gedroogd fruit kunnen een gezond gewicht behouden of gewichtsverlies veroorzaken, terwijl fruitsap gewichtstoename kan veroorzaken. 4. Suikerhoudende dranken kunnen gewichtstoename veroorzaken.

**Conclusie** | De meeste producten met veel natuurlijke suikers kunnen overvoeding negatief beïnvloeden, terwijl producten hoog in vrije suikers overvoeding positief kunnen beïnvloeden.

**Aanbevelingen** | Voeg meer vers en gedroogd fruit toe aan je dieet en maak je eigen fruitsap door vers fruit in de blender te doen. Houd je totale calorie inname bij voor een paar dagen, zodat je weet of je energiebalans goed is. Verminder (overdadige) consumptie van suikerhoudende dranken mettertijd.

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<sup>3</sup> Overvoeding kan leiden tot verschillende ziektebeelden; de focus ligt hier alleen op overgewicht en obesitas.

## 1. Introduction

*Sugar... modern day society cannot live with, nor without it. Especially not with it...*

Nowadays, an obesogenic environment is more common than ever. Already defined in 1999 by Swinburn and his colleagues, the obesogenic environment is “the sum of influences that the surroundings, opportunities, or conditions of life have on promoting obesity in individuals or populations.” (Swinburn, Egger, & Raza, 1999). With the prevalence of obesity almost tripled from 1975 to 2016, the disease has become an increased threat to human health. The precursor of obesity is overweight, and the WHO refers to these two as separate diseases. The difference between being overweight or obese has to do with the individual’s Body Mass Index [BMI]. BMI is calculated by the individual’s weight in kilograms divided by the square of the individual’s height in meters. An individual with a BMI of 25 or higher is classified as overweight, while an individual with a BMI of 30 and over is classified as obese (table 1.1., World Health Organization, 2018). (WHO, 2018).

TABLE 1.1. WEIGHT CLASSIFICATION BY BMI.

Classification	BMI (in kg/m <sup>2</sup> )
<b>Underweight</b>	< 18.5
<b>Normal range</b>	18.5 – 24.9
<b>Overweight</b>	≥ 25
<b>Obese</b>	≥ 30
<b>Class I obese</b>	30 – 35
<b>Class II obese</b>	35 – 39.9
<b>Class III obese</b>	≥ 40

Note. Original general table note. Reprinted from Global Database on Body Mass Index, BMI classification by World Health Organization, 2018. Copyright 2018 by World Health Organization.

Affecting countries all over the globe, a high BMI can be a root cause for many diseases such as type-2-diabetes, hypertension, cardiovascular diseases and certain cancers; and can lead to several psychological problems in individuals (WHO 2017; Eurostat, 2017; Sherry et al. 2010). Looking at the most recent global numbers from 2017, around 39% of the adult population (18 and over) are overweight, while 13% is obese (WHO, 2017). In Europe, most Member States have seen a rapid increase in the rate of weight problems and obesity in the past few years. In 2014, it was estimated that 51.6% of the European Union’s adult population were overweight (Eurostat, 2017). An additional 20% of the adult population is obese in Europe (WHO, n.d.). In the United States, the obesity rate differs state-to-state, but is still quite high throughout the country. Nationwide, around 38% of the adult population were obese in 2013-2014 (The State of Obesity, n.d.).

Simultaneously with the global rise in the prevalence of overweight and obesity, there has been an increasing interest in the scientific world to attempt to determine the potential mechanisms that could lead to these diseases. The WHO claims that one of the root causes is poor dietary intake, better known as malnutrition. Their definition of malnutrition states the following: “any deficiencies, excesses or imbalances in a person’s intake of energy and/or nutrients”. It can either present itself in the form of ‘undernutrition’ or ‘overweight, obesity and noncommunicable diseases [NCDs]’. (WHO, 2016). The four most common NCDs are cardiovascular diseases, cancers, chronic respiratory diseases and diabetes.



These, and other chronic diseases, are worldwide the leading cause of all deaths, accounting for nearly 40 million people each year – which is equivalent to 70% of all deaths annually in the world. (WHO, 2017).

Overnutrition is characterized by the consumption of energy or nutrients which exceeds requirements, to the point where it can lead to adverse health effects (“Overnutrition”, n.d.). Because this [food intake] exceeds the number of calories that a person burns off through physical activity, it can result in overweight and obesity. (National Health Service [NHS], 2016). There is accumulating scientific evidence that believes sugar is one of the root causes of the rise in BMI around the globe. From epidemiological associations it can be argued that there is a link between sugar intake and the prevalence of obesity (Johnson et al., 2007; Kaartinen et al., 2017). For instance, the wealthy were the first ones who could afford sugar, and the first group where obesity was prevalent. Moreover, countries where sugar was introduced to the public later, the obesity epidemic surfaces later as well. (Johnson et al., 2007). Excessive sugar consumption has been studied, and it has been identified as one of the determinants of weight gain (A Te Morenga & Mallard, 2013). Also, it has been suggested that sugar consumption exceeding the recommended intake set by national governments, puts an individual at a higher risk for developing obesity (Edwards, Rossi, Corpe, Butterworth & Ellis, 2016). Although there are presumably many causal factors for weight gain, such as physical inactivity and overeating, sugar is believed to play a major causal role (Johnson et al., 2007).

### **Current consumption patterns**

The extra calories that are typically consumed when overnutrition occurs, are usually high in energy, and/or processed foods that are loaded with saturated fats, salt and refined/added sugars. Additionally, many individuals do not consume the appropriate amounts of healthy products such as fruit, vegetables and whole grains. (National Health Service, 2016; WHO, 2015). These product groups do not only provide the necessary macronutrients, but also present the much-needed micronutrients to the body, such as dietary fiber, antioxidants, vitamins and minerals. As the name suggest, micronutrients are only needed in small amounts, but when a deficiency occurs, the consequences can be rather severe. Micronutrients are, among many things, essential for optimal brain functions; maintaining muscles, bones and nerves; and the immune system and blood circulation. (WHO, n.d.; Merz, 2016). Where a poor diet can result in many diseases, a healthy diet can have a rather positive impact on an individual’s health. It can protect against any form of malnutrition, including overweight, obesity, and many of the NCDs. (WHO, 2015). On a healthy diet, a person 1) does not consume too little or too much food; 2) consumes mainly plant-based foods; and 3) consumes a limited amount of animal products (Gezondheidsraad, 2015; National Institute for Public Health and the Environment [RIVM], 2017). Conducting food surveys can provide valuable insight into the dietary patterns of a nation’s population. With the outcome of these surveys it is becoming increasingly clear that dietary patterns in the Western world are not equal to a healthy diet. A “Western diet” has been defined as: “one high in saturated fats, red meats, ‘empty’ carbohydrates – junk food – and low in fresh fruits and vegetables, whole grains, seafood and poultry.” (“Western diet”, 2012). Food consumption surveys carried out in different Western countries show that its populations do not consume a healthy diet and do the term ‘Western diet’ justice with their current unhealthy consumption patterns.

For instance, one of the Dutch guidelines for healthy nutrition states that an individual should consume at least 200 grams of fruit per day. According to the most recent food survey, the average adult only

consumes around 113 grams of fruit per day. Another guideline specifies that the consumption of sugar sweetened beverages [SSB] should be ‘kept to a minimum’. To turn this guideline into something measurable, it roughly translates into a cut-off value of 25 grams per day. In 2015, the typical Dutch adult consumed an average of 336 grams of SSB. Nearly every age group, from children to adults and seniors, consumes more than this daily cut-off value. (Van Rossum et al., 2017; Gezondheidsraad, 2015).

Sugar intake for adults in Germany originates mostly from confectionaries such as sweets, ice cream, sweet spreads and sweeteners. For the average German male, this equivalates to 55 grams per day; for women, this is slightly lower with 48 grams per day. Germany’s Nutrition Society recommends individuals to drink 1.5 liters of liquid per day, preferably water and low-calorie drinks. Even so, both men and women consume around 10 – 11% fruit juices and nectars, and 10% (men) and 4% (women) sugar sweetened lemonade. (Bundesforschungsinstitut für Ernährung und Lebensmittel [BMEL], 2008).

In the United Kingdom, confectionaries contribute, with 25%, to the highest amount of sugar intake for individuals aged 19 – 64 years. With 24%, cereals are in second place, while non-alcoholic beverages are third with 21%. Government recommendations set the total daily energy intake of sugars for individuals over 2 years at 5%. Nearly every age group exceeds this recommendation, with the mean adult intake at 11% for men and women aged 19 – 64 years, and 12% for men and 10% for women aged 65 years and older. (Roberts et al., 2018).

The same results are seen in the United States of America. Dietary guidelines recommend that no more than 5% of total daily energy intake originates from any type of sugars. Most adolescents and adults are currently at 16% added sugar per day (Bethene & Ogden, 2013). The main source of added sugar comes from sugar sweetened beverages, a food group which includes sugary drinks like soda. Around 63% of U.S. adolescents daily consume at least one SSB, and this is somewhat lower for adults with 49% per day. (Centers for Disease Control and Prevention, 2017). Almost equal to the USA, Canada’s consumption of added sugar intake was estimated to be around 11 – 13% in the adult population in 2010. (Brisbois, Marsden, Anderson & Sievenpiper, 2014).

### Empty or essential carbohydrates?

While carbohydrates [CHO] are an important part of a healthy diet, it depends on which form they are ingested. As previously mentioned, in the current Western diet, carbohydrates are mostly consumed as ‘empty calories’ – a term which means “calories from food that supply energy but have little to no nutritional value” (“Empty calories”, 2018). In their natural form, carbohydrates represent an important macronutrient that provides the body of glucose, better known as sugar, which is converted into energy for bodily functions and physical activities. CHO are the output of photosynthesis, which is a complicated process that takes place solely in plants, during which a plant uses carbon dioxide (CO<sub>2</sub>), water (H<sub>2</sub>O) and sunlight to produce glucose (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>) and oxygen (O<sub>2</sub>). Some of the glucose is needed and used by the plant itself, and any remaining molecules that are not being used, are stored as starches. These starches – also called polysaccharides – are long chains of glucose molecules linked together. Although glucose can also be synthesised in the body from proteins, glycerol and lactic acid, the amounts are so insignificantly small, that it cannot provide enough energy for the body to function properly. The plants’ starches are therefore an excellent source of carbs for humans and animals. (De Jong, 2016, Chapter 2).

Glucose is directly available to the body as fuel, while fructose and galactose can be used as ‘semi-direct’ fuel, because they first need to be converted into glucose by the liver. These three molecules are all called ‘monosaccharides’ (Figure 1.1., Kenniscentrum voeding en suiker, 2013, p. 2). They are the simplest form of carbohydrates, commonly found in fruits and milk, and these molecules make up the units of which larger carbohydrates exist. When two monosaccharides are linked together, a disaccharide is formed. One of the best-known disaccharides is table sugar – a disaccharide consisting of one glucose and one fructose molecule (Figure 1.2., Kenniscentrum voeding en suiker, 2013, p. 2). As previously mentioned, glucose can also form compounds such as starches or glycogen (in the body), by turning it into polysaccharides (Figure 1.3., Kenniscentrum voeding en suiker, 2013, p. 2). Polysaccharides can consist of many monosaccharides bound together, ranging from just 10 to 60.000 molecules. Products like potatoes and legumes are mainly made up of polysaccharides. (De Jong, 2016).

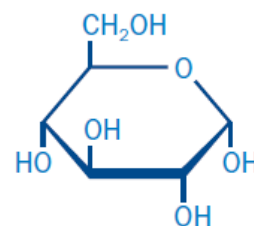


Figure 1.1. Monosaccharide; glucose<sup>4</sup>

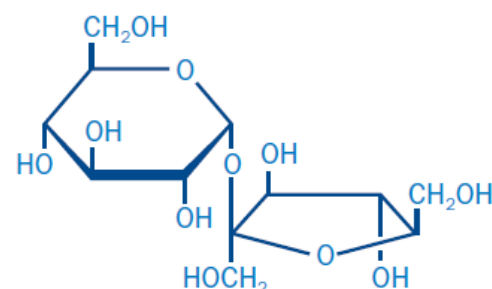


Figure 1.2. Disaccharide; sucrose<sup>4</sup>

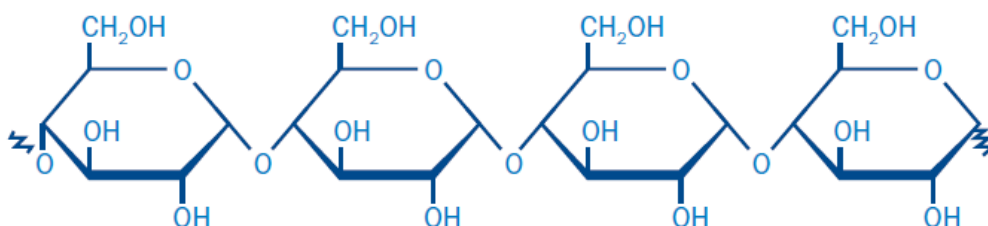


Figure 1.3. Polysaccharide; amylose<sup>4</sup>

As illustrated above, naturally occurring sugar are usually found in fruits and milk, in the form of mono- or disaccharides. These sugars are also referred to as ‘intrinsic sugars’ since they are usually encapsulated within the cell membrane of fruits and vegetables. Added sugar on the other hand, is defined as “all mono- and disaccharides that are added to foods by the manufacturer, cook or consumer and sugars naturally present in honey and syrups.” (Kaartinen et al., 2017). However, this definition excludes extrinsic sugars like juiced or pureed fruits and vegetables. Since there is reported evidence that any type of extrinsic sugar can cause adverse [health] effects, the WHO introduced the term ‘free sugars’, which refers to “all monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates.” (WHO, 2015; WHO 2018). When the terms ‘naturally occurring sugars’ and ‘free sugars’ are used in this thesis, abovementioned definitions are meant, unless otherwise stated in the text.

<sup>4</sup> Figures 1.1. – 1.3. Adopted from Factsheet Definities Koolhydraten en Suikers (p. 2) by Kenniscentrum voeding en suiker. Copyright 2013, Baarn.

## Research question and aim

While there is already plenty of (scientific) information available on the possible causes of overweight and obesity, and the effects of [free] sugar consumption, most information is limited to one or two aspects. Therefore, this thesis will gather as much relevant, available studies and information as possible on the relationship between the development of overweight and obesity and the consumption of sugars, either naturally occurring or free, and bundle it into a literature review. A research question with supplementary sub questions will serve as the backbone of the thesis. The research question that this thesis aims to answer, is formulated as follows:

*How can the consumption of products high in naturally occurring sugars and the consumption of products high in free sugars affect overnutrition<sup>5</sup> in adults over 18 years old on a Western diet?*

- How can overnutrition lead to overweight and obesity?
- What happens to naturally occurring sugars and free sugars in the body?
- How does the consumption of fresh, dried, or juiced fruit affect overnutrition?
- How does the consumption of sugar sweetened beverages affect overnutrition?

The focus of the research question is on naturally occurring sugars and free sugars, and therefore (non) caloric artificial sweeteners will not be discussed in this thesis. Sub question three focuses on fruit in different forms, since this is the main consumption source of naturally occurring sugars, as illustrated in the paragraph 'Empty or essential carbohydrates?'. Sub question four focuses on sugar sweetened beverages, such as sodas and fruit juices with free/added sugar, because this is the main consumption source of free sugars, as illustrated in the paragraph 'Current consumption patterns'.

The aim of this review is to draft a scientifically substantiated, but simplified thesis on the health effects of different types of sugar. This simplified insight into scientific evidence on the topic could raise consumer awareness concerning the effects of the consumption of different types of sugar. The scientific data will serve as a backbone to draft several recommendations on sugar consumption for the average adult consuming a Western diet. It is hypothesised that these recommendations could provide consumers with the necessary information to make educated decisions on what type of sugars they consume. This may conceivably lead them to change their sugar consumption patterns.

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<sup>5</sup> Overnutrition can result in many different diseases; the focus of this thesis was on overweight and obesity.

## 2. Study design

This literature review aimed to gain insight into the current knowledge concerning some of the health effects of the consumption of different types of sugar in the adult population on a Western diet. To gather this knowledge and answer the research question, an extensive literature research was conducted. To collect data as exhaustive as possible, a step-by-step approach comparable to Cronin, Ryan, and Coughlan's (2008) '*step-by-step approach for literature reviews*' has been followed. These five steps provided guidance and structure throughout the research.

### Step one: Topic selection and defining the research question

Selecting a review topic was the first step in the process. A general research was conducted into the area of interest with broad key terms, to gain as comprehensive insight as possible into the available information on the subject. Resources like scientific articles, government reports and popular articles were consulted in this phase. After this initial search, a first draft for the research question and sub questions was proposed. Based on the collected information, and the help of peers and supervisor(s), the first draft was refined to comprise a manageable scope. This implied the demarcation of the subject and its components. With this final research question stated, and its sub questions to provide guidance as to how the research question was answered, the next step was undertaken.

### Step two: Searching the literature/data collecting

A systematic approach for collecting data was needed to generate the most appropriate references. An array of references was needed to gain a complete as possible understanding of the chosen topic. Different scientific electronic databases were used, alongside generic search machines and (inter)national health organizations. Below, a list of the databases that were used during data collection is shown (table 2.1.). For this thesis and its purposes, this list is exhaustive, since there were no additional references used during the actual data collection. Additionally, references from previously collected scientific articles were consulted for the acquisition of other useful articles and/or references.

TABLE 2.1. DATABASES AND TYPES OF REFERENCES USED DURING DATA COLLECTION.

Scientific	Food/health organizations	Generic
ScienceDirect	World Health Organization [WHO]	Google
Wiley Online Library	Food and Agriculture Organization [FAO]	Dictionaries
SpringerLink	Centers for Disease Control and Prevention [CDC]	National food survey/ consumption patterns data
National Center for Biotechnology Information	Food and Drug Administration [FDA]	International food survey/ consumption patterns data
PubMed	National Health Service [NHS]	
Google Scholar	European Food Safety Authority [EFSA]	
Research Gate	National Institute for Public Health and the Environment [RIVM]	

Before a reference was included in the matrix (table 2.2.), it had to meet a few inclusion criteria. These criteria provided guidance in the decision making of the usefulness of the reference. For scientific references, inclusion criteria were as follow:

- The reference applies to Western countries only, since the focus is on Western diet (i.e. no references with data from Asia, Africa or other countries/continents);
- The reference is no older than 18 years (publication date)<sup>6</sup>;
- The reference is peer-reviewed.

For references that provided general information on the subject, such as definitions and symptoms of diseases, the following inclusion criteria applied:

- Information is as recent as possible;
- Information is cited in more than one reference, to ensure accuracy.

For references that provided (statistical) data on national and international food consumption patterns, the inclusion criteria were as follow:

- Data is (preferably) the most recent data available;
- Data is representative for the population of the nation.

TABLE 2.2. MATRIX FOR DATA COLLECTION (IN EXCEL).

Key word (s)	N°	Title article	About?	Reference link	Type of reference	Publication date	DOI	Date retrieved	< 10 years old?	Peer reviewed?
-	-	-	-	-	-	-	-	-	-	-

It was important to establish a list of relevant keywords prior to the research. This resulted in the most effective search as possible, since omission of certain keywords could omit certain literature and affect the quality of the outcome. The inclusion of synonyms and alternative terms were an important aspect to ensure this. (Timmins and McCabe, 2005). Therefore, an extensive list of keywords was provided (table 2.3.), and the combinations in which the terms were used.

TABLE 2.3. MATRIX WITH SEARCH KEYWORDS AND SEARCH COMBINATIONS.

Section	Keywords	Keyword combinations
Introduction	1. Prevalence	1 AND 2 AND 3
	2. Overweight	1 AND 2 / 1 AND 3
	3. Obesity	
	4. Body Mass Index [BMI]	2 AND 3 AND 4
	5. Health effects	2 AND 3 AND 5
	6. Carbohydrates	
	7. Sugar / Monosaccharides	5 AND 8 AND 7 OR 9 AND 7
	8. Natural occurring	
	9. Added	7 AND 10 AND 11 OR 12
	10. Consumption	

<sup>6</sup> Scientific articles that exceed the 18 years limit, were used as means to provoke further research into the subject, in search of more recent references that could prove similar results.

	11. Netherlands / United States of America / Canada 12. Europe 13. Food survey	10 AND 6 OR 7 13 AND 7 AND 11 OR 12 13 AND 10 AND 11 OR 12
<b>Sub question 1</b>	1. Overnutrition 2. Overweight 3. Obesity 4. Weight gain 5. Root cause(s) 6. Effect(s) 7. Induced	1 AND 7 AND 2 AND/OR 3  5 AND 1 AND 2 AND/OR 3 5 AND 1 AND 4  6 AND 1 AND 2 AND/OR 3 6 AND 1 AND 4
<b>Sub question 2</b>	1. Sugar / Monosaccharides 2. Natural occurring 3. Added 4. Effects 5. Metabolism / Metabolized / Absorption / Digestion 6. Pathways 7. Human body	1 AND 5 AND 7 1 AND 6 AND 7  2 AND 1 AND 4 AND 5  3 AND 4 AND 4 AND 5
<b>Sub question 3</b>	1. Sugar 2. Consumption 3. Fruit 4. Fresh 5. Dried 6. Juice(d) 7. Health effects 8. Overweight 9. Obesity	3 AND 1 AND 2 3 AND 1 AND 2 AND 8 AND/OR 9  7 AND 3 AND 8 AND/OR 9 7 AND 4 AND 3 7 AND 5 AND 3 7 AND 6 AND 3
<b>Sub question 4</b>	1. Sugar 2. Consumption 3. Excessive 4. Added 5. Soda 6. Sugar Sweetened Beverages 7. Health effects 8. Overweight 9. Obesity	2 AND 6  3 AND 2 AND 6 AND 8 AND/OR 9  7 AND 2 AND 5 OR 6 7 AND 3 AND 2 AND 5 OR 6

### Step three: Analysing the literature

After the initial data collection, mainly based on the abstract of references, scientific literature was downloaded in PDF form and saved to the computer. The articles were then thoroughly read and key words were assigned in a matrix (table 2.4.). The matrix served as means to analyze the data and in it, each reference was assigned to the sub question it could potentially answer. Notes on the study design were also included in the matrix, since the study design of a research provided insight as to how the results were obtained.

TABLE 2.4. MATRIX FOR ANALYSING DATA AND INDICATION WHICH REFERENCE CAN ANSWER WHICH SUB QUESTIONS.

First author + article title	Key words (e.g. 'overweight', 'obesity', 'fructose', 'fruit', 'HFCS')					Notes on study/discussion points	Answers SQ?
-	-	-	-	-	-	-	-

#### Step four: Writing the review

Once an extensive 'database' was established, the thesis was written. Results were presented in a clear and consistent way. Long and confusing words were kept to a minimum as well as jargon. Any words or terms essential to understand the results, were either shortly defined in text or included in the glossary.

The discussion provided room to interpret the results. Study designs of researches were reviewed, and strong and weak points were discussed. Additionally, the study design of the thesis itself was also critically reviewed. In the conclusion, the information from the results and discussion sections were used to provide a concluding answer to every sub question. Subsequently, the research question was answered, based on the conclusions from the sub questions. In the final chapter, the findings and conclusions of the thesis were translated into several recommendations for the target audience.

The spelling and grammar were consistent with Canadian English throughout the paper. Furthermore, the structure of the thesis followed the guidelines set by Aeres University of Applied Sciences Almere for writing a graduation thesis and the checklist 'report writing'.

#### Step five: Reference list

The thesis was concluded with a reference list that included every book, (scientific) article, report and other reference that was used. Every citation was referenced in text in APA format, and was cited in the references list in APA format as well.



### 3. Results

During the data collection, the carefully drafted search plan was followed. The data collection went smoothly, the search terms provided an abundance of (scientific) references. To analyse which reference contained useful information for each sub question, a matrix was intended to be used. However, after an initial search and analysis of a few references, it became apparent that the matrix was not good enough to execute a proper analysis. Therefore, the analysis matrix was adapted and included in chapter two, step three (table 2.4.).

#### 3.1. How can overnutrition lead to overweight and obesity?

To answer this sub question, the term ‘overnutrition’ needs to be defined first. The term has been defined more than once, and the many similar definitions are adding up. An overview of the most common definitions of ‘overnutrition’ is given, alongside their sources (table 3.1.1.).

TABLE 3.1.1. DEFINITIONS OF ‘OVERNUTRITION’.

Definition	Source
The excessive supply of nutrients so as to hinder growth and metabolism	Collins English Dictionary
The frequent or habitual overconsumption of nutrients by eating too much food to the point where it become dangerous to your health	Live Strong
Excessive food intake especially when viewed as causing adverse health effects	Merriam-Webster Dictionary
Getting more nutrients than you need	National Health Service, UK

Overweight and obesity are defined as “abnormal or excessive fat accumulation that may impair health” (WHO, 2017). This abnormal or excessive fat accumulation (adiposity) is essentially caused by an energy imbalance between calories consumed and calories expended (WHO, 2017). Since overnutrition basically comes down to ‘getting more nutrients than you need’, it is likely that this is one of the leading causes of the development of overweight and obesity. Even though there are other factors that can contribute to the development of overweight and obesity (table 3.1.2.), overnutrition has many direct and indirect contributors, which in turn could lead to unhealthy weight gain, and therefore overweight and obesity (table 3.1.3.).

TABLE 3.1.2. FACTORS THAT CAN CONTRIBUTE IN THE DEVELOPMENT OF OVERWEIGHT AND OBESITY.

Factor	Contribution	Reference
Genetics	The heritability of obesity is estimated at 40% to 70%. Around 244 genes can strongly affect adiposity when they are overexpressed or deleted.	Shawky & Sadik, 2012
Emotional eating	Overconsumption is more closely related to weight gain in people with high degrees of emotional eating, and emotional eaters are therefore at a higher risk for developing overweight.	Van Strien, Herman & Verheijden, 2012.

Substance use	Young adults (aged 11-17) that use substances (i.e. drugs, alcohol, smoking) are more overweight and therefore have a predisposition to develop health-compromising behaviours, such as becoming obese and developing NCDs.	Farhat, Lannotti & Simons-Morton, 2010
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*Note: these factors are a small selection out of many possible factors that contribute to overweight and obesity. Therefore, this table is not an exhaustive list of possible contributors besides overnutrition.*

TABLE 3.1.3. DIRECT AND INDIRECT CONTRIBUTORS TO OVERWEIGHT AND OBESITY THROUGH OVERNUTRITION.

<b><i>Directly contributes to overweight and obesity through overnutrition</i></b>	
<b><i>Contributor</i></b>	<b><i>Reference</i></b>
Increase in eating out or away from home; foods away from home (e.g. in restaurants) are usually higher in energy, fat, sodium and lower in micronutrients than home cooked meals	Nestle & Jacobson, 2000; French, Story & Jeffery, 2001; Swinburn et al., 2004
Consumption of restaurant meals; usually contain around 1000-2000 kcal per meal, which is 35% - 100% more calories than an individuals' daily energy requirements	Nestle & Jacobson, 2000; Chopra, Galbraith & Darton-Hill, 2002
Increase in consumption of highly refined foods, meat and dairy	Chopra et al., 2002
Increase in consumption of products that contain a lot of saturated fats	Chopra et al., 2002; WHO, 2017
Increase in consumption of products that are high in [added] sugars.	Chopra et al., 2002
Increased portion size; contributes to higher total energy intake	French et al., 2001; Chopra et al., 2002; Swinburn et al., 2004
Inability to estimate portion size/calories; therefore, underestimating the actual number of calories one consumes	French et al., 2001; Swinburn et al., 2004
Increase in fast food restaurants ("Fast Food Culture") and soft drink vending machines	Chopra et al., 2002
Food industry/restaurants/movie theaters offer bigger portions for only a few cents more; which encourages consumers to buy and eat more	Nestle & Jacobson, 2000
<b><i>Indirectly contributes to overweight and obesity through overnutrition</i></b>	
<b><i>Contributor</i></b>	<b><i>Reference</i></b>
Decrease in home cooked meals; neglecting the consumption of traditional diets which are high in fibre and whole grains	Chopra et al., 2002
Overweight and obese individuals eat larger meals away from home (restaurants and other locations) than normal weight individuals	De Castro, King, Duarte-Gardea, Gonzalez-Ayala, & Kooshian, 2012

Reduced energy expenditure; little to no physical activity to burn off excess energy or nutrients consumed	Nestle & Jacobson, 2000; Chopra et al., 2002; WHO, 2017
Increase in television watching; double burden because of sedentary behaviour and meanwhile the person is exposed to multiple advertisements on fast food and other unhealthy foods	Nestle & Jacobson, 2000
Heavy advertising of fast food and energy dense foods and drinks	Swinburn et al., 2004

### 3.2. What happens to naturally occurring sugars and free sugars in the body?

To understand if different types of sugars have different effects on the human body, definitions of the types of sugar need to be clear. With this information, potential metabolic differences can be discussed, and lastly, glucose uptake and fructose uptake will be briefly addressed.

TABLE 3.2.1. DEFINITIONS OF NATURALLY OCCURRING AND FREE SUGARS AND EXEMPLARY PRODUCT GROUPS.

Type of sugar	Definition	Product groups
Total sugars	All mono- and disaccharides present in any type of food (Mela & Woolner, 2018).	<ul style="list-style-type: none"> <li>See product groups below</li> </ul>
Naturally occurring sugars / intrinsic sugars	Sugars incorporated into the structure of intact fruits and vegetables, and lactose and galactose found in milk (WHO, 2015).	<ul style="list-style-type: none"> <li>Fruits</li> <li>Vegetables</li> <li>Milk</li> </ul> (WHO, 2015)
Free sugars / extrinsic sugars	“All monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates.” (WHO, 2018).	Sugars like: <ul style="list-style-type: none"> <li>Brown sugar</li> <li>Table sugar (sucrose)</li> <li>(High Fructose) Corn Syrup</li> </ul> Added in: <ul style="list-style-type: none"> <li>Ice cream, puddings</li> <li>Cakes, cookies, pastries, pies</li> <li>Sugar-sweetened beverages</li> <li>Candy, jams, frosting, syrups</li> </ul> (U.S. Food & Drug Administration [FDA], n.d.)

#### Potential metabolic differences between naturally occurring sugars and free sugars

Based on the definitions provided above, one of the main sources of naturally occurring sugars is fruit. Fruit contains mainly carbohydrates in the form of either glucose, fructose or sucrose (De Jong, 2016, chapter 15) and is also rich in micronutrients like vitamins, antioxidants and dietary fiber (Keast, O’Neil & Jones, 2011; Madero et al., 2011; Egan, 2013; Petta et al., 2013). These characteristics of fruit are suggested to be one of the distinguishing factors between the metabolism of intrinsic or extrinsic sugars in the human body. For example, multiple cross-sectional studies in humans found that individuals with the highest intake in dietary fiber had a lower risk at obesity compared to individuals

with the lowest fiber intake. It is suggested that high-fiber intake leads to individuals consuming less in between meal foods and reduce food intake in their next meal. High-level fiber consumption could possibly reduce the risk of weight gain and developing obesity by almost 30%. (Anderson et al., 2009). Petta and colleagues (2013) suggest that dietary fiber and antioxidants found in fresh fruit can positively affect the way fructose behaves in the body. The absorption of fruit fructose is slowed due to the presence of these fibers. The digestive tract must break down the fruits' cell wall, which contains dietary fiber, and therefore the sugar enters the bloodstream more slowly. This way, the liver has more time to metabolise the sugars, which causes a minimal surge in blood sugar.

The metabolism of sugars in the human body revolves around multiple different reactions. These chemical reactions are usually very long, complicated and require sufficient background in biochemistry. Therefore, instead of these complicated chemical reactions, simplified explanations will be given to provide enough knowledge to understand the effects of naturally occurring sugars and free sugars in the human body. Since the body can only use monosaccharides to convert to energy, the glucose metabolism and fructose metabolism will be reviewed separately below.

### Glucose metabolism

Glucose uptake can be considered as the 'normal' sugar metabolism. After consumption, when glucose reaches the blood, the pancreas secretes a hormone called insulin. As explained in table 3.2.2., insulin stimulates different processes like glycolysis, glycogenesis and lipogenesis (Ludwig, 2013; Palmer, n.d). The primary process that takes place after glucose ingestion, is glycolysis. This process provides the body with the necessary energy by breaking down glucose molecules. When there is still enough glucose left that does not need to be converted to energy directly, it is stored in the form of glycogen. This glycogenesis process stores glucose in a different form of energy, for later use, in liver and muscles cells. When there is too little glucose available for direct energy, glycogen is broken down again to provide this energy. When there is still an abundance of glucose in the bloodstream after these two processes, the lipogenesis process is initiated. This process uses glucose to synthesis fatty acids, that are converted into triglycerides, which is stored in fat tissue. Lipogenesis is the least favoured process during glucose metabolism. (Ludwig, 2013; Palmer, n.d). The insulin hormone also stimulates the secretion of leptin and suppresses the production of ghrelin. The former is a hormone that is involved in the regulation of reducing energy intake and stimulating energy expenditure, which suppresses a hunger feeling, leading to less food intake. The latter is related to short-term hunger, food intake and body weight, since it induces a hunger feeling which leads to food intake. (Melason et al., 2007). Teff and co-researchers (2004) conducted an experiment to look at the effects of glucose-sweetened beverages and different hormones. The plasma ghrelin concentration decreased by 30-35% after each meal on the glucose diet, suggesting insulin influences glucose uptake as well as ghrelin suppression.

TABLE 3.2.2. INSULIN MEDIATED PROCESSES AFTER GLUCOSE CONSUMPTION.

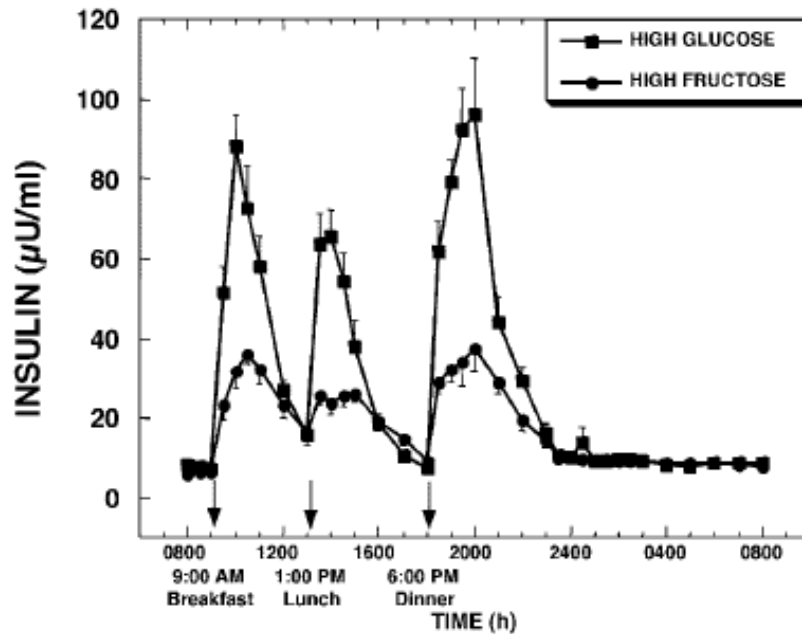
<b>Glycolysis</b>	Breaking down of glucose into pyruvate to generate ATP (energy).
<b>Glycogenesis</b>	Storage of glucose in its polymeric form, glycogen, in the liver and muscle tissue.
<b>Lipogenesis</b>	After glycogen storage is satiated but there is more glucose available, it will be used in the synthesis of fatty acids, which are converted into triglycerides (TGA), better known as fat.

## Fructose metabolism

The two most commonly used extrinsic sugars are sucrose (table sugar) and high fructose corn syrup [HFCS]. These sweeteners are made up of (almost) equal parts glucose and fructose. (Jensen et al., 2018; Mock, Lateef, Benedito & Tou, 2016). High fructose corn syrup is produced in two variants: HFCS-42 and HFCS-55. The former contains 42% free fructose, the latter 55% free fructose and the remaining parts are mainly free glucose. (White, 2008). Since the sugar molecules in HFCS are free, and not bonded the way they are molecularly tightly bound in sucrose, it means there is little to no digestion needed when it is consumed. This leads to almost instant absorption of fructose and glucose into the blood stream, where it goes straight to the liver. (Hyman, n.d.). Since fructose is one of the biggest contributors as free sugars in the Western diet, the metabolism of this monosaccharide will be briefly explained.

Even though glucose and fructose are both monosaccharides, fructose uptake differs greatly from glucose uptake. Fructose metabolism stimulates hepatic *de novo lipogenesis [DNL]*, a process better known as the synthesis of fatty acids in the liver. (Jensen et al., 2018; Mock et al., 2016; Sun & Empie, 2012; Bray, Nielsen & Popkin, 2004). These free fatty acids can form triglycerides (lipids) that are mainly stored in adipose tissue (Palmer, n.d.). Since there is no negative feedback loop or inhibition on fructose consumption, continued stimulation of DNL could lead to increasing adipose tissue and therefore weight gain (Jensen et al., 2018; Mock et al., 2016; Sun & Empie, 2012; Bray et al., 2004).

Also contrary to glucose, fructose uptake does not stimulate insulin secretion (figure 3.2.1., Teff et al., 2004). This is likely due to the fact that pancreatic  $\beta$ -cells have a very low amount of fructose transporters (Teff et al., 2004). Johnson and colleagues (2013) also discovered that fructose consumption does not stimulate insulin, nor leptin secretion and therefore does not induce the satiety response. A limited or absent satiety response leads to increased food intake, which in turn can lead to overconsumption in general. (Johnson et al., 2013). Another way that fructose might induce a decreased satiety response involves the blood-brain barrier. Fructose molecules, unlike glucose, are unable to cross the blood-brain barrier and can therefore not trigger the central nervous system glucose sensors that are involved in food intake regulation. (Teff et al., 2004).



**Figure 3.2.1.** Plasma insulin concentrations during a 24-h period (0800–0800 h) in 12 women consuming HGI or HFr beverages with each meal. To convert insulin concentrations to micromoles per liter, multiply by 6. Reprinted from “Dietary Fructose Reduces Circulating Insulin and Leptin, Attenuates Postprandial Suppression of Ghrelin, and Increases Triglycerides in Women” by Teff et al., 2004, *The Journal of Clinical Endocrinology and Metabolism*, 89, 6, p. 2966. Copyright 2004 by The Endocrine Society.

### 3.3. How does the consumption of fresh, dried, or juiced fruit affect overnutrition?

Since fruit is the main source of naturally occurring sugars in the Western diet, it could be interesting to understand how different forms of fruit may affect overnutrition and its consequences. Sugars found in juiced fruit are defined as free sugars, meaning they are extrinsic sugars and that the body reacts differently to these sugars than the naturally occurring sugars in whole fruits, as illustrated in paragraph 3.2. This section is concerned with the analysis of the different effects of fruit consumption on the development of overweight and obesity.

#### Fresh fruit consumption

With the controversy around sugar and the sudden rush to avoid sugars in general, many individuals have been avoiding fruits (Egan, 2013). However, the consumption of fruit, as nature intended it, fresh and intact with all its nutrients, vitamins and minerals, can potentially [inversely] affect overnutrition in several ways (table 3.3.1.).

TABLE 3.3.1. OVERVIEW OF EFFECTS OF FRESH FRUIT CONSUMPTION AND POTENTIAL MECHANISMS AS TO IT CAN AFFECT WEIGHT LOSS OR GAIN.

Study findings	Potential mechanisms	Reference
Participants with a high intake of fruits and vegetables had a lower risk of obesity. The group with the largest increase in fruits and vegetables intake had a 25% lower risk of developing obesity. The group with a considerable decrease in fruits and vegetables intake had a higher risk of long-term major weight gain	One of the potential mechanisms discussed in the paper, is the theory that a high intake of fruits and vegetables equals a healthy lifestyle. Therefore, the lower risk at obesity is logical.	He et al., 2004
A high intake in fiber was associated with higher fruit and vegetable consumption. The increased fiber intake was associated with a lower risk of weight gain over five years. Additionally, there was an inverse association between fruit and vegetable consumption and weight gain over five years.	In this study, fruits and vegetables were the main source of fiber intake (89%). High fiber intake is inversely associated with body weight. This is likely so because fiber intake is linked to decreased hunger and therefore lower energy intake.	Bes-Rastrollo, Martínez-González, Sánchez-Villegas, de la Fuente Arrillaga & Martínez, 2006
Fruit consumption did not increase in individuals, even so, fruit consumption contributed to the prediction of absolute weight and BMI. It was negatively associated with body weight, meaning it resulted in weight loss.	While not the goal of the study, possible mechanisms to explain the results were: nutrient combination in fruits can affect metabolic rate; and fruit consumption is generally associated with more physical activity and a healthier lifestyle.	Schroder, 2010
Low fructose group was restricted to consume less than 20 g/day of fructose; while the moderate natural group consumed around 50-70 g/day, mainly in the form of fruits. The moderate natural fructose group showed greater weight loss than the group with low fructose intake.	Fruits contain many beneficial antioxidants, which could lead to the greater weight loss. Additionally, the low fructose diet had a higher glycemic index. This usually results in a higher postprandial insulin concentration, which could lead to hunger and overeating.	Madero et al., 2011
Increased fruit consumption associated with lower body weight and lower risk of obesity and associated diseases.	Antioxidants, vitamins and minerals, and fiber can have a potential positive effect. Fiber: gives a full feeling. Fiber rich foods, fruits, are metabolised slowly, and trigger the satiety hormone. This keeps individuals from overeating.	Egan, 2013; Ludwig, 2013

### Dried fruit consumption

The effects dried fruit consumption can have on overnutrition have been researched as well. These effects and potential mechanisms are illustrated below (table 3.2.2.). Components such as dietary fiber intake and triglycerides concentrations can be indicators for weight loss or gain, and studies examining these components have therefore been included in the overview.

TABLE 3.3.2. OVERVIEW OF EFFECTS OF DRIED FRUIT CONSUMPTION AND POTENTIAL MECHANISMS AS TO IT CAN AFFECT WEIGHT LOSS OR GAIN.

Study findings	Potential mechanisms	Reference
Figs provided an additional energy intake of 330 kcal/day; energy from carbohydrates and sugar was increased, while energy from fat and protein was reduced. There was also an increase in fiber intake. No significant weight gain was measured in figs added group.	While the figs added 330 kcal/day, the total diet reported only 187 kcal/day extra. This indicates a compensatory restriction of other foods consume.	Peterson, Montgomery, Haddad, Kearney & Tonstad, 2010
The intervention group consumed two fruit/nut bars, which provided 340 kcal more than control group. There was no significant weight gain or change from baseline.	Energy compensation in the intervention group is one explanation for the absence of significant weight gain. The bars could possibly have increased energy expenditure (nuts) and provided high satiety (fruits).	Davidi, et al, 2011
Dried fruit consumers had lower weight and BMI than non-consumers; waist circumference and subscapular skinfolds were also lower in dried fruit consumers.	Dried fruit consumers consumed more fiber than non-consumers. Fiber intake is associated with several health benefits including improved weight status.	Keast, O'Neil & Jones, 2011
Dried fruit can cause unnoticed excessive calorie consumption. However, because of the intact cell structure, dried fruits provide fibers, which makes it better than fruit juice.	The volume of dried fruit poses a threat: calories and sugars are concentrated, which makes it easier and less noticeable to consume excessive calories.	Egan, 2013

### Fruit juice consumption

Fruit juices are typically viewed as a healthy, natural option for fruit consumption (Caswell, 2009). A serving of 150 ml 100% fruit juice can contribute to the 5-a-day norm in countries like the United Kingdom. However, in recent years, there has been some evidence that creates reasonable doubt to believe that liquid calories act differently than solid calories in the body (Auerbach et al., 2018; Caswell, 2009). Liquid calories do not trigger the same satiety response as its solid counterpart, and can therefore contribute to the overconsumption of energy (Caswell, 2009). Despite these suggestions and theories, there is still little evidence that liquid calories could lead to weight gain. In several cases, 100% fruit juice consumption even has a positive effect on weight loss or normal weight status (table 3.3.3.).



TABLE 3.3.3. OVERVIEW OF EFFECTS OF FRUIT JUICE CONSUMPTION AND POTENTIAL MECHANISMS AS TO IT CAN AFFECT WEIGHT LOSS OR GAIN.

Study findings	Potential mechanisms	Reference
Daily consumption of fruit juice was associated with a decrease in BMI. The moderate negative association between fruit juice and BMI indicates that moderate consumption of fruit juice can contribute to a normal weight status.	The natural sugars in fruit juice can possibly act differently in the body than sugars from sugar sweetened beverages. Also, juice contains relatively more fiber than sugar sweetened beverages, which may also play a beneficial role.	Akhtar-Danesh & Dehghan, 2009
Fruit juice can be consumed on a healthy, balanced diet, however, in moderation. The consumption of 100% fruit juice was associated with better nutrient intake and was not associated with weight status or even the prospect of obesity.	It has been suggested that the body does not detect fluids as well as solid foods, and therefore does not compensate the energy ingested in liquid form in subsequent meals. Liquid calories can contribute to weight gain because of the lower satiety response it triggers.	Caswell, 2009
100% fruit juice consumption potentially leads to consuming more calories because of its liquid form, and faster release of fructose into the blood stream.	Chewing of fruit slows down consumption and therefore different responses in the body, such as the release of satiety hormones. Drinking liquids does not result in these responses. This leads to consuming more calories than needed without the feedback loop. Additionally, there is little to no fiber in juice, which also slows down absorption and triggers the satiety response.	Egan, 2013
An average weight gain of 3.2 lbs over 3 years. Each 6 oz. serving of 100% fruit juice was associated with weight change. The consumption of 100% fruit juice was associated with a modest amount of long-term weight gain.	Potential mechanisms for weight gain can be caloric and non-caloric. Liquid calories do not stimulate satiety response, therefore there is incomplete compensation for the consumed calories during other meals. Also, the juice can stimulate appetite because of the postprandial insulin response.	Auerbach et al., 2018

### 3.4. How does the consumption of sugar sweetened beverages affect overnutrition?

Over the past few decades, there has been a rise in the consumption of sugar sweetened beverages [SSB] all over the world (Jurgens et al., 2005; Brown, Dulloo, Yepuri & Montani, 2008; Ebbeling et al., 2012). Sugar sweetened beverages include any liquid drinks that are sweetened with all sorts of added sugars, for instance sucrose, corn syrup, fructose, and HFCS. Examples are regular (carbonated) sodas, fruit drinks that are not 100% fruit juice, sports and energy drinks, and coffee and tea with added sugars.

(CDC, 2017). The World Health Organization suggests that the consumption of SSB is a marker for poor dietary quality because of the large amounts of sugars added to them. This contributes to the energy density of an individuals' diet, even though it does not provide any additional nutritional value or a feeling of fullness. In turn, this could lead to an increase in total energy intake, which could lead to weight gain (WHO, 2018).

The overconsumption of sugar sweetened drinks is associated with health threats such as obesity, type 2 diabetes and cardiovascular diseases (Grasser, Dulloo & Montani, 2014). In the Western diet, soft drink consumption contributes 30% of the total added (free) sugar intake. While there is an array of different types of sugars that are added to beverages, fructose might be of special concern. The primary source of fructose intake in the Western diet does not come from fruits, but from sugar sweetened beverages (Melason et al., 2006; Madero et al., 2010; Ebbeling et al., 2012; Keim, Stanhope & Havel, 2016). In most beverages, it is either added in the form of sucrose or HFCS. (Keim et al., 2016). The fructose in SSB can make up 7 to 15% of the total weight of the beverage (Jurgens et al., 2005).

As demonstrated in sub question 2 (pages 18-20), fructose uptake differs from glucose uptake in the human body. Furthermore, multiple references suggest that the intake of liquid calories have a different effect on satiety and total energy intake than solid calories. These two aspects are both represented in SSB and are therefore the main arguments on why sugar sweetened beverages can be associated with weight gain and obesity (table 3.4.1.).

TABLE 3.4.1. OVERVIEW OF POTENTIAL MECHANISMS AS TO HOW SUGAR SWEETENED BEVERAGES CAN AFFECT WEIGHT LOSS OR GAIN.

Study findings	Potential mechanisms	Reference
Women with an increased intake of SSB, consumed 385 kcal more a day than those who did not consume SSB. Women with a reduced intake of SSB, had a reduced intake of 319 kcal/day. Women who increased their SSB intake from low to high, had a significant larger weight gain and BMI than those who maintained a low intake of SSB.	SSB can potentially contribute to weight gain because of the low satiety response. Furthermore, the energy intake from SSB is not compensated in subsequent food and energy intake. This means that the calories provided from liquid forms are not compensated by the reduction of the consumption of solid foods. This can lead to a positive energy intake and consequentially weight gain and obesity.	Schulze et al., 2004
In mice, body weight significantly increased when group was given a fructose sweetened solution. It was determined (by MRI) that the weight gained was caused by an increase in body fat. It was also observed that the total caloric intake did not differ from three different groups of sugar-sweetened solutions. Therefore, the weight gain in the fructose group was likely not caused	The mice exposed to the fructose-sweetened beverages did not show an increase in insulin levels, blood glucose or leptin concentration. They also did not show a decrease in ghrelin concentration. These hormones are involved in the energy homeostasis. Insulin and leptin should trigger a satiety response and refrain an individual from consuming more	Jurgens et al., 2005

by excessive calorie intake. However, the study design may be faulty, since the researchers only measured total caloric intake at the end of the two-month trial.	energy than needed. Ghrelin suppression also contributes to this. However, fructose does not stimulate the secretion of these hormones, and therefore does not trigger this satiety response.	
SSB contain on average around 140 – 150 kcal and 35 – 37.5 g of added sugar in a 12-oz serving (350 mL). The sugar/HFCS in SSB does not suppress intake of solid foods to maintain energy balance. Moreover, multiple studies show that energy intake and weight gain is greater when beverages are consumed, in contrast to solid foods with the same number of calories.	One of the predominant mechanisms is the decreased satiety response after SSB consumption, contrary to the normal satiety response when an isocaloric solid meal is consumed. When energy intake is increased with solid foods, the total energy intake is compensated in subsequent meals, while liquid beverages do not trigger this response.	Malik, Popkin, Bray, Després & Hu, 2010
Experimental studies show that fructose sweetened beverages do not trigger a response to compensate total calorie intake in subsequent meals. Intake from other food sources should be reduced, but because this does not happen, total energy intake increases, and weight gain can be observed.	Fructose lacks the ability to stimulate the secretion of hormones that regulate the long-term food intake (insulin, ghrelin and leptin). The normal suppression of ghrelin concentrations is mitigated by fructose beverages. This leads to a decreased satiety response, which in turn can cause a positive energy balance. This could eventually result in weight gain and obesity.	Keim et al., 2016

## 4. Discussion

The aim of this research paper is to raise consumer awareness concerning the health effects of the consumption of different types of sugar, substantiated by scientific evidence. It is hypothesised that this simplified insight into scientific evidence and the subsequent recommendations could provide consumers with the necessary information to make educated decisions on what type of sugars they consume. This may conceivably lead them to change their sugar consumption patterns.

The target audience, individuals on a Western diet, typically high in [free] sugars among other things, might deem the results and recommendations in this thesis useful, since it could provide them with knowledge that they were previously lacking. The broader scope of this thesis, the underlying aim, is to provide consumers with the necessary information to make educated decisions on what type of sugars they consume. As the famous saying coined by Francis Bacon goes: *“Knowledge is Power”*; this thesis could provide that ‘power’ to the consumer (Rodríguez García, 2001). However, knowledge does not necessarily mean change, and this thesis can therefore not guarantee behavioural changes whatsoever. Even though knowledge has the power to motivate change, it does not guarantee consumers will implement these changes. While some individuals might find truth in the outcome of this research, others might not, and it will always be up to every individual to decide what knowledge they do and do not choose to believe.

### 4.1. Overnutrition, overweight and obesity

Out of the multiple definitions for ‘overnutrition’ (table 3.1.1.), there is no set definition yet. The WHO does not use the term overnutrition at all – they differentiate malnutrition into two broad groups: undernutrition and overweight, obesity and NCDs (WHO, 2016). This could suggest that the WHO already links the excessive intake of energy and/or nutrients directly to the development of overweight and obesity, while many other (scientific) sources are still reluctant to proclaim this. A huge organisation such as the WHO boldly stating something like this, without scientific information available as a reference, raises the question as to how they came to this conclusion. It could be considered somewhat foolish of such an exemplary organisation to state this, especially since other references imply other causal factors influencing overweight and obesity as well. One research hints that genetics may play a role as well in the development of overweight and obesity. However, when looking at this evidence, it can be argued that it is not representative. Shawky and Sadik (2012) cite that only 5 studies (up to 2012) have supported the hypothesis that genetics might play a role in the development of obesity. According to them, body weight is largely dependent on food intake, energy expenditure and adipogenesis, and while genetics may play a role in this, the scientific evidence could be considered marginal. Even though literature might suggest that these other factors have little effect on overweight and obesity, this thesis could not possibly comprehend all the evidence and information available in science. With the focus on a literature search, it is possible that evidence proving the influence of these factors on overweight and obesity was neglected. To determine if these factors do contribute to overweight and obesity, a more elaborate (literature) research is needed into this specific area of interest.

As illustrated in table 3.1.3. many direct, as well as indirect, contributors to overnutrition have been identified in past years. It can be argued that most of the references used to compose this table are nearly 18 years old and can therefore be considered almost outdated. However, more recent references that were initially reviewed to answer this sub question, were referencing to the older sources. For instance, research conducted by Nuttall (2015), Donaldson and colleagues (2015), Lima and Galea (2018) and McCormack et al. (2018) were all referencing to these sources from the early 2000s. Hence, it is probable that these ‘older’ reference are still up to date and for this reason, they were included in the current research paper. Looking at these (in)direct contributors, and considering the hypothesis of this thesis, the question remains if the desired change is likely to happen. While these

contributors have been uncovered, this thesis did not include quantitative data how these contributors could affect individuals on the typical Western diet, or how behavioral changes can be encouraged.

#### 4.2. Naturally occurring sugars and free sugars

While scientists have a pretty good understanding of the glucose metabolism by now, the same cannot yet be said for the fructose metabolism. As noted by Teff et al. (2004), Melason et al. (2007) and Sun and Empie (2012), early research into fructose metabolism only investigated the acute exposure to a high dose of fructose. Since fructose is rarely consumed on its own, it sparked new researches into the effects of fructose. For example, in Teff's et al. (2004) nutritional intervention study, twelve subjects were observed during four different study days on which they were given three meals a day, and either a glucose or fructose sweetened beverage with each meal. The outcomes of the study suggest that fructose does not stimulate insulin secretion as much as glucose does (figure 3.2.1.), and it also does not stimulate the secretion of leptin or the suppression of ghrelin. Even though these outcomes have been demonstrated in other studies as well (Melason et al., 2007; Johnson et al., 2013), the number of people participating in the studies was usually rather small, and it is worth considering if these outcomes are applicable on a larger scale. All researches conclude with the notion that further research is necessary to determine if these effects are detectable on a larger scale as well. Even though Sun and Empie's 2012 review includes an array of references, more research is still needed to understand the effects fructose has on the human body.

#### 4.3. Fresh, dried or juiced fruit and overnutrition

In Schroder's weight loss intervention (2010), there was no significant increase in the consumption of fruit, and yet there was the significant negative association with body weight, which means it led to weight loss. However, this finding could be otherwise explained because the study design was already focussing on weight-loss and therefore it is possible that other factors than fruit consumption contributed to the weight loss. While most references cited in this thesis are in accordance of the positive effects of fruit consumption, mainly that the dietary fiber content in fruit plays an important role in its sugar uptake, it is possible there are studies conducted that found the opposite. These studies might not have surfaced during the research because of the search terms that were used. It is therefore possible that fresh fruit consumption has been linked to weight gain as well, but it has not been described in this thesis.

One of the more recent studies looking into dried fruits consumption had a questionable approach in their method. Peterson et al. (2010) investigated the effects of the addition of dried figs on lipid concentrations in their study. Even though the addition of 330 kcal of figs did not lead to a much higher intake of total energy intake (187 kcal more than the control group), individuals in both groups were consuming their habitual diet during the trial. Their suggestion that the consumption of figs might stimulate compensatory restriction of other foods could therefore be jumping to conclusions too fast, since every individuals' habitual diet could (greatly) differ. On the contrary, research conducted by Davidi et al. (2011) and Keast et al. (2011) differentiated a control and intervention group and gave both groups a standardized meal on the intervention days. Both studies concluded almost the same outcome as Peterson's study, suggesting that the habitual diet in Peterson's study did not greatly influence the outcomes. Nevertheless, data on dried fruit consumption is still minimal, and more intervention studies could provide a better understanding of the effects on overnutrition.

Scientific evidence on a link between (100%) fruit juice and weight gain is divided. In Caswell's 2009 study, the regular consumption of 100% fruit juice was not associated with weight gain. Contradictory to this however, in Auerbach et al.'s 2018 study, it is suggested that the regular consumption of 100% fruit juice is linked to long-term weight gain. Even though these references do report some (contradictory) findings on a link between fruit juice and BMI, literature is still scarce (Akhtar-Danesh & Dehghan, 2009). Most (intervention) studies that do find a positive link between juice and BMI mainly

include sweetened juice drinks, and not 100% fruit juice. It is difficult to conclude something from studies like this, since there is a lot of inconsistency found between definitions of (100%) fruit juices and drinks. The former is usually not sweetened with extra sugar, while the latter is. Different studies use different juices and drinks, and it is not always stated which products or brands are used. This inconsistency leads to inconsistent data and results from different studies, which makes it more difficult to compare and determine if there is even a difference between 100% juice and sweetened fruit drinks and its effects on overweight and obesity.

#### 4.4. Sugar sweetened beverages and overnutrition

Schulze et al. (2004) based their findings on the Nurses' Health Study II [NHS II], which started in 1989. This huge prospective cohort study into chronic diseases in women used questionnaires in 1991 and 1995 to collect its data. It could be argued that the information is outdated and therefore not applicable under current circumstances anymore. However, a prospective cohort study does not investigate short term exposure and effects but collects data over a much longer period. Baseline information is collected before any diseases develop and the subjects are then followed for several years, with follow-up questionnaires, to see if they develop any diseases and if their exposure status changed. (LaMorte, 2017). It might therefore be that the outcomes of NHS II are the most representative up to this date. Additionally, up until now, there are no other large prospective cohort studies investigating these effects.

Jurgens and colleagues (2005) animal intervention study suggests that the excessive amount of energy intake is not a cause for weight gain, but the consumption of fructose is. However, their study design could potentially be faulty, since they only measured the total calorie intake at the end of their two-month trial. In this time, the 'excessive' calories could have already balanced out the total calorie need, suggesting there is no excessive energy intake. This would fall in line with other results, such as the results from Keim et al. (2016). Their research suggest that sugar sweetened beverages lead to excessive calorie intake, which in turn leads to weight gain. This finding is also reported by Schulze et al. (2004) and Malik et al. (2010).

#### 4.5. Study design

Due to a limited time available for this graduation thesis, it is possible that the subject is not explored properly. A seven-week time frame is quite short to properly set up and execute a literature thesis and it is therefore certainly possible that the search terms and data arising therefrom do not give adequate insight into the subjects' broad background and available research. Furthermore, even though the search terms yielded enough results to sufficiently substantiate this thesis with, some eligible scientific articles were not accessible. Based on the abstracts, certain scientific articles were deemed interesting, but could not be accessed with the students' institutional rights. These articles could have substantiated the thesis with more data and possibly provided an even better understanding into the effects of overnutrition on overweight and obesity. Lastly, to answer and achieve the formulated hypothesis, the focus of the study probably should have been broader. To encourage behavioral changes, more factors than just information provision are likely involved. New research studies can be dedicated to answering the formulated hypothesis, considering all the (in)direct contributors that could potentially affect overnutrition.

Even though not every article was accessible, the thesis contains over 50 scientific studies which are peer-reviewed. These references provide a large enough database to provide the information needed to fulfil the goal of this thesis. Every scientific article was selected, amongst other aspects, based on the journal they were published in, and every journal was checked if it was peer-reviewed or not. This increased the probability of the use of scientifically correct and unbiased information. Additionally, the use of sources other than international scientific researches provides this thesis with a strong foundation. Both national and international sources, such as health institutes, dictionaries and

statistical data were used to provide a sufficient background with information needed to understand the results and conclusions of this thesis. To conclude with, the author's drive and motivation to expand her own knowledge on the subject, and to translate and communicate said knowledge to a broader target audience, could have positively contributed to the writing process and contributed to the fact that the research was conducted as properly and in-depth as possible in the time available.



## 5. Conclusion

This research was conducted to explore the topic of naturally occurring sugars versus free sugars, the effects of consumption of both types of sugar on the human body, and the possible link to the development of overweight and obesity. The aim was to conduct a scientifically substantiated literature research that could potentially raise consumer awareness concerning the effects of the consumption of different types of sugar. Recommendations that followed from the results could provide individuals with the necessary information to make educated decisions on their sugar consumption patterns.

An extensive data sheet was compiled with scientific literature and was analysed to answer the four proposed sub questions, which will answer the research question of this thesis.

### 5.1. How can overnutrition lead to overweight and obesity?

- Overweight and obesity are the result of an energy imbalance between calories consumed and calories expended, to a point where fat accumulation is abnormal or excessive.
- Frequent or habitual consumption of restaurant meals; larger portions; highly refined foods; products high in fat and (added) sugar can lead to an energy imbalance and can therefore encourage the development of overweight and obesity.

### 5.2. What happens to naturally occurring sugars and free sugars in the body?

- The uptake of naturally occurring sugars triggers insulin secretion as well as leptin secretion and ghrelin suppression. These hormones contribute to glucose utilization and storage, and a satiety response.
- Free sugar are mainly fructose molecules, and fructose uptake does not trigger insulin or leptin secretion, and neither ghrelin suppression. This results in a lacking satiety response. Fructose also stimulates hepatic *de novo lipogenesis [DNL]*, the synthesis of fatty acids in the liver, which are then stored in adipose tissue.

### 5.3. How does the consumption of fresh, dried, or juiced fruit affect overnutrition?

- Fresh fruit consumption is generally linked to a healthier lifestyle, due to dietary fiber, antioxidants and vitamins found in fruit, and could lead to weight loss.
- Total energy intake is usually compensated when dried fruits are consumed, likely because of the high fiber content. Therefore, weight gain due to dried fruits is suggested to be minimal.
- Liquid calories are not detected as well as solid calories, and that the calories consumed from [any kind of] fruit juices are therefore likely not compensated in subsequent meals, potentially leading to a positive energy balance and weight gain.

### 5.4. How does the consumption of sugar sweetened beverages affect overnutrition?

- Calories consumed in the form of SSB are not compensated in subsequent meals because of a decreased satiety response, which leads to a positive energy balance. Additionally, fructose in SSB contributes to *de novo lipogenesis*, which leads to the storage of fatty acids in adipose tissue and can subsequently lead to weight gain, overweight and obesity.



Combining the results from the four sub questions, the following research question can be answered:

*How can the consumption of products high in naturally occurring sugars and the consumption of products high in free sugars affect overnutrition<sup>7</sup> in adults over 18 years old on a Western diet?*

- Products high in naturally occurring sugars are fruits and vegetables. Fresh and dried fruit consumption can contribute to a healthy weight status and even inversely affect overnutrition, meaning it can stimulate weight-loss.
- Products high in free sugars are predominantly sugar sweetened beverages, but also products like pastries and candies. The consumption of sugar sweetened beverages can negatively affect overnutrition. The excessive intake of free sugars can trigger multiple mechanisms by which weight gain is induced and can therefore eventually results in overweight and obesity.

### 5.5. Relevance of results

This thesis attempted to describe the effects of different types of sugar on overweight and obesity in a clear yet simplified manner. Relevant data was translated into simpler, understandable terms so that the typical Western consumer can comprehend the scientific data as well. The subsequent recommendations could potentially raise consumer awareness about the type of sugar they consume and provide the necessary information to make an educated decision about the type of sugar they consume.

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<sup>7</sup> Overnutrition can result in many different diseases; the focus of this thesis was on overweight and obesity.

## 6. Recommendations

These recommendations are drafted mainly based on the conclusion of this thesis. They are specifically directed to consumers on a typical Western diet. However, these recommendations can also be found useful by other individuals, those who do not consume the typical Western diet but still want to act more conscious when it comes to their sugar consumption. Some recommendations can be implemented (almost) immediately by an individual and can be considered 'short-term recommendations'. Other recommendations might take a little more time to implement and are therefore deemed 'long-term recommendations'.

### Short-term recommendations

- Increase the fresh fruit intake in your diet, preferably with skin. For example: eat an apple or pear with its skin, instead of peeling it.
- Small portions of dried fruits are a good addition to your daily diet; however, it should not replace fresh fruits completely.
- When craving fruit juices, make your own by tossing some fresh fruits in a blender and adding some water.
- Consume a sugar sweetened beverage with additional solid calories, so it might give you a better satiety response, which could trigger energy compensation in a following meal.
- Read up on the different types of sugar that can be added in production processes of food stuffs, so you can identify different types of added sugar in [highly] processed foods.

### Long-term recommendations

- Gradually decrease consumption of sugar sweetened beverages. For example: if you drink multiple servings of such beverages, start by switching one of these servings to a diet option, or (unsweetened) coffee, tea or water. Gradually switch to these options for every serving, until you only occasionally consume a sugar sweetened beverage or not at all.
- Try tracking your total calorie intake for a few days to see if your energy status (consumed vs. expended) is balanced. This could make you aware of the calorie content of certain types of foods. If needed, when you do consume a product high in calorie intake (e.g. a sugar sweetened beverage), you could potentially compensate this energy by consuming a little less in a following meal.

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