Consumption of sugar during complementary feeding: an observational study describing total sugar intake and food sources of sugar among nine- to eleven-month-old infants in Aotearoa New Zealand

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Science

in

Nutrition and Dietetics

Massey University, Albany

New Zealand

Anna Lily Morgan

2021

Abstract

Background: Complementary feeding is a formative step in an infant's life, bridging the gap between-milk feeding and family foods, and setting the scene for future health outcomes and eating behaviours. From birth, infants are exposed to sugars and the sweet tastes they provide. Breastmilk and infant formula are high in the intrinsic sugar, lactose, which is an important source of energy for the growing infant. Infants then begin the transition onto complementary foods around six months of age, a stage necessary to provide them with adequate nutrients for growth and development beyond what breastmilk can provide. The first foods and beverages provided to them during this stage are important for predicting future health outcomes. Infant feeding recommendations across the world advise against the introduction of added sugars, honey or sweeteners during the complementary feeding period on the premise that they do not provide any nutritional benefit (other than energy provision). Despite these recommendations, infants are being introduced to foods containing added sugars in their first year of life. The New Zealand Food and Nutrition Guidelines for Healthy Infants and Toddlers currently do not address sugars naturally present in milk/milk products, grains and cereals, or the sweet fruits and vegetables commonly found in many infant foods as there is currently no evidence of the negative effects of consuming these. Few studies have described the total sugar intake from complementary foods consumed by New Zealand infants, or analysed sources contributing to these.

Aim: To investigate the quantity of total sugars obtained from complementary foods and beverages and the food and beverage sources contributing to these in the diets of nine- to eleven-month-old infants in Aotearoa-New-Zealand

Methods: A cross-sectional study design was used. Four-day weighed food records **(**4dWFR) were completed on non-consecutive days by the parents of 95 infants (aged between nine and eleven months) across New Zealand. Descriptive analyses were carried out to determine the energy intake, nutrients (including carbohydrates, total sugars, % energy from sugar) and the foods and beverages contributing to sugar intakes in the infants.

Results: The mean ± SD daily total sugar intake from complementary foods and beverages was 23.8 ± 13.7g, which contributed to 22.0% of the total energy intake derived from complementary foods among infants (range 7.0 to 55.0%). Infants consumed sugars from seven food groups (vegetables, fruits, breads and cereals, commercial infant products, dairy and dairy-free alternatives, meat and meat-substitutes, and discretionary foods and beverages). The majority of sugar was contributed by fruits (46.2 ± 20.1%) and vegetables (14.6 ± 13.4%) in particular those of the sweeter variety (bananas, apples, pears, kumara, carrots and pumpkin). Sixty percent of infants consumed sugar from commercial infant products, which tend to be fruit based; these contributed to 19.1 ± 20.6% of the infants' total sugar intake from complementary foods.

Conclusion: Fruits, vegetables and commercially-available complementary foods are the greatest contributors to total sugars from foods consumed by NZ infants, and are predominantly those that impart

an overall sweet taste, rather than vegetables which would expose infants to a more bitter taste experience. Manufacturers of infant foods should be encouraged to reformulate commercially available complementary foods (CACFs) available in New Zealand to shift towards the use of more vegetable and savoury products, rather than fruit-based and sweet foods.

Keywords: infant, complementary feeding, sugar, intake, dental caries, obesity

Acknowledgments

I would like to say a massive thank you to my supervisors Cath Conlon, Kathryn Beck and Pamela von Hurst for all your contributions to this thesis. I can't thank you enough for your patience (particularly as we adapted to virtual meetings), guidance and abundant feedback throughout this process.

I am also insanely grateful for the previous work of Amy Judd and Ashleigh Jackson, whose prior thesis work provided me with a dataset to analyse (due to a level 4 COVID-19 lockdown delaying participant recruitment in my initial study).

I want to express my love and appreciation to the friends I have made throughout my six years at university, especially my dietetics group, who have been a constant support throughout this journey. You guys have always been so encouraging and have always been there for me throughout this degree. I am forever grateful for your care, support and understanding, and being my sounding board throughout our two years together.

Finally, I want to say the biggest thank you to my amazing family and partner who have stuck by me every step of the way, provided encouragement when I needed it the most, and provided a constant source of reassurance throughout all six years of university. Your interest in my degree, feedback and advice was invaluable. I also appreciate the patience you have shown and constant wisdom you have provided.

Table of Contents

List of tables

List of figures

Supplementary results tables

List of abbreviations

4dWFR	Four-day weighed food record
AI	Adequate intake
BMI	Body mass index
BF	Breast feeding
CACF	Commercially available complementary foods
CF	Complementary feeding
CI	Confident interval
EAR	Estimated average requirement
E CF	Energy from complementary foods
FSANZ	Food Standards Australia and New Zealand
IF	Infant formula
MOH	Ministry of Health
NMES	Non-milk extrinsic sugars
NRV	Nutrient reference value
NZ	New Zealand
OR	Odds ratio
RDI	Recommended dietary intake
RR	Relative risk
SSB	Sugar-sweetened beverage
TE	Total daily energy
WHO	World Health Organization

Chapter 1: Introduction

1.1 Background

Nutrition plays an essential role supporting infants to grow, learn, and develop during the first 1000 days of life (from conception through to 24 months of age), and serves as a foundation for their health status for rest of their life (Alles et al., 2014; Darling et al., 2020; Finn et al., 2018; Koletzko et al., 2012; WHO, 2003a). Complementary feeding is initiated around six months of age, a vulnerable period where infants are gradually introduced to solid foods alongside their usual milk feeds (breast milk and/or infant formula) to help them adapt to family foods (MOH, 2008; WHO, 2003a; Dewey, 2003). These early complementary foods are important for bridging any nutritional gaps caused by the changing requirements of growing infants (Cowbrough, 2010). Ensuring adequate energy intake is vital for growth, however, there is the potential for sugar in complementary foods to contribute to excess energy intake leading to obesity and a greater risk of dental caries in childhood (Amoutzopoulus et al., 2018; Arnold et al., 1977; de Ruyter et al., 2012; Ruottinen et al., 2004; Sheiham & James, 2015; WHO, 2015). The 2018/2019 NZ Health survey indicated that 31.1% of NZ children (aged 2-14 years) are either overweight or obese (19.8% and 11.3%, respectively) (MOH, 2019). Currently, there is no national data for those aged 0-2 years in New Zealand. Establishing optimal nutrition and good dietary practices in the early years of life is important for the maintenance of a healthy weight.

Current feeding recommendations for the New Zealand population are to exclusively breastfeed infants for the first 6 months of life, with continued breastfeeding, alongside the introduction of solids, up to at least one year of age (MOH, 2008). These recommendations are in line with the World Health Organisation's (WHO) Global Strategy for Infant and Young Feeding (WHO, 2003b). Exclusive breastfeeding refers to the provision of breast milk only (either directly from the breast or expressed), as well as any prescribed medications (MOH, 2008). Breastmilk is the ideal source of nutrition for infants and toddlers as it can meet the complete nutritional needs for around the first six months of an infant's life and aid in development (both physical and mental) and help protect from many acute and chronic infectious diseases (MOH, 2008). These benefits of breastmilk continue beyond the first six months of life; however, breast milk can no longer solely provide all nutrients needed for optimal growth and development beyond this age (Abeshu et al., 2016; Butte et al., 2000; UNICEF, 1998). The introduction of solid foods alongside breast milk and milk feeding (with infant formula) is known as complementary feeding and is an important step for bridging the gap between infant nutrient requirements and the nutrients breastmilk is able to provide, particularly during this pivotal stage of growth (Abeshu et al., 2016). Breastmilk contains a naturally occurring sugar, lactose, which has a sweet taste and provides infants with energy.

Table 1
Relevant definitions for sugars

Type of sugar		Definition
Sugars		Scientific term for all monosaccharides (glucose, galactose, fructose) and disaccharides (sucrose, lactose, maltose) (Cummings & Stephen, 2007; Scientific Advisory Committee on Nutrition (SACN), 2015).
Total sugars		All dietary sugars in a food, including extrinsic sugars (i.e free and added sugars) as well as those intrinsic to a food (Cummings & Stephen, 2007).
Intrinsic sugars		Sugars found naturally within the cellular structure of intact plant cell walls (e.g.sugars in intact fruits and vegetables) (Cummings & Stephen, 2007; Fidler-Mis et al., 2017).
Extrinsic sugars		Sugars not located within the cellular structure of a food e.g. added and free sugars, and galactose and lactose in milk/milk products (Committee on Medical Aspects of Food Policy, 1989; Cummings & Stephen, 2007).
	Added sugars	All sugars that are added to foods/beverages during preparation and processing (i.e. by a manufacturer, chef, or when cooking at home) including white sugar, brown sugar, raw sugar and corn syrups (Bresson et al., 2009; EFSA Panel on Dietetic Products, Nutrition and Allergies, 2010; Fidler-Mis et al., 2017).
	Free sugars	All sugars which have been added to foods/beverages during processing and manufacturing, as well as those found naturally in syrups, honey, fruit juice and fruit juice concentrates (Cummings & Stephen, 2007; WHO, 2015). These sugars are also referred to as 'non-milk extrinsic sugars' (NMES) (Cummings & Stephen, 2007; Committee on Medical Aspects of Food Policy, 1989).
	Milk sugars	Sugars occurring naturally in milk and milk products (e.g. lactose), however, are not located within the cellular wall (Committee on Medical Aspects of Food Policy, 1989).

The New Zealand Food and Nutrition Guidelines for Healthy Infants and Toddlers advise against consumption of free sugars in infancy on the premise that they do not provide any nutritional benefit (other than energy provision) (MOH, 2008). Sugars within an infant's diet should instead be those naturally found in foods (i.e., milk sugars lactose milk, milk products, and unsweetened dairy products, and intrinsic sugars in fruits, vegetables and wheat products). These naturally occurring sugars contribute to an infant's total sugar intake, as well as their total carbohydrate content (Fidler Mis et al., 2017; WHO, 2015). Currently, the only recommendations around these naturally occurring sugars for infants are found in the Nutrient Reference Values (NRVs) for Australia and New Zealand, which indicate 51g/day of carbohydrate, specifically from complementary foods, is adequate for growth and development (National Health and Medical Research Council et al., 2006). There is not sufficient evidence to indicate consumption levels greater than this will have adverse effects. However, there are some emerging concerns around consumption of total sugars, whether from naturally occurring or intrinsic sugars, having the potential to ingrain preferences for sweet tastes from a young age (Campoy et al., 2018; Alles et al., 2014). These innate preferences are continually developed and modified through multiple exposures, interactions and experiences with a variety of foods (Beauchamp & Mennellam 2009; Cornwell & McAlister, 2011).

Commercially available complementary foods (CACFs) are a convenient alternative to homemade infant foods, particularly at times when family foods contain amounts of sugar and protein in quantities higher than recommended for infants (MOH, 2008). Results from the *Growing Up in NZ* study indicate a large proportion of infants (60.0%) are consuming CACFs daily as they progress into toddlerhood (Thornley et al., 2020). All commercially produced infant foods sold in NZ must comply with the Australia New Zealand Food Standards code, which provides regulation regarding the nutritional composition of foods intended for infant use, in particular the amount of free sugars in products (Food Standards Australia NZ (FSANZ), 2002; MOH, 2008). A recent report from WHO, based on four European countries, identified that commercial infant foods can contain high levels of total sugars (WHO, 2019). In three of the countries, at least half of the products for which data was collected were found to provide more than 30% of energy from sugars. Another concern highlighted by the WHO report was the prevalent use of sugar and concentrated fruit juice as sweetening agents in many commercial infant foods, contributing to the free sugar content of these foods. Country-specific surveys of commercial infant foods have identified similar findings; many infant-based products, including products marketed as savoury, have had fruit added to them to impart a sweet flavour (Garcia et al., 2016). A large number of complementary feeding products available on the New Zealand market also contain high amounts of sweet-tasting vegetables, such as sweet corn, kumara, and carrot (Padarath et al., 2020), therefore, there could be cause for concern regarding the quantity of total sugars from complementary foods consumed by infants in New Zealand, not just free sugars.

While the importance of adequate nutrition in infancy is well documented, the research analysing sugar intakes from foods and beverages provided to infants during the complementary feeding period is limited. The majority of research available on sugar intake of infants from complementary feeding originates from overseas and indicates eating patterns trending towards high intakes of energy-dense products, specifically foods with low nutrient content and high in added sugars (Butte et al., 2010; Chan et al., 2011; Cowin et al., 2007; Siega-Riz et al., 2010; Webb et al., 2006; Yuan et al., 2017; Zhou et al., 2012), accompanied by intakes of fruits and vegetables that fall below the recommended daily servings (Fox et al., 2004; Fox et al., 2006; Siega-Riz et al., 2010). The evidence within New Zealand is limited.

1.2 Statement of the problem

Early consumption of sugar during the complementary feeding period in infancy is likely to track through to later life, ingrain preferences for particular tastes and contribute to the growing burden of non-communicable diseases. This research was undertaken to describe total sugar intakes in New Zealand infants and to recognise complementary food sources contributing to these intakes.

1.3 Study Purpose

Significance of this research

Assessing the intake of sugar from complementary foods will provide insight into whether infants' diets are in line with the current Ministry of Health Food and Nutrition Guidelines for Healthy Infants and Toddlers and what foods contribute to their intake of sugar.

Aim

To investigate the quantity of total sugars obtained from complementary foods and the food sources contributing to these in the diets of nine- to eleven-month-old infants living in Aotearoa-New-Zealand.

Objectives

The specific objectives for this study were to:

1. Describe the total sugar intake of infants' diets from complementary foods
2. Describe the major complementary food and beverage sources contributing to total sugars in the infants' diets
3. Assess the contribution of commercial foods to the intake of total sugar from complementary foods in infants' diets.

1.4 Thesis Structure

The introduction, outlined in chapter one, sets the scene for this research and identifies the aims, objectives and justification for this particular study. Chapter two reviews the literature pertaining to the importance of adequate nutrition in infancy, the transition from milk feeding to complementary feeding and the importance of both stages, the current recommendations around carbohydrate intake in infants, current intake of sugars in infants, and the health consequences associated with high intake of sugars. Chapter three describes the research study, including materials and methods, the findings and conclusions from this study, presented as a manuscript. Chapter four identifies the strengths and limitations of the research, provides a final conclusion and proposes future research directions. Appendices include supplementary methods, supplementary results and details of 4dWFR templates used by the participants.

1.5 Contribution of researchers

Anna Morgan
MSc Nutrition and Dietetic student and primary researcher – reviewed the literature, performed the statistical analysis and interpretation of the data, formulation of the results and main author of the thesis.

Associate Professor Cath Conlon
Primary academic supervisor – assisted with ethical approval of prior research study, involved in the development and research design, assisted with statistical analysis and supervised with progression of the research process through to final manuscript.

Associate Professor Kathryn Beck
Academic co-supervisor – involved in the development and research design, assisted with statistical analysis and supervised with progression of the research process through to final manuscript.

Professor Pamela von Hurst
Academic co-supervisor – involved in the development and research design, assisted with statistical analysis and supervised with progression of the research process through to final manuscript.

Amy Judd and Ashleigh Jackson
NZ Registered Dietitians and previous Massey students – involved in the recruitment of participants and data collection in 2016 and 2018 to provide the dataset used for this secondary analysis.

Chapter 2: Literature Review

2.1. Introduction

This review of the literature describes the current recommendations around infant feeding, and the impacts of early-life nutrition. The review places a particular focus on the complementary feeding stage and quantities of sugars consumed during this period, guidelines on sugar intakes in the infant group, and the current evidence around infant dietary intakes.

The relevant literature was identified through comprehensive searches of electronic databases (including PubMed, Web of Science and Google Scholar) using a variety of search term combinations (Figure 1). The search terms were aligned with the study's purpose, aims and objectives. Only full-text English journal articles that had been retrieved between the dates of October 2019 and December 2020 were used. Reference lists from relevant articles were also screened for relevant literature. Global infant feeding guidelines and position statements were also reviewed.

Dates searched: October 2019 – December 2020

Electronic databases: Web of Science, PubMed, Google Scholar

Search terms:

Sugar

AND intake OR nutrition OR infant nutrition OR diet OR feeding OR complementary feeding OR complementary food*

AND infant OR infancy OR baby OR babies

AND diet record* OR weighed record* OR weighed food record* OR food record* OR diet* assess*

AND obesity OR childhood obesity OR adiposity OR weight

AND taste preference OR taste development OR flavour development OR flavour preference

AND dental caries OR tooth decay OR dental decay

Figure 1. *Search strategy for literature review*

2.2. The importance of the first 1000 days

Early nutrition is a key part of the first 1000 days of life (from conception through to 24 months of age); it plays an essential role in growth and development (Darling et al., 2020). A wealth of research establishes optimal nutrition during infancy as a foundation for later health (Finn et al., 2018; Koletzko et al., 2012; Mustard, 2009; Shonkoff et al., 2012). The brain and its network of synaptic connections grow and adapt with every new experience encountered, particularly throughout the first few years of life. A suboptimal nutritional environment (i.e., nutrient deficiencies or excesses) during this period may negatively impact

brain and central nervous system development (Abeshu et al., 2016; Krebs et al., 2011; Moore et al., 2017; Perry, 2002; Schwarzenberg & Georgieff, 2018).

Food preferences are formed during the first two years of life; both the types of foods provided to infants and the timing of introducing these are important factors in the early establishment of healthy eating habits (Birch & Doub, 2014). The first solid foods also have more immediate roles in helping them grow and reach important developmental milestones (Ministry of Health (MOH), 2008), therefore, special consideration of the nutrient profile of these foods is required. It is ideal for parents and caregivers to provide age-appropriate and nutritious food, which expose infants to a range of tastes and flavours. Despite the significant impact nutrition has on the immediate and future health status of infants, accurate assessment of dietary intake during these formative years is a challenging task and, therefore, the intake of complementary foods among New Zealand infants is not well understood.

2.3. Nutrition during infancy – Breastfeeding

Breastmilk is a dynamic fluid which adapts to the changing requirements of infants as they grow (Kunz et al., 1999). It provides the optimal combination of macronutrients, micronutrients and digestive enzymes for sustained growth, as well as microbial and antibacterial components which help to establish the immune system (Martin et al., 2016; Robinson, 2015). Breastmilk has early protective effects against common childhood infections (Lamberti et al., 2011), as well as the long-term protective role against the development of non-communicable diseases (NCD), including obesity, type 2 diabetes and cardiovascular disease (Kelishadi & Farajian, 2014). Global recommendations for infants state that exclusive breastfeeding until six months of age ensures infants are provided with all the required nutrients for growth, development and protection (WHO, 2003b), with continued breastfeeding up to two years of age alongside the introduction of complementary foods. The New Zealand Ministry of Health Food and Nutrition Guidelines for Healthy Infants and Toddlers align with these global recommendations (MOH, 2008). However, the NZ Health survey from 2019/2020 indicated only 49.9% of mothers exclusively breastfed their infant beyond four months old and only 7.6% continued until six months old (Ministry of Health, 2020).

2.4. Nutrition during infancy – Complementary Feeding

Around six months of age, infants require an additional source of energy and nutrients in their diet, as breastmilk can no longer provide them with all nutrients required for growth (Abeshu et al., 2016; Faldella et al., 2003; Male et al., 2001; WHO, 2003b). In New Zealand, it is recommended that complementary foods be introduced alongside milk feeds (BM/IF) around six months of age to bridge any nutritional gaps which may occur due to the increasing requirements of growing infants (MOH, 2008). Complementary

feeding is a period of high vulnerability to nutritional deficiencies due to rapid growth, and associated nutrition demands and restrictions in energy could affect growth and development (Alexy et al., 1999; Black et al., 2017). As infants transition from an exclusive diet of breast milk and/or infant formula to family foods, the nutritional composition of their diet changes from high-fat to a lower fat diet during childhood, placing a greater emphasis on provision of energy through carbohydrate and protein intake (Black et al., 2017). In New Zealand, it is recommended that infants between six to twelve months should consume 51g of carbohydrate from complementary foods (National Health and Medical Research Council et al., 2006).

In the early stages of complementary feeding, breastmilk is still the most important source of nutrients. Therefore, the foods provided to infants should be introduced in small amounts after breast/formula feeding. However, as infants progress beyond eight to nine months, complementary foods make an increasing contribution to the infant's requirements and it is encouraged to offer these foods prior to milk feeds (MOH, 2008). During these first experiences with solid foods, it is recommended that infants are not exposed to any added sugars, honey or any other sweeteners, as most foods containing these may ingrain preferences for the sweet tastes these foods provide. The NZ Food and Nutrition guidelines for Healthy Infants and Toddlers recommend fruit, vegetables, breads and cereals as first foods for infants (MOH, 2008).

2.5. Carbohydrate recommendations for infants

Carbohydrates are an important nutrient, providing energy for growth and the developing brain (National Health and Medical Research Council et al., 2016). The types and quality of carbohydrates introduced during this stage are important. New Zealand has a staged approach for introducing these foods to infants from six to 12 months; the eight to twelve-month-old stage includes incorporating many foods high in carbohydrates, such as porridge, wheat biscuits, infant cereals, yoghurt, bread, and soft fruits and vegetables (MOH, 2008).

Infants are the only population group where an adequate intake (AI) is available for carbohydrates, which takes into account the lactose content of breastmilk, and then at six months includes the amount required from complementary foods. The AI for carbohydrates specifically from complementary foods is 51g/day, a value produced with the carbohydrate content of breastmilk (predominantly lactose) taken into consideration. Combined they provide a value adequate for aiding in the growth and nutritional demands of infants between seven to twelve months old (National Health and Medical Research Council et al., 2016). As solid foods begin to become a larger part of infants' diets, with breastmilk/IF feeds reducing, an increasing quantity of carbohydrates will be derived from solid foods.

With regards to sugar-specific recommendations in the infant population, the Food and Nutrition Guidelines for Healthy Infants and Toddlers recommend against the introduction of any added sugar, fruit juice, fruit juice concentrates, flavoured milks or soft drinks among this younger age group (MOH, 2008). There are currently no recommendations specific to total sugar intake or contributions of total sugars to energy requirements.

2.6. Current intake of carbohydrates in infants

Carbohydrates are an important source of energy for infants, and the types and quantities provided, are an important consideration. Nutrition experts have emphasised the importance of reducing sugar intake during infancy (WHO, 2008), however, sugar intake for this age group is not well described in the literature and consequently adherence to recommendations is difficult to determine.

2.6.1. Sugar intake in infancy

Analysis of infants' and young children's diets has raised concerns about types of food provided during the complementary feeding period (Butte et al., 2010; Chan et al., 2011; Cowin et al., 2007; Siega-Riz et al., 2010; Webb et al., 2006; Yuan et al., 2017; Zhou et al., 2012). Excessive consumption of energy-dense and nutrient-poor foods, particularly those high in sugars, has been highlighted as a major concern (Fox et al., 2004; Siega-Riz et al., 2010). In addition, food group analysis has identified that fruits and vegetables are not being consumed by infants on a daily basis (Fox et al., 2004; Siega-Riz et al., 2010).

Early introduction of complementary feeding and formula-feeding have been associated with high sugar intakes in infants (Alexy et al., 1999; Yuan et al., 2017). Yuan et al. (2017) identified that infants (at eight and twelve months old) were more likely to have a higher intake of added sugars if they had started complementary feeding earlier than four months of age (OR = 1.4; 95% CI: 0.99, 1.9 for the eight-month-olds; OR = 1.6; 95% CI: 1.2, 2.2 for the 12-month-olds) and if they consumed commercially-produced products (OR = 3.9; 95% CI: 2.6, 5.8). An earlier analysis in Germany identified greater intakes of added sugars among formula-fed infants compared to breastfed infants (Alexy et al., 1999). In the formula-fed group, between 4.8% and 9.4% of total energy intake (among six month old boys and girls, respectively) was attributed to added sugars, whereas breastfed infants were found to consume no more than 0.1% daily energy from added sugars despite some infants having started on solid foods (Alexy et al., 1999). However, these results are not generalisable to the NZ infant population, as the European Commission allows added sugars (including sucrose, glucose and maltodextrin) to be included in infant formula, whereas, food regulations in New Zealand do not allow their inclusion (Food Standards Australia NZ (FSANZ), 2002).

A comprehensive systematic review describes the carbohydrate intakes of children (from birth to ten years of age) from both complementary and BM/IF (Stephen et al., 2012). The researchers stratified their results according to how sugars were classified within the included studies (i.e., total sugars, added sugar, non-milk extrinsic sugars, and specific monosaccharides e.g., sucrose). Results from studies addressing total sugars indicated 25% to 36.8% of total energy intake was attributed to total sugars among infants 12 months and under (Bialostosky et al., 2002; Conn et al., 2009; Fisher et al., 2008; Gibney et al., 1995; Hagman et al., 1986; Marriot et al., 2008; Marriot et al., 2009; Mills & Tyler, 1992; Noble et al., 2001). Although these levels appear significantly elevated (approximately 30% of energy), they include both added sugars and intrinsic sugars (i.e., those in fruit, vegetables and milk products), the latter of which do not have set limitations within dietary recommendations. Studies that described only the added sugar intakes of a similar participant age group, found intakes ranged from 9% to 17% of total daily energy (Alexy et al., 1999; Andersen et al., 2003). These results, however, do not provide the full extent of sugars eaten, as they neglect the inclusion of any additional free sugars that could have been consumed from fruit juice or honey. Similarly, one study which specifically addressed sucrose intake among two to eleven-month-old infants in the US, found sucrose contributed 14% of daily energy intake (Bialotosky et al., 2002).

Results from an early UK review, indicated an average NMES consumption contributing to 10.7% of total daily energy among those under 12 months old (Mills & Tyler, 1992). Older infants in this study (>12 months old) consumed even greater levels, with NMES intakes ranging from 12.3% to 18.7% of total energy intake. The systematic review comprised studies from a variety of countries, including Britain, Australia, Germany, Bulgaria, UK, US, Greece, Sweden and Finland. Similar consumption trends of elevated sugar intakes have also been identified by Ruottinen et al. (2004) in a slightly older group of 13-month-old infants living in Turku, Finland.

Dietary trends towards high sugar foods tend to continue beyond infancy through to childhood. Lioret et al. (2013) recorded the dietary habits of infants at eight months old and again at 18 months old. Their results indicated consumption of sweet energy-dense foods and sugar-sweetened beverages (SSB) had more than doubled by the time the infants reached 18 months old. The observed increases could partly be explained by the parallel increase in overall energy intake during the ten months between investigation periods, however, intake was still considered high when taking energy levels into consideration, particularly considering the energy-dense, nutrient-poor nature of the foods consumed. These foods are nonessential for growth, and are likely to displace nutrient-rich foods (Bell et al., 2005). A longitudinal study in Germany confirmed the sustained relationship between high added sugar intakes from complementary foods during infancy (particularly from commercially produced foods) and subsequent increased intake during pre-school years (Foterek et al., 2016). Results from this study indicated the use of homemade complementary foods, in lieu of commercially produced alternatives, may be one strategy

to address the early consequences of increased sugar (such as obesity and dental caries), as well as managing eating behaviours that track into later life.

Within New Zealand, there is a lack of information about sugar intakes specifically from complementary foods. Metcalf et al. (2007) analysed 24-hour recalls, from one- to four-year-old children, and observed 31% of energy intake was attributed to total sugars. Almost half was attributed to added sugars (12.9% of total energy intake). The sample size for this group was small, with only 125 children included, although the range of ethnicities was representative of the ethnic diversity in NZ. The Baby-led introduction to solids (BLISS) study analysed differences in nutrient intakes between varying complementary feeding routes (i.e. baby-led weaning versus spoon-feeding) (Erickson et al., 2018). Results indicated added sugars are being consumed in the first 12 months. Added sugars contributed between 0.6 to 0.7% of total energy intake at seven months of age and had increased to between 2.8% and 3.5% of total energy intake by 12 months of age, however the results do not provide an indication as to the quantity contributed by complementary foods alone. While not specifically focused on sugar intake, data on the first foods provided to NZ infants was collected in the *Growing Up in NZ* study (Morton et al., 2012). Results identified that infants had been introduced to a number of carbohydrate-rich foods by the age of nine months; the most common foods being baby rice, fruit and vegetables. By nine months of age, more than half of the infants had also been introduced to a range of carbohydrate-containing foods which are outside the Ministry of Health Food and Nutrition guidelines for Healthy Infants and Toddlers, including lollies, chocolate, hot chips, and potato chips (MOH, 2008).

2.6.2. Sources of carbohydrate in infants' diets

A few studies have addressed the dietary sources contributing to these sugar intakes of infants. A comprehensive survey of 488 British infants, conducted by Mills and Tyler (1992), indicated that non-milk extrinsic sugars (NMES) (see Table 1) provided 29% of total sugar intakes for infants aged six to nine months old, and 41% for those aged nine- to 12-months-old, with the greatest contribution coming from juice and other sweetened beverages. More recent analysis of the UK National Diet and Nutrition Survey (NDNS) also indicated roughly one third (31%) of NMES were similarly consumed in the form of beverages (with 17% from fruit juice and 12% from soft drinks), although this data was collected from a slightly older group of one-to-three-year-olds (Bates et al., 2010). Erkkola et al. (2009) also indicated fruit juice to be the largest contributor of added sugars among infants and toddlers in Finland, contributing roughly one third of daily total sugar intake. Jardi et al. (2019) similarly attributed elevated free sugar intakes to consumption of sugary drinks, while also identifying sweetened breakfast cereals, biscuits, chocolate, sugar and honey as major contributors.

Fruit and vegetable consumption, among complementary fed infants, has also been described in various largescale surveys in the US. Results from the 2005-2012 American National Health and Nutrition Examination Survey (NHANES) dataset indicated deep-yellow vegetables were the most commonly consumed vegetable (consumed by 47.8% of infants between 2005-2008 and 42.0% between 2009-2012), whereas dark green vegetables were consumed by roughly only 6.3% of the young infants (6.1% between 2005-2008 and 6.6% between 2009-2012) (Miles & Siega-Riz, 2017). Although this research did not focus on sugar quantities consumed by the infants, the results do indicate a higher consumption of sweeter vegetables compared to the more bitter-tasting ones, which could influence the development of early preferences to sweet tastes among this young cohort. These findings support previous consumption patterns, analysed in the 2008 United States Feeding Infants and Toddlers Study (FITS), which identified an absence of dark green vegetables (based on the USDA-defined vegetable categories (USDA, 2020)) among the top five consumed vegetables in complementary fed infants (four to 12 months old) (Siega-Riz et al., 2010). Instead, sweeter vegetables, such as carrots, kumara, squash and peas, were preferred. To complement these studies, research undertaken by Moding et al. (2018) identified a lack of vegetable products (particularly the dark green vegetables) available in the US, which could explain the observed increased intake of sweeter vegetables and fruit products. This research investigated the available infant-food products in the US and identified that only 9.5% of the vegetable products contained single-vegetables; the remainder contained a combination of fruits and vegetables, none of which included any dark green vegetables, peas or beans. Among the available products, fruits were also more commonly listed as the primary ingredient. This lack of vegetable-only products in the American market may hinder the accustomisation to, and subsequent acceptance of, darker green vegetables at this early stage in life. Similar findings in New Zealand have recently been published, highlighting the availability of CACFs in New Zealand (Padarath et al., 2020). The majority of products in NZ (69.0%) contained ingredients which impart a sweet flavour, including vegetables such as carrot and sweetcorn in lieu of bitter options, such as broccoli and spinach. In addition to these findings, more than one third (34.0%) of the CACFs analysed contained free sugars despite MOH guidelines advising against their consumption.

2.7. Health consequences associated with high sugar intake

Sugar intake has been linked to a number of health concerns, including dental caries development (Arnold et al., 1977; Ruottinen et al., 2004; Sheiham & James, 2015), increased risk of obesity (de Ruyter et al., 2012), enduring preferences for sweet tastes (Liem & Mennella, 2002; Mennella & Beauchamp, 2002), and displacement of other nutrients (Alexy et al., 2003; Erkkola et al., 2009; Joyce & Gibney, 2008; Kranz et al., 2006; Ruottinen et al., 2008). These reasons will be discussed in further detail below.

2.7.1. Dental caries and sugar intake

Dental caries (defined as the demineralisation of tooth enamel due to acidic by-products of bacterial metabolism of sugars) (Burt & Pai, 2001; Selwitz et al., 2007; WHO, 2017), has been identified as a consequence of high sugar intake, particularly in infantile teeth. As an infant's diet diversifies from an exclusive milk diet to include a variety of food and drinks, it brings an increased number of potential cariogenic risks. Dysfunction within the oral cavity will negatively impact health, particularly in early life when food serves as an important vector for both physical and mental development (Naidoo & Myburgh, 2007; Petersen, 2003). The disease process can begin as early as infancy and persist throughout the life course (Peres et al., 2019). Recent NZ data indicated 4.5% of children below the age of 14 have experienced a tooth extraction due to dental decay (MOH, 2019). Additionally, the report showed only 56.1% of NZ children (aged 0-14 years old) recounted brushing their teeth more than once a day with fluoridated toothpaste. Numerous observational studies have confirmed the impact impairment to dentition can have on quality of life throughout the life course (Chaffee et al., 2017; Do & Spencer, 2007; Duangthip et al., 2020; Filstrup et al., 2003; Kramer et al., 2013; Krisdapong et al., 2009; Singh et al., 2020; WHO, 2017; Wong et al., 2011). Despite being widely recognised as preventable, dental diseases remain prevalent worldwide, with very few population groups exempt (Pitts et al., 2017). According to the 2015 Global Burden of Disease study, chronic oral diseases, such as dental caries, affect more than 560 million children globally (Kassebaum et al., 2017).

International research has implicated sugar in the etiology of dental caries (tooth decay) development (Sheiham & James, 2015); it cannot occur unless teeth are exposed to both dietary carbohydrates (predominantly free sugars) and cariogenic bacteria (Pitts et al., 2017). Evidence validates how influential these early years are for future dental health and highlights the importance of establishing healthy eating behaviours from an early age (Alm et al., 2012; Chaffee et al., 2015; Mattila et al., 2001). An eight-year cohort study describes this lasting impact of sugar on early life dentition; the risk of developing caries in permanent teeth was nearly three times greater in children who had experienced caries in their childhood primary teeth (RR = 2.6 (95% CI: 1.4, 4.7, $p < 0.001$), compared to those who were free of caries in early childhood (Li & Wang, 2002). Comparable longitudinal research from Alm and colleagues (2020) identified a statistically significant elevated risk of developing dental caries in teenage years when sweet products (such as soft drinks, fruit, soup, confectionery, ice cream and biscuits) were consumed in the first three years of life.

Frequency of sugar intake is also a predictor of dental caries development (Grindefjord et al., 1996; Karjalainen et al., 2001; Mattila et al., 2001; Rodrigues & Sheiham, 2000; Wendt et al., 1996). Matilla et al. (2001) established a positive dose-response association between frequent intake (classified as daily or more than once a week) of sweet products in early life and caries development by ten years of age (OR =

3.1 (95% CI: 1.5, 6.6, p <0.006)). Certain food textures that are able to adhere to teeth for longer periods, i.e., sticky foods compared with liquid sugars, may pose more cariogenic risks. Repeated episodes of sugar consumption may provide cariogenic bacteria on the teeth with a continual substrate for acid-production, therefore, causing degradation of dental enamel.

Researchers within New Zealand recently investigated the relationship between dietary intake and dental caries progression among 4111 infants involved in the longitudinal *Growing Up in NZ* study (Thornley et al., 2020). Their results indicated an association between dental caries and consumption of foods high in sugar and unrefined starch, including soft drinks, white bread, fruit juice, congee and noodles. Conversely, certain vegetables, cheese, and unrefined wheat were negatively associated with dental caries progression. New Zealand infants are exposed to foods high in sugar from a young age, therefore, there is potential for this to contribute to the high incidence of dental caries in NZ children.

Dental caries in young infants is often the result of a combination of cariogenic determinants, including the interplay of social, biological and behavioural factors within a family, not just the intake of sugar-containing products (Bener et al., 2013; Wendt et al., 1996). Despite dental caries having this multi-factorial nature, a common recommendation presented in the literature is the importance of reducing infant exposure to free sugars (alongside positive dental behaviours, such as regular toothbrushing) to reduce the prevalence of caries in later life.

2.7.2. Obesity in infancy

Inadequate dietary intake in early childhood contributes to serious health complications that have historically presented in older adults, such as obesity (Klesges et al., 1995), which is a risk factor for many non-communicable diseases, such as type 2 diabetes, cardiovascular disease, gout and fatty liver disease (Andreyeva et al., 2011; Escobar et al., 2013; Ni Mhurchu et al., 2014; Wilson & Hogan, 2017). The most recent data from the 2019/2020 New Zealand Health Survey indicates 29.6% of children, under the age of 15, are classified as either obese or overweight; these weight indicator values have remained unchanged over the last 10 years (MOH, 2020). Early intervention may be a fundamental preventative strategy for obesity, as early eating habits have been indicated as strong predictors of food preferences and eating behaviors in later life (Caballero, 2001). The sugar content of the diet is consistently a subject of much debate where obesity is concerned, given its potential to impact on excess energy intake, leading to storage as fat.

2.7.2.1. Rapid weight gain in infancy

Infancy is a critical period in life where nutrition and growth patterns may have an enduring effect on weight and metabolism (Koplin et al., 2019; Mennella & Trabulsi, 2012). Rapid weight gain (outside of expected growth rates) during this critical period is one factor which has been associated with higher Body Mass Index (BMI) scores during childhood, as well as being linked to an increased risk of obesity in later adulthood (Eriksson et al., 2003; Parsons et al., 1999; Stettler et al., 2002). Evidence from twin analyses indicates genetic factors may not influence weight trajectories until later in life, signalling diet and other environmental factors to be more influential than genetics during the infancy period (Johnson et al., 2014).

Rapid infantile weight gain may independently predict overweight and obesity risk in later childhood and adulthood, even when controlling for birth weight (Dennison et al., 2006; Eid, 1970; Mellbin & Vuille, 1973; Stettler et al., 2002; Stettler et al., 2003). This link was confirmed by a study in the United States, which analysed 27,889 children from birth to seven years (Stettler et al., 2002). Results produced by Stettler et al. (2002) indicated an increased risk of obesity at age seven among the cohort who grew more rapidly during their first four months of life, compared to those who grew according to their expected growth trajectories. Results were concordant after adjusting for several confounding factors, including birth weight and weight at one year of age. Various other studies have since confirmed this link between rapid weight gain in infants (outside of expected growth trajectories), and higher BMI z-scores and body fat percentage at six months of age (Gluckman & Hanson, 2008; Karaolis-Danckert et al., 2006; Ong et al., 2009; Taveras et al., 2009). Systematic reviews have also provided further support for this concept of accelerated growth in infancy predicting future weight status (Baird et al., 2005; Monteiro & Victora, 2005; Ong & Loos, 2006; Weng et al., 2012), helping highlight the important role of managing growth trajectories from an early age.

The literature has not confirmed the influence specific dietary factors have on this observed rapid weight gain in infancy, therefore, it is hard to ascertain how certain foods or nutrients (i.e. sugars and sweet foods) contribute to obesity, or whether overall energy surplus is a more pertinent factor.

2.7.2.2. Current evidence on carbohydrate intake and adiposity

The importance of managing weight from an early age has been addressed extensively in many cohort studies, however, confirmation of the link between carbohydrate consumption in infancy and adiposity is scarce. The literature which has addressed this association is inconsistent. The DONALD (Dortmund Nutritional and Anthropometric Longitudinally Designed) study indicated a positive correlation between consumption of added sugars during the second year of life and BMI z-score in participants, whereas, an elevated sugar intake in the first year was contrastingly linked to a lower BMI-score in later childhood (at seven years of age) among participants (Herbst et al., 2011). A meta-analysis of randomised controlled

trials, conducted by Te Morenga et al. (2013), also indicates a positive association between intakes of sugars (free, added and sugary beverages) and subsequent body weight in both adults and children. Within this meta-analysis, studies focusing on weight outcomes in children identified a link between excess consumption of sugars from sugar-sweetened beverages and many non-communicable diseases, including hypertension, dyslipidaemia, and insulin resistance, whereas, a comparable meta-analysis, conducted by Forshee et al. (2009), projected an association which neared zero. Te Morenga et al. (2013) hypothesise this observed weight gain may be explained by differences in energy intakes among the participants, instead of differences in sugar intakes. In instances where energy was kept consistent among participants in the reviewed studies, iso-energetic exchanges of sugars for other macronutrients did not lead to any significant differences in weight among participants, supporting the researchers' postulations.

Research undertaken in Mexico assessed the link between infant feeding practices at intervals during the first six months and adiposity indicators at 12 months in a group of 106 infants and found a significant relationship between early introduction of added sugars (prior to four months old) and higher waist circumferences at 12 months old (Rodriguez-Cano et al., 2020). Longitudinal research has also investigated this relationship, analysing free sugar intake and weight of infants throughout regular intervals during their first two and a half years (Jardi et al., 2019). These researchers identified nearly half of their participants (40.4%) were consumers of free sugars by 12 months of age, with consumption rates significantly higher in children who were classed as having excess weight (based on expected BMI z-scores). In addition, high body fat at 30 months of age was associated with high consumption of free sugars at 12 months of age. This research from Jardi et al. (2019) indicates elevated intakes of free sugars impact on both immediate and future weight. However, Maunder et al. (2015) produced conflicting results when investigating added sugar intakes among a slightly older group of one-to-eight-year-old children living in South Africa. Their results, also from 24-hour recall analysis, found no association between obesity and added sugar intake in the one-to-three-year-old group. A Korean-based study further investigated the effect of different types of sugars (i.e. total sugars compared with those in specific food groups, such as sugars in fruit, milk and sugar sweetened beverages) on adiposity risk (Hur et al., 2016), and similarly failed to identify a significant association between total sugar intake and elevated adiposity at 4 years of age. Their results instead indicated a statistically significant association between high intake of sugars from fruit and lower BMI z-scores, even when adjusting for fibre content, indicating the potential adipose-sparing effect from fruit. Proposed mechanisms behind this protective effect of fruit are centred around characteristics common in all fruits; they are a low energy-density food that is rich in water, vitamins, minerals and dietary fibre. These components, particularly fibre, help promote satiety, therefore, may modulate any subsequent consumption of additional energy-dense foods (Yao & Roberts, 2001). It is also believed that fibre may have functions in reducing the absorptive function of the gut, lessening the quantity of sugar available for adipose tissue storage (Elia & Cummings, 2007; Wisker & Feldheim, 1990). After adjusting for fibre intake, the direction and significance of the results produced by Hur et al.

(2016) remained consistent. These results further highlight the importance of continuing to encourage consumption of specific foods within the guidelines (i.e. number of servings of fruit and vegetables per day), instead of focusing on nutrients.

2.7.2.3. Sugar sweetened beverages and adiposity in infants

Sugar from sugar-sweetened beverages (SSBs) have a more definitive effect on the adiposity risk in infants than sugar from solid foods. Sugar-sweetened beverages are defined as non-alcoholic beverages with added caloric sweeteners, including carbonated soft-drinks, juice drinks, sports drinks and flavoured milks (Stacey et al., 2019; WHO, 2016b). Sugar in liquid form does not elicit the same satiety response as that from solid foods (Vartanian et al., 2007), therefore, there is a lack of compensatory reduction in dietary intake after their consumption (DiMeglio & Mattes, 2000; Lustig et al., 2012; Mourao et al., 2007; Ni Mhurchu et al., 2014; Sundborn et al., 2014) which can lead to an energy imbalance and subsequent storage as fat in the body (Libuda & Kersting, 2009).

The Ministry of Health recommends against introducing of sugar-sweetened beverages in the Food and Nutrition Guidelines for Healthy Infants and Toddlers (MOH, 2008). Associational evidence from the Infant Feeding Practices study indicates intake of SSBs during infancy is linked to higher BMI values throughout childhood and adolescence (Pan et al., 2014); the risk of obesity in later childhood was 71% greater in children who had consumed any amount of SSBs during infancy compared to those who had not been exposed to them. The associated risk was even more pronounced (92% greater risk) in children who had been introduced to SSB before the age of six months (OR = 1.92 (95% CI: 1.01, 3.66). A similar association was observed in a later Spanish study which analysed children who had been introduced to SSB during infancy (Cantoral et al., 2015). Participants were separated into tertiles based on their levels of SSB consumption during their first five years of life. A positive dose-response association was observed between SSB consumption and weight status; children with the highest cumulative SSB consumption had a three-fold increased likelihood of being obese in their later child years, compared to the lowest SSB consumers. Sonneville et al. (2015) also observed a similar positive dose-response association between juice intakes and BMI scores; a greater juice intake in infancy was associated with an elevated BMI z-score in later childhood. Although global infant feeding guidelines advise against introduction SSBs in the first year of life (and ideally longer), a recent study from Australia indicated that almost half the mothers (42.7% of the 934 participants) provided SSBs to their infants in their first year (Irvine et al., 2020), indicating non-adherence to global guidelines.

Excess energy may be more influential on weight status than sugar on its own. However, the importance of establishing health-promoting dietary behaviours in early infancy, including restricting free sugars, has been widely promoted as a means of minimising the risk of obesity development.

2.7.3. Taste preference development

Flavour learning begins *in utero*; the amniotic environment exposes infants to flavours from foods consumed by their mother (Mennella et al., 1995). These early prenatal exposures have been shown to heighten an infant's preference for those same flavours after birth (Hepper, 1988; Schaal et al., 2000; Spahn et al., 2019). Inborn preferences are often considered responsible for cementing early acceptance of flavours, however, early life experiences and repeated exposures during complementary feeding may be foundational for future acceptance of foods (Birch and Doub, 2014; Coulthard et al., 2010; Foterek et al., 2016; Johnson & Hayes, 2017; Mennella, 2014; Saveedra et al., 2013; Skinner et al., 2002a; Ventura & Mennella, 2011; Ventura & Worobey, 2013), and may track through childhood and persist into adulthood (Kelder et al., 1994; Lytle et al., 2000; Mennella & Beauchamp, 2010), indicating the benefit of intervening from an early age. Therefore, the first steps in transitioning onto solids foods from milk feeding (either breast milk or formula feeding) should expose infants to a varied diet, with foods which allow them opportunities to develop preferences for a wide variety of nutritious and health-supporting foods (Chambers et al., 2016; MOH, 2008).

Infancy is a critical time in the establishment of taste preferences, as infants are readily accepting of new flavours. Preferences continue to develop throughout the lifetime through exposure and experiential learning (Mennella et al., 2016a; Schwartz et al., 2011), however, receptiveness to new tastes is greatest in infancy; fewer exposures are required to create tolerance to certain flavours and to ingrain preferences for them (Birch et al., 1998; Caton et al., 2014; Coulthard et al., 2014; Harris, 2008; Mennella et al., 2011). This indicates that the early experiences with food, i.e. during the complementary feeding period, provide parents with a unique chance to familiarize their infants with a diverse range of foods, not just those with sweet tastes (Schwartz et al., 2009). Nutrient-rich foods, which are low in sugars, should be provided early during infancy as it becomes increasingly difficult to enhance acceptance of flavours beyond the toddler years (Cook et al., 2004; Nicklaus et al., 2005; Skinner et al., 2002a; Skinner et al., 2002b; Wardle et al., 2003a; Wardle et al., 2003b) and, therefore, variation in the diet can easily become restricted past infancy.

Taste preferences have an important role in establishing healthy eating habits from an early age. Infants have an innate preference for sweet tastes, which makes it easy for parents to feed them sweeter varieties of fruit and vegetables as their first foods (such as kumara, corn, pumpkin, apple, banana, pear) and inherently more difficult to incorporate bitter tasting vegetables and tart fruits. While infants are receptive to all tastes at this early age, they will instinctively reject these bitter flavors (Mennella, 2007; Schwartz et al., 2009; Steiner, 1977; Steiner et al., 2001), unless learned through experience, or when combined with previously accepted flavours that mask the bitterness (Hayes & Johnson, 2017; Keast & Breslin, 2003; Mennella, 2014; Moding et al., 2018). A consequence of this is that parents may choose to begin

feeding only these sweeter foods to their infant, due to the positive response they elicit (Lange et al., 2013).

The evidence indicating early taste preferences are influential on foods preferences throughout the life course is well-established through observational and experimental studies (Beauchamp & Mennella, 2009; Lioret et al., 2013; Mikkila et al., 2005; Singer et al., 1995). Flavour learning continues to evolve beyond the pre-natal environment, with research undertaken on children with Phenylketonuria (PKU) (a disease characterised by an inborn enzyme deficiency) identifying a period of sensitivity in infancy, where the palatability of non-preferred flavours, such as highly bitter components, can evolve (Owada et al., 2000). From diagnosis of PKU (generally a few days after birth), infants are put on a dietary regimen, which contains an extremely bitter-tasting hydrolysate formula (hydrolysed casein formula which has had phenylalanine removed). Flavour testing among PKU and non-PKU individuals (aged 19-22 years), conducted by Owada et al. (2000), showed participants with PKU were more likely to accept bitter-tasting formulae over ones identified as more palatable (generic cow's milk formula), compared to their healthy (non-PKU) counterparts. These early life experiences with the characteristically bitter formula imbue a preference for the bitter tastes which lasts beyond childhood. More recently, experimental data has demonstrated an analogous association through the use of a combination of bitter vegetables at the start of complementary feeding and subsequent acceptance of these foods in early childhood (Maier et al., 2008), however much of the available research has follow up periods which do not tend to extend beyond seven years, so it is difficult to ascertain whether this acceptance tracks through to adolescence and adult life.

There is general consensus within the literature that complementary feeding is the perfect time to introduce bitter vegetables and tarter fruits, in lieu of sweeter tasting foods (including fruits and vegetables which are sweeter in taste), in order to effectively capitalize on infant receptivity to eating foods foreign to them (Ahern et al., 2013) and reduce the risk of children resisting these foods later on in life (Chambers et al., 2016). Various Public Health Organisations have implied the potential benefits of lowering the overall sweetness of infant foods by reducing the total sugar content (Pan American Health Organisation, 2016; WHO, 2016a). While non-intrinsic sugars are generally thought to pose the most risk to health, intrinsic sugars (i.e., those from fruits, vegetables and milk products) still contribute to the overall sweetness profile of foods.

2.8. Summary

Guidelines on feeding infants acknowledge the important role of nutrition in aiding growth and development of infants, setting up their taste preferences and influencing their future health status. Carbohydrates are an important source of energy for infants during this period of rapid growth, however, the types of carbohydrates being consumed can have differing impacts on health. Assessment of

carbohydrate and sugar intake from complementary and the food sources provided during this complementary feeding period is essential for determining whether current practices in New Zealand align with our Food and Nutrition Guidelines for Healthy Infants and Toddlers or whether there is a need for further intervention to increase compliance to these recommendations.

Chapter 3: Research Manuscript: **Consumption of sugar during complementary feeding: an observational study describing total sugar intake and food sources of sugar among nine- to eleven-month-old infants in Aotearoa New Zealand**

3.1 Abstract

Background: Complementary foods form a large component of an infant's diet. Many complementary foods are high in sugar. A high sugar intake in infancy has been associated with increased rates of dental caries, increased risk of obesity, and predisposition to sweet tastes later in life. Few studies have described the sugar intake from complementary foods consumed by New Zealand infants, or analysed sources contributing to these.

Aim: To investigate the quantity of total sugars obtained from complementary foods and beverages and the food sources contributing to these in the diets of nine- to eleven-month-old infants living in Aotearoa-New-Zealand.

Methods: A cross-sectional study design was used. Four-day weighed food records **(**4dWFR) were completed on non-consecutive days by the parents of 95 infants (aged between nine and eleven months) across New Zealand. Descriptive analyses were carried out to determine the energy intake, nutrient intakes (including carbohydrates, total sugars, % energy from sugar) and the food and beverage groups contributing to sugar intakes in the infants.

Results: The mean ± SD daily total sugar intake from complementary foods was 23.8 ± 13.7g which contributed to 22.0% of the total energy intake derived from complementary foods among infants (range 7.0 to 55.0%). Infants consumed sugars from seven food groups (vegetables, fruits, breads and cereals, commercial infant products, dairy and dairy-free alternatives, meat and meat-substitutes, and discretionary foods and beverages. The majority of sugar was contributed by fruits (46.2 ± 20.1%) and vegetables (14.6 ± 13.4%), in particular those of the sweeter variety (bananas, apples, pears, kumara, carrots and pumpkin). Sixty percent of infants consumed sugar from commercial infant products which tend to be fruit based; these contributed to 19.1 ± 20.6% of the infants' total sugar intake from complementary foods.

Conclusion: Fruits, vegetables and commercially-available complementary foods are the greatest contributors to total sugars from foods consumed by NZ infants, and are predominantly those that impart an overall sweet taste, rather than vegetables which would expose infants to a more bitter taste experience. Manufacturers of infant foods should be encouraged to reformulate commercially-available complementary foods available in New Zealand to shift towards the use of more vegetable and savoury products, rather than fruit-based and sweet foods.

Keywords: infant, complementary feeding, sugar intake, food sources

3.2 Introduction

Early nutrition plays an essential role in helping infants grow, learn, and develop during the first 1000 days of life (from conception through to 24 months of age), and serves as a foundation for their health status throughout life (Alles et al., 2014; Darling et al., 2020; Finn et al., 2018; Koletzko et al., 2012; WHO, 2003a). Complementary feeding is initiated around six months and is a period where infants are gradually introduced to solid foods alongside their usual milk feeds (breast milk and/or formula). This transition period helps infants adapt to family foods and bridges any nutritional gaps caused by disparities between nutrients available in breastmilk and the requirements of growing infants (Alvisi et al., 2015; Cowbrough, 2010; Dewey, 2003; MOH, 2008; WHO, 2003a). In New Zealand, the Ministry of Health recommends exclusive breastfeeding for the first 6 months of life, around which time complementary foods should be introduced to infants alongside continued milk feeding up to two years of age (MOH, 2008). Ensuring adequate energy intake from a variety of nutrient dense foods at this stage is vital for growth.

In New Zealand, the Food and Nutrition Guidelines for Healthy Infants and Toddlers recommend providing infants with a wide variety of foods from the five main food groups (fruits, vegetables, grains, dairy/dairy-free alternatives and meat/meat-substitutes) (MOH, 2008). The guidelines discourage introduction of foods and beverages with free sugars on the premise that they do not provide any nutritional benefit (other than energy) and may cause infants to become accustomed to their sweet taste (Dewey, 2003; MOH, 2008; Padarath et al., 2020).

Infants eating patterns globally are trending towards high intakes of energy-dense foods and beverages during complementary feeding, specifically those with high added sugars (Butte et al., 2010; Chan et al., 2011; Cowin et al., 2007; Siega-Riz et al., 2010; Webb et al., 2006; Yuan et al., 2017; Zhou et al., 2012), accompanied by intakes of fruits and vegetables that fall below the recommended daily servings (Fox et al., 2004; Fox et al., 2006; Siega-Riz et al., 2010). Where vegetables are consumed, infants tend to have more of an affinity to the sweeter deep-yellow and orange varieties (including carrots, pumpkin and kumara) compared to the more bitter-tastes from dark-green vegetables (American Guidelines Group, 2020; Miles & Siega-Riz, 2017; Siega-Riz, 2010). These eating patterns are reflected in the infant food products available in the US and NZ food markets; there is a lack of vegetable-only commercial infant products (particularly the dark green vegetables) available in the food market, with most products containing a combination of sweet fruit and vegetable varieties (Miles & Siega-Riz, 2017; Siega-Riz, 2010; Padarath et al., 2020). Among the products available in the US and NZ markets, fruits are also more commonly listed as the primary ingredient. The *Growing Up in NZ* study indicated a large proportion of NZ infants (60.0%) are being fed these commercially-available complementary foods (CACFs) daily as they progress into toddlerhood (Thornley et al., 2020). In a study investigating the nutritional aspects of commercial infant foods available in NZ, over one third (34.0%) of the CACFs contained free sugars (Padarath et al., 2020), despite MOH Food and Nutrition Guidelines for Healthy

Infants and Toddlers advocating against this (MOH, 2008). The majority of products (69.0%) also contained fruit or vegetables ingredients which impart a sweet flavour, rather than green leafy vegetables which would expose infants to a more bitter taste experience.

There are concerns around the dietary patterns of NZ infants during complementary feeding, with particular concern around sugar intake. Limitations on free sugars (defined as all sugars which have been added to foods/beverages during processing and manufacturing, as well as those found naturally in syrups, honey, fruit juice and fruit juice concentrates (Cummings & Stephen, 2007; WHO, 2015) during infancy are recommended for a number of reasons. Intake of sugar during infancy has been linked to an increased risk of obesity in both childhood and later life (de Ruyter et al., 2012) and can also create enduring preferences for the sweet tastes that sugar provides (Liem & Mennella, 2002; Mennella & Beauchamp, 2002). High and frequent intake of free sugars during this early sensitive period of life have also been implicated as an etiological factor in the development of dental caries, one of the most prevalent diseases worldwide (Alm et al., 2012; Li & Wang, 2002; Mattila et al., 2001; Mejare et al., 2001; Skeie et al., 2006; Vanderas et al., 2004; Karjalainen et al., 2001; Kassenbaum et al., 2017; Rodrigues & Sheiham, 2000; Ruottinen et al., 2004; Sheiham and James, 2015).

There is limited research in New Zealand describing sugar intake during the complementary feeding period and foods contributing to these intakes. Given the effect early exposure to sugar may have on future food choices and health outcomes, this research was undertaken to describe total sugar intake from complementary foods consumed by New Zealand infants and to identify food sources contributing to these intakes.

3.3 Methods

Study Design

This manuscript reports a secondary analysis of data from a 2018 study which collected four-day weighed food records (4dWFR) from infants aged nine to eleven months in order to validate a complementary food frequency questionnaire. Ninety-five parent-infant dyads were recruited throughout New Zealand between 2016 to 2018. Participants were able to complete all aspects of the study at home and were supported through email and phone calls throughout the duration of the study. The methods are fully described elsewhere (Judd et al., 2020). Below is a description relevant to this analysis of total sugar intake from complementary foods in infants, with further detail about dietary data collection provided in *Appendix A*.

Study population and recruitment

From the original dataset, all 95 participants had completed the 4dWFR and were included in this secondary analysis. Participants were parent-infant dyads from across New Zealand, including a parent, or primary caregiver, and their nine to eleven-month-old infant. Participants were recruited using a

convenience sampling method, which used posters in early childcare centres, newsletters, and advertisements on social media (Facebook and Twitter). Everyone who registered their interest in the study received a detailed information pack about the study via email, including an information sheet, a consent form, and an online questionnaire (through Survey Monkey). If preferred, participants were posted a hard copy of the information pack in the mail. Participants were excluded if their infant had been previously diagnosed with any illness or taken any medication that could impact their growth or dietary intake, or if they were born preterm (gestational age <37 weeks). This study was conducted by researchers from the Department of Sport, Exercise and Nutrition, Massey University. The research was ethically approved by the Massey University Human Ethics Committee, Southern A, Application NOR15/061. All parents/caregivers provided informed written consent for participation in the study (including consent on behalf of their infant).

Demographic data collection

Parents/caregivers completed an online questionnaire (through Survey Monkey). Data was collected on the age and weight of the infant, ethnicity, length of gestation in weeks, the age the infant started complementary feeding, current breastfeeding status, and parity.

Dietary data collection

Parents/caregivers completed a 4dWFR of foods eaten by their infant across non-consecutive days (midnight to midnight) over a two week period, including one weekend day. Parents/caregivers were provided with a set of Tablefair® dietary scales, all calibrated to within one gram, as well as written instructions detailing how to complete the food record and how to work the dietary scales, with examples of how to weigh and record foods (*See Appendix C for 4dWFR templates*). Participants were encouraged to choose recording days where they would be with their infant all day (i.e. days where their infant was not in childcare or with relatives). The importance of maintaining the infants' normal dietary intake throughout the duration of the study, was also stressed to the parents and caregivers. The completed 4dWFRs were then emailed, or posted, back to the main researcher.

Assessment of dietary intake

The information collected from the food records was then entered into FoodWorks® software (version 9, 2018, Xyris Software, Queensland, Australia) by two student dietitians, and pulled through into the latest version for analysis (version 10, 2020, Xyris Software, Queensland, Australia). Three infants were receiving a prebiotic supplement which was not included in this analysis as it did not impact on total sugar intake. FoodWorks® is a nutrition software programme which uses the New Zealand Food Composition database to allow for a detailed analysis of dietary intake. The New Zealand Diet and Recipe Analysis (FOODfiles database) version was chosen, which provided a range of nutrient values for food products available in New Zealand (The New Zealand Institute of Plant & Food Research

Limited, 2017). Where required, foods were inputted into FoodWork® as a new recipe. Similarly, the nutrition information panel was used to create new food products not located in the FoodWorks® NZ Food composition database. If micronutrients were not included on the nutrition information panel of these products, the most comparable food was selected from the Australian or other NZ food databases. Energy and macronutrient intakes (carbohydrates, fat, protein, total sugar, and dietary fibre) were reported as mean ± SD for the participants. These nutrients were described in grams, kilojoules and as a percentage of energy intake. The sugars were then converted to kilojoules and calculated as a percentage of energy intake for each individual, to compare to guideline references.

Food products and beverages were categorised into one of the following seven groups; 'dairy/dairy-free alternatives', 'fruits', 'vegetables', 'discretionary foods and beverages', 'commercial infant foods, 'breads and cereals', 'meat/meat-substitutes, to determine the groups contributing significantly to sugar intake. Fruits and vegetables that were within commercial products were categorised under 'commercial infant products', separately from the fruit and vegetable groups. Fruit and vegetables found in infant products were excluded from the individual fruit and vegetable groups and included in the commercial infant products group. In this study, the discretionary foods and beverages group contained highly processed foods and those high in sugar, fat and sodium, for example, potato chips, fruit juices, and home baking.

Statistical analysis

All statistical analyses were carried out using SPSS® statistical software package (IBM SPSS Statistics Version 26). Descriptive statistics (participant characteristics, energy and macronutrient intakes (including total sugar), and percentages of foods contributing to total sugar intakes) were defined using frequencies and percentages for categorical data. All continuous variables were presented as means, standard deviation and ranges. Continuous data was treated as normal, based on the central limit theorem, which states that a sample greater than 30 is sufficient for making the assumption that the data approximates a normal distribution (Kwak & Kim, 2017).

3.4 Results

Characteristics of the study participants

The characteristics of the 95 participants in this analysis are outlined in Table 2. The mean ± SD age of infants involved was 9.7 ± 1.2 months. Half the population (51.0%) consisted of boys and over three quarters (82.0%) were of NZ European ethnicity. Overall, nearly three quarters were reported to have consumed breast milk during the dietary recall (74.0%). The mean ± SD age of starting solids was 5.5 ± 0.6 months.

Table 2
Characteristics of study participants (N = 95)

Characteristics	Mean ± SD	N (%)
Age (months)	9.7 ± 1.2	
Weight (kg)	8.8 ± 1.2	
Sex of infant [a]		
Male		45 (51)
Female		43 (49)
Length of gestation (weeks) [b]	39.2 ± 1.6	
Ethnicity of infant [b c]		
NZ European		70 (82)
Asian		7 (8)
Māori		4 (5)
Pacific		1 (1)
Indian		2 (2)
Other		1 (1)
Parity [b]		
Primiparous		44 (52)
Multiparous		41 (48)
Currently breastfed		
Yes		70 (74)
No		25 (26)
Age infant started solids (months)	5.5 ± 0.6	
Milk or solids provided first at meal times		
Milk		28 (30)
Solids		67 (70)

[a] Data available for 88 participants
[b] Data available for 85 participants
[c] Ethnicity is parents self-selected main ethnicity (other = unspecified)

Dietary analysis of complementary foods

i. Macronutrient analysis of complementary food and beverage intake (energy, carbohydrate, total sugar, fat, protein and dietary fibre)

The mean ± SD energy and macronutrient intakes (in grams (g), kilojoules (kJ), and their percentage contributions to energy intake (%E CF)) from complementary foods are presented in Table 3. The mean ± SD daily energy intake of the 95 infants from complementary foods, was 1842.8 ± 701.7kJ; just over half of this energy intake (52.0%) was attributed to carbohydrate intake, 28.6% from fat, and 17.4% from protein.

Adequate intake (AI) values are available for carbohydrates (51.0g/day), fat (5.7g/day) and protein (7.1g/day) intakes from complementary foods (National Health and Medical Research Council et al.,

2006) (see Table 3). The mean intake of carbohydrates from complementary foods was 56.5 ± 27.5g, the mean intake of protein was 18.7 ± 8.0g and the mean intake of fat was 14.2 ± 7.2g. The mean ± SD daily sugar intake from complementary foods was 23.8 ± 13.7g, which contributed to 22.0% of total energy from complementary foods (range 7.0 – 55.0%).

A number of infants consumed discretionary foods and beverages that do not align with MOH Food and Nutrition Guidelines for Healthy Infants and Toddlers (MOH, 2008), including biscuits (consumed by 12% of infants), table sugar (19%), juice (10%), chocolate (5%) and lollies (1%).

Table 3

Mean intake of energy and macronutrients (carbohydrates, protein, fat, sugar, and dietary fibre) from complementary foods and beverages (%E CF)

Nutrients	N	Mean ± SD	Range		AI (from CF)
			Minimum	Maximum	
Energy (kJ)	95	1842.8 ± 701.7	417.9	3489.4	-
Carbohydrate (g)	95	56.5 ± 27.5	9.6	148.9	51.0
Carbohydrate (kJ)	95	960.4 ± 468.1	163.2	2531.3	-
Carbohydrate (%E CF)	95	52.0 ± 13	20.0	92.0	-
Total sugar (g)	95	23.8 ± 13.7	4.4	67.2	-
Total sugar (kJ)	95	405.0 ± 233.7	74.8	1142.4	-
Total sugar (%E CF) [b]	95	22.0 ± 9.0	7.0	55.0	-
Dietary fibre (g)	95	8.4 ± 3.7	1.4	21	-
Total fat (g)	95	14.2 ± 7.2	0.9	40.6	5.7
SFA (g)	95	5.7 ± 3.2	0.2	15.6	-
PUFA (g)	95	1.9 ± 0.9	0.4	0.5	-
MUFA (g)	95	5.2 ± 3.3	0.1	27.1	-
Fat (kJ)	95	525.8 ± 266.5	33.3	1502.2	-
Fat (%ECF)	95	28.6 ± 10.3	5.6	355.6	-
Protein (g)	95	18.7 ± 8.0	2.1	38.2	7.1
Protein (kJ)	95	318.0 ± 136.3	35.7	649.4	-
Protein (%E CF)	95	17.4 ± 4.7	4.4	44.6	-

Note: AI, Adequate Intake

[a] AI's sourced from *Nutrient Reference Values for Australia and New Zealand* (National Health and Medical Research Council et al., 2006).

[b] Total sugar = sucrose, fructose, maltose, lactose, galactose (all intrinsic and free sugars)

[c] Data available for 88 participants

ii. Contribution of food and beverage sources to sugar intake

The sixty-six different foods and beverages recorded in the participants 4dWFRs were categorised into seven main groups, as presented in **Table 4** and **Supplementary table 1 (in Appendix B)**, which also show the number of participating infants (N, %) who consumed each of these foods. Outlined in **Table**

4 and **Supplementary table 1 (in Appendix B)** is the the mean contribution, alongside ranges (minimum and maximum), of each group and individual food/beverage to the infants' total sugar intakes from complementary foods.

Each of the seven food groups were consumed by more than three quarters (75%) of the participating infants. Vegetables were the most commonly consumed food group, with almost all of parents reporting their infant's consumption of these in their food records (99%), followed by fruits (98% of participating infants), and breads and cereals (consumed by 96% of infants). Seventy seven percent of infants were also consumers of commercially available complementary foods (CACFs).

Fruits contributed 45.2 ± 21.0% to the infants' total sugar intakes from complementary foods. The three highest sources of total sugars among the fruit group were bananas, which contributed to nearly one fifth (18.5 ± 15.0%) of the total sugar intake from complementary foods, apples (6.6 ± 12.2%), and pears (4.5 ± 7.0%). Vegetables contributed to 14.9 ± 13.9% of the infants' total sugar intakes from complementary foods. Carrots, kumara and pumpkin were the three most commonly consumed vegetables, all eaten by over half of the infants (73%, 56%, 54%, respectively). These three also contributed the greatest amount of total sugar within the vegetables group (3.3 ± 4.3%, 3.7 ± 5.5% and 2.7 ± 4.8%, respectively).

In this cohort, the majority of infants (77%) consumed CACFs, which contributed to 14.7 ± 13.9% of the infants' total sugar intakes from complementary foods. In one infant, these foods contributed 85.2% of the total daily sugar from complementary foods.

Table 4

Mean contribution of food and beverage sources to total sugar intake from complementary food intakes[a]

Food groups and foods[d]	N (total %)[b]	Percentage contribution to sugars from complementary foods		
		Mean[c] ± SD	Minimum	Maximum
Fruit	**93 (98)**	**45.2 ± 21.0**	**4.4**	**82.3**
Bananas	82 (86)	18.5 ± 15.0	0.1	57.4
Apples	51 (54)	6.6 ± 12.2	0.4	76.9
Pears	46 (48)	4.5 ± 7.0	0.1	27.1
Mandarin	45 (47)	4.1 ± 6.2	0.3	25.9
Kiwifruit	31 (33)	2.6 ± 4.7	1.3	18.3
Vegetables	**94 (99)**	**14.9 ± 13.9**	**0.1**	**73.0**
Kumara	53 (56)	3.7 ± 5.5	0.6	23.3
Carrots	69 (73)	3.3 ± 4.3	0.13	28.1
Pumpkin	51 (54)	2.7 ± 4.8	0.14	32.5
Beans/peas	44 (46)	1.2 ± 1.8	0.02	9.8
Tomatoes	40 (42)	0.8 ± 1.4	0.1	6.5

Commercial infant foods	**73 (77)**	**14.7 ± 19.8**	**0.2**	**85.2**
Puree/pouch products	57 (60)	12.3 ± 19.0	0.1	85.1
Infant cereals (incl. baby rice)	22 (23)	1.5 ± 5.1	0.1	36.9
Infant biscuits/crackers	45 (47)	1.0 ± 2.7	0.1	23.5
Dairy/dairy-free alternatives	**80 (84)**	**9.7 ± 9.9**	**0.03**	**37.6**
Yoghurt	57 (60)	5.7 ± 7.8	0.1	37.6
Milk	52 (55)	3.0 ± 5.4	0.04	25
Dairy-free alternatives	13 (14)	0.9 ± 4.4	0.03	35.4
Cheese	16 (17)	0.1 ± 0.4	0.04	3.4
Cream and butter	22 (23)	0.02 ± 0.1	0.01	0.6
Discretionary foods and beverages	**75 (79)**	**8.3 ± 10.1**	**0.2**	**36.1**
Dried fruit	27 (28)	2.0 ± 4.4	0.4	28.5
Custard/mouse	11 (12)	1.1 ± 3.4	2.0	20.1
Muesli bars	11 (12)	1.1 ± 4.2	2.3	28.4
Sugar	18 (19)	0.8 ± 3.2	0.2	23.51
Cakes/pastries	16 (17)	0.7 ± 4.8	0.1	46.1
Breads and cereals	**91 (96)**	**5.6 ± 6.7**	**0.2**	**36.1**
Bread	87 (92)	2.8 ± 3.2	0.2	18.1
Cereals	54 (57)	1.7 ± 4.3	0.1	33.6
Pasta	31 (33)	0.5 ± 1.8	0.04	12.1
Crackers	36 (38)	0.5 ± 1.6	0.02	10.8
Rice	18 (19)	0.1 ± 0.3	0.02	3.1
Meat/meat-substitutes	**71 (74)**	**0.9 ±1.3**	**0.02**	**6.8**
Nuts, seeds and nut butters	13 (14)	0.2 ± 0.7	0.01	5.2
Legumes/plant-based meat substitutes	22 (23)	0.2 ±0.6	0.1	4.5
Meat (Beef, chicken, lamb, pork)	22 (23)	0.2 ± 0.5	0.1	3.3
Eggs	30 (32)	0.2 ± 0.3	0.02	1.5
Fish	18 (19)	0.1 ± 0.2	0.03	1.1

[a] The table outlines the five foods within each food group contributing the most to total sugar intake – the full list of foods consumed can be found in the full table in *Appendix B – Supplementary Results.*
[b] Total percentage is calculated based on the total number of infants (N = 95).
[c] Mean percentage contribution to energy from complementary foods is calculated taking into account all 95 infants in the study, not just those infants who consumed the specific food.
[d] Categorisation of food group is outlined in the methods.

3.5 Discussion

This study reports the total sugar intakes of nine to eleven-month-old infants in Aotearoa-New Zealand as they transition from milk feeds (BM and/or IF) to family foods. The study specifically investigates total sugar intakes from complementary foods and highlights the food sources contributing to sugar intake.

The intake of total carbohydrates from complementary foods ranged between 9.6g/day to 148.9g/day among infants, with intakes from almost half the infants exceeding the adequate intake (AI) of 51g, as stipulated in the Nutrient Reference Values for Australia and New Zealand (NRV) (National Health and Medical Research Council et al., 2006). The mean total sugar intake from complementary foods consumed by infants in this study was 23.8 ± 13.7g/day, which contributed an average of 22.0% of the daily energy from complementary foods. This aligns with previously described intakes, which indicated around 25% to 36.8% of daily energy intake from complementary foods is attributed to sugar in infants 12 months and under (Bialostosky et al., 2002; Conn et al., 2009; Fisher et al., 2008; Gibney et al., 1995; Hagman et al., 1986; Marriot et al., 2008; Marriot et al., 2009; Mills and Tyler, 1992; Noble & Emmett, 2001). While carbohydrates are an important source of energy for growing infants, high intakes from complementary foods above the AI, could lead to excess energy intake among these infants and subsequent storage as fat. Alternatively, they could displace other important nutrients needed by a growing infant (i.e. fats and protein).

Over half the infants had been exposed to a wide range of foods by the age of 9-11 months, an important concept for increasing their acceptance of a variety of foods. These results are consistent with those from the *Growing Up in NZ* study, which also indicated NZ infants had been introduced to a number of food options by the age of nine months; the most common foods being baby rice, fruit and vegetables (Morton et al., 2012). The *Growing Up In NZ* study also identified that more than half of the infants were exposed to lollies, chocolate, hot chips, and potato chips at some stage by nine months old. These are all foods which are not recommended during the complementary feeding stage, due to their low nutritive value. In this study only a small number of infants in this study were exposed to these foods (no more than 5% of infants consumed these foods during the time of dietary analysis). Differences in these findings could be attributed to the population group; the *Growing Up in NZ* study was a representative study population, while this small sample of infants was a convenience sample. The parents and caregivers in this study were a volunteer group who may have been more interested in health and, therefore may have been more aware of the foods provided to their infants.

The majority of the infants in this study appeared to be consuming their sugars from intrinsic sources, such as fruit and vegetables, however, some did consume products identified in the *Growing Up in NZ* study, for example, sugar, biscuits, juice, chocolate, honey, and confectionary (consumed by 19%, 12%, 10%, 5%, 2%, 1%, and of infants, respectively) (See Appendix B: Supplementary Table 1). While these foods were not high contributors to the total sugar intake of complementary foods consumed by the infants (contributing no more than 2.1% in total), their presence is of concern as these foods are not recommended in this age group, due to their high quantities of free sugars and subsequent impact on dental caries and obesity (Ruottinen et al., 2004; Alm et al., 2012). The infants in this study predominantly adhered to MOH recommendations advising against consumption of sugar-sweetened beverages, except for juice which was consumed by nine participants (See Appendix B: Supplementary Table 1). Overseas, in similar aged participant groups, SSBs (with a predominant focus on carbonated

drinks) were the most abundant source of added sugars in the infants' diets (Jardi et al., 2019; Mills & Tyler, 1992; Bates et al., 2010; Erkkola et al., 2009). While it is a positive finding that infants in this present study were not consuming carbonated drinks, the consumption of discretionary foods and beverages, such as fruit juice, by the infants in this study is of concern due to their link with adverse health outcome (WHO, 2003a; MOH, 2008; Mennella et al., 2014).

Total sugars from CACF products were also analysed. Although CACFs were not the primary source of total sugars, they were abundant in the food records of infants involved in this study. Approximately 77% of infants consumed CACFs during the study period, contributing between 0.2% and 85.2% of the total sugar intake from complementary foods.

A recent study identified that 34.0% of the CACFs available in New Zealand contained free sugars. Repeated exposure to these CACFs, particularly those with sweet tastes, could enhance infants' inborn preferences for sweet flavours (Mennella et al., 2014; Mennella et al., 2016b; Rosenstein, & Oster, 1988; Schwartz et al., 2009). The literature also indicates a consistent relationship between high added sugar intakes from these commercial infant products and subsequent increased intake during pre-school years (Foterek et al., 2016).

International research indicates infant eating patterns trending towards high intakes of energy-dense products, specifically foods high in added sugars and low nutrient content (Butte et al., 2010; Chan et al., 2011; Cowin et al., 2007; Webb et al., 2006; Yuan et al., 2017; Zhou et al., 2012) accompanied by intakes of fruits and vegetables that fall below the recommended daily servings (Fox et al., 2004; Fox et al., 2006; Siega-Riz et al., 2010). Although this cohort is not representative of the NZ population, analyses from this present study appear to contradict these global findings, with results demonstrating fruit and vegetables were major contributors to participating infants' diets, consumed by 98% and 99% of participants, respectively, which contrasts with results from a USA study which indicated nearly 30% of participating infants and toddlers did not consume not consume any vegetables within a given day (Siega-Riz et al., 2010).

Results from this study indicate a large intake of sweeter-tasting vegetable and fruits; the most commonly consumed fruits and vegetables in this study were bananas, apples, pears, kumara, carrots, and pumpkin, all of which impart a sweet flavour. These findings may be partially explained by the availability of CACFs in the New Zealand food market. Padarath et al. (2020) identified nearly three-quarters of CACFs available in NZ contained ingredients that provided an overall sweet flavour, while only 8% contained a bitter vegetable, all of which still used sweeter ingredients, such as carrots, sweetcorn, kumara and pumpkin, to mask more bitter tasting components. Similar trends in the infant-food market have also been identified across USA, UK, Canada and Germany (Garcia et al., 2016; Elliot, 2011; Crawley & Westwood, 2017; Moding et al., 2018). Incorporation of these sweeter ingredients is a technique used by manufacturers to dampen the bitterness of certain vegetables to make them more palatable (Mennella et al., 2014; Sharafi et al., 2013). Research has indicated a lack of green vegetables in CACF products in NZ; red and orange sweet vegetables (predominantly carrots, kumara,

tomatoes, pumpkin and sweetcorn) dominate the CACF market, representing over half of the single-vegetable products (Padarath et al., 2020). It appears the consumption patterns of infants in this study may reflect the product availability in NZ; intake of darker green vegetables among infants in this study was negligible, with less than half the infants exposed to them. These results are concerning as exposure to the individual flavours of more bitter vegetables during the complementary feeding period, is important for early flavour learning and reducing rigidity in children's diets (Barends et al., 2013; Johnson & Hayes, 2017; Remy et al., 2013; Saavedra et al., 2013; Skinner et al., 2022b). Parents and caregivers may not be aware that exposure to sweet fruits and vegetables in foods restricts their infant's exposure to bitter flavours. The first steps in transitioning onto solids foods from milk feeding (either breast milk or formula feeding) should expose infants to a variety of tastes, providing them with opportunities to develop preferences for a wide variety of nutritious and health-supporting foods (Chambers et al., 2016; MOH, 2008). It could be beneficial for manufacturers of commercial infant foods to produce more single-vegetable products, and reduce the sweetening of products with fruit-based ingredients, fruit concentrates and sweet vegetables, to help enable these early flavour learning opportunities. This recommendation is particularly pertinent to NZ, as results from this study indicated 77% of infants were consuming CACFs at the time of this study, which were contributing 14.7 ± 19.8% to total sugar intake from complementary foods.

This study has several strengths. It describes the total sugar intakes from complementary foods in NZ infants, and highlights the food sources contributing to these intake levels. The use of the weighed food records provides a strong level of accuracy in quantifying the small quantities consumed by infants. The use of weighed records also helps reduce the risk of caregivers forgetting to record their infant's foods, as they are expected to record them throughout the day at the time they are eaten, as opposed to attempting to recall foods at the end of each day. Caregivers were also asked to include one weekend day, helping to capture the overall eating patterns of the infants. Changes to normal intakes of foods and beverages consumed by infants when in day care were also taken into consideration, with parents/caregivers asked to only record on days where they would be able to accurately record their infants intake (e.g. days where the infants were not in day care nor being looked after by others). The mean weight of infants (8.8 ± 1.2kg) included in this study is also a strength. The recommendations within the NRVs for carbohydrate, protein and fat intake from complementary foods are based on an infant with a reference weight of 9kg (National Health and Medical Research Council et al., 2006), highlighting the justification for using this particular dataset to explore the carbohydrate intakes of NZ infants from complementary foods.

This study also has some important limitations, with a few relating to the participant sample and their recruitment. Firstly, the use of a convenience sampling recruitment method means the results will not be an accurate depiction of the infant population in Aotearoa-New Zealand. It is acknowledged that the voluntary nature of participants could have led to selection of those who are more health conscious and, therefore, bias the results to indicate more health-focused intakes. Secondly, the sample

of 95 participants was small compared to other infant dietary intake studies and its predominant NZ-European participant base is not an accurate depiction of New Zealand's multi-ethnic population, therefore, feeding patterns and food choices may not reflect different ethnic groups within NZ. In future research, it would be useful to have a more diverse participant group from across all cities in New Zealand, including more participants of Māori, Pacific, and Asian ethnicity, to help provide results representative of the multi-ethnic population. It is possible that the high level of participant burden exerted by the use of a 4dWFR may have resulted in a reporting bias; parents and caregivers were required to weigh each food given to their infant, which may have swayed them to feed their infant foods which were easier to weigh during the four recorded days, in lieu of mixed dishes which are more burdensome to weigh, thus providing an inaccurate picture of the normal foods consumed by participating infants (Gibson, 2005; Thompson & Byers, 1994). A level of reporting bias may also have skewed the results in favour of more health promoting outcomes, if parents and caregivers believe the foods provided to their infants are considered unhealthy or did not align with the MOH guidelines (Krebs-Smith et al., 2000). The use of an existing dataset, due to COVID-19 limitations, produced one of the major limitations for this study, in that we were only able to analyse total sugar intakes, instead of free sugar intakes in food records available to us.

3.6 Conclusion

In conclusion, our analysis of a convenience sample of NZ infants demonstrated the primary source of sugar in infants diets to be from fruit and vegetables (separate from those in CACFs), predominantly those of the sweeter-tasting variety, such as bananas, apples, kumara, pumpkin and carrots. CACFs were not the primary source of total sugars, they were abundant in infants' diets. This research also highlighted a number of findings that did not align with the MOH recommendations, with some infants consuming honey, fruit juice and chocolate before the age of 12 months. A deeper understanding around the potential impacts of total sugar intakes and minimal exposure to a variety of tastes (bitter and sweet) on the future health outcomes of infants may be warranted. These insights may also encourage manufacturers of infant foods to reformulate CACFs in NZ to shift more towards vegetable and savoury products, rather than fruit-based and sweet foods. Future research should include analysis of free sugar intake among infants to provide a more complete picture of infantile sugar intakes in New Zealand.

3.7 Acknowledgments

We are grateful for 186 parents and infants who volunteered to participate in this study and are thankful for the final 95 infants and their families whose completion of all aspects of the study contributed to this research.

3.8 Conflicts of interest

The authors declare no conflicts of interest.

Chapter 4: Conclusion and Recommendations

4.1 Research outcomes

The aim of this study was to investigate the quantity of total sugars from complementary foods in the diets of nine to eleven month old infants in Aotearoa-New Zealand and explore the major food sources contributing to these intake levels. The total sugar intakes of infants in this study aligned with those previously described in overseas literature. Our analysis of a convenience sample of NZ infants affirms the primary sources of sugar in infants diets are fruit and vegetables, predominantly those of the sweeter-tasting variety, such as kumara, pumpkin and carrots, as well as commercial infant products. The results from this research complement findings from current evidence which describes the availability of infant-products in the NZ market. This research also highlights a number of findings which do not align with the MOH Food and Nutrition Guidelines for Healthy Infants and Toddlers, with infants in this study consuming free sugars in the form of honey, fruit juice and chocolate before the age of 12 months old, all of which may have future implications to their health.

4.2 Strengths and Limitations

This research has a number of strengths and limitations, including sample size, sample ethnicity, recruitment method, and reporting bias due to the nature of the chosen dietary assessment method (4dWFR).

4.2.1 Strengths

This study has several strengths. A high level of accuracy was assured through the use of weighed food records, as parents were able to accurately quantify the small quantities of food consumed by their infants. Parents and caregivers were given many instructions (all included in the handouts provided) which attempted to minimise any changes to the infants normal eating patterns, such as requests to include one weekend day in the food records, and record on days where the infant was in their care for the full day. The mean weight of infants in this study provided strong justification for using this particular dataset to describe the carbohydrate intake of NZ infants. The mean weight (8.8 ± 2.2kg) was comparable to the reference weight that is used within the NRVs for carbohydrate, fat and protein recommendations from complementary foods, as they are based on an infant with a reference weight of 9kg (National Health and Medical Research Council et al., 2006).

4.2.2 Limitations

The use of a convenience sampling recruitment method meant the results were not an accurate depiction of the infant population in Aotearoa-New Zealand. The voluntary nature of this sample could have led

to participation from those who are more health conscious, swaying the results in favour of more health-focused intakes. This convenience sample of 95 participants was small compared to other infant dietary analysis studies, with a predominant NZ-European participant base, therefore, it will not accurately represent New Zealand's multi-ethnic population. Implications of this are that the feeding patterns and food choices may differ considerably in ethnicities that are not well-represented in this participant sample. In future research, it would be useful to have a more diverse participant group from across all cities in New Zealand, including more participants of Māori, Pacific, and Asian ethnicity, to help provide results representative of the multi-ethnic population. These results are subject to potential reporting bias from the possible high level of participant burden exerted by the use of a 4dWFR. While this helps provide a more accurate picture of infant intakes if completed correctly, asking parents and caregivers to weigh each food may have swayed them to choose foods which are less burdensome to weigh, in lieu of mixed dishes they may normally feed their infant, thus providing an inaccurate picture of the normal foods consumed by participating infants. Similarly, parents and caregivers may have chosen to give their infants more health-promoting foods during the four recorded days if they believed believe the foods they regularly provided to their infants were considered unhealthy or did not align with MOH guidelines.

4.3 Recommendations

Assessing sugar intake in infants is important not only due to their impact on immediate and long term health concerns, such as dental decay and adiposity (Fidler Mis et al., 2017; Palmer et al., 2010; Wu & Chen, 2009), but also because early exposure to the sweeter tastes that sugars provide can influence dietary preferences throughout life, and further impact on later health outcomes (Beauchamp & Mennella, 2009; Cornwell & McAlister, 2011; Cogswell et al., 2015; Fidler Mis et al., 2017; Lioret et al., 2013). There is limited research describing the sugar intakes of infants living in Aotearoa-New Zealand specifically from complementary foods. While this study identifies that consumption of total sugars is predominantly from sweet-tasting fruits and vegetables, it would be beneficial for further research to focus on the breakdown of sugars consumed in these foods i.e., total, added and free sugars. This would address the components of total sugars consumed by infants and whether these are exceeding global limitations set at less than 10% of energy intake from free sugars. Further research may also address the long-term effects of total sugars and consumption of sweet-tasting foods on adverse health outcomes. The implementation of further guidelines and public health messaging that promotes the intake of more savoury foods during the complementary feeding period, particularly those from vegetables, and wholegrain breads and cereals may be warranted. This study also highlighted the widespread use of commercial products in the diets of infants, which is concerning considering current evidence identifying the high added sugar content of these products and their predominantly sweet taste (in conjunction with abundant lack of vegetables). In the future, it would be beneficial for infant food

manufacturers to develop more bitter vegetable and savoury food products, in lieu of the fruit-based and sweet foods that are dominating the food market, to reduce the total and added sugar content of infant foods. Further encouragement should be given to parents to use a balance between homemade and commercial baby products. Additionally, parents and caregivers should be made aware of the potential implications of sweet-tasting CACFs in NZ and encouraged to incorporate more bitter-tasting foods in their infant's diet to facilitate their future acceptance of family foods.

Appendices

Appendix A: Supplementary Methods

3.5 Dietary data collection

Once signed consent was obtained, and eligibility was confirmed, participants were asked to complete a 4-day weighed food record (4dWFR) which requested details of all complementary foods eaten by the infant. Participants received instructions in their information pack on how to complete these accurately.

Four-day weighed food records

All eligible participants received detailed instructions on how to complete the four-day weighed food records. If required, they were also provided with a set of Tablefair® white electronic dietary scales. The dietary scales were accurate to within ± one gram. A five-page guide at the beginning of the food diary provided participants with written instructions detailing how to complete the food record and how to work the dietary scales, with examples included. All participants received email correspondence after the first week to help answer any questions or concerns they had. Participants were alerted of foods which are commonly forgotten or missed, such as oils and sauces.

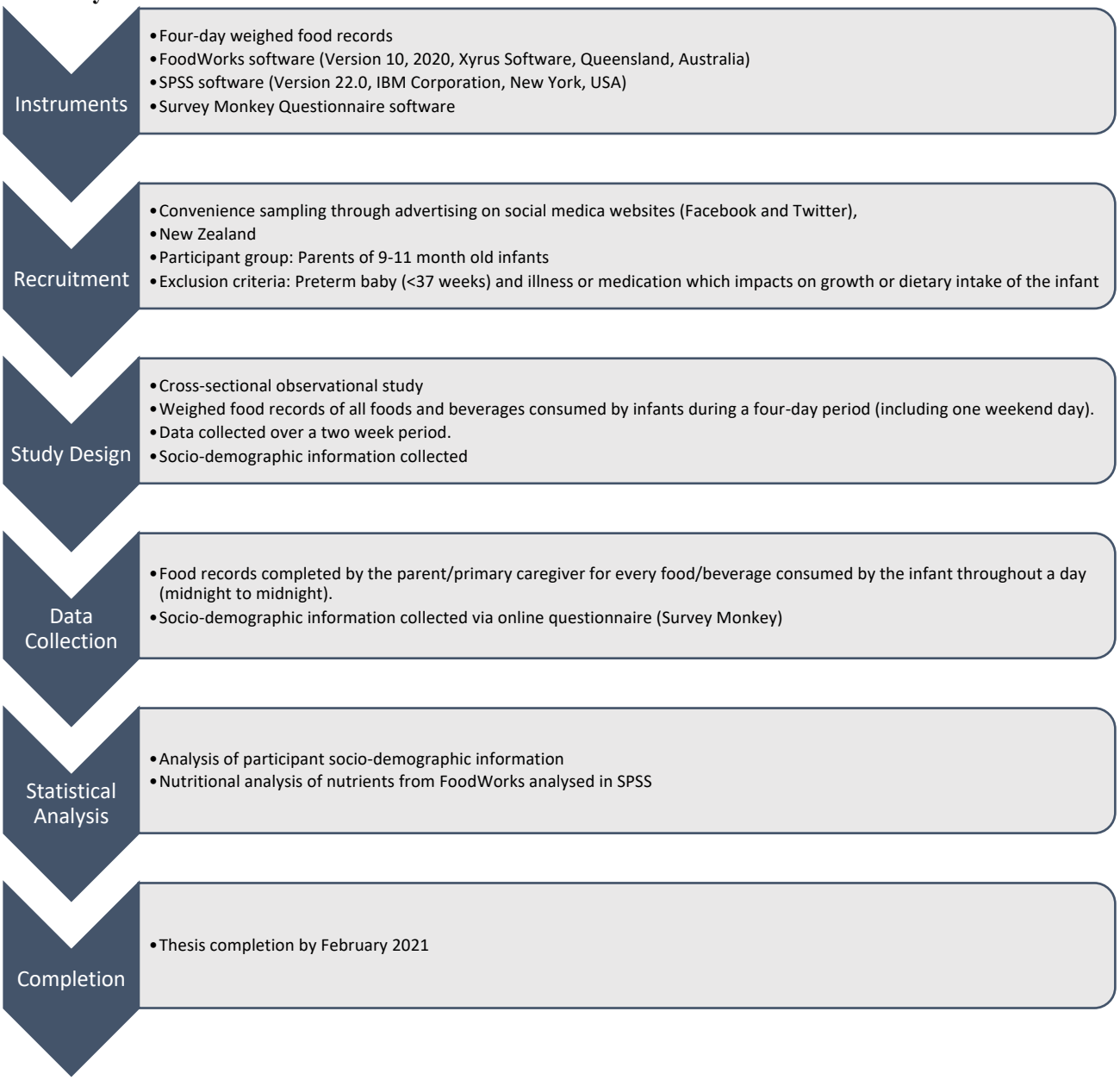
The parent or primary caregiver were asked to complete the 4dWFR in four non-consecutive recording days, including one weekend day, within a two-week period. Participants were instructed to record on days they would be with their infant all day (i.e., days where their infant was not in childcare centres or with relatives). Each recording day was defined as midnight-to-midnight, in order to incorporate any later foods consumed at night. For each recording day, participants were asked to record the weights of all food and drinks that were consumed by their infant. The importance of maintaining the infants' normal dietary patterns, throughout the duration of the study, was also stressed to the parents and caregivers.

For homemade food, participants were asked to provide details of all ingredients included in the recipes and record the weighed amount of each in their food diary, prior to offering the food to the infant. Participants were then asked to record the total amount consumed by the infant (either in grams or the proportion of the recipe eaten). Parents were asked to record any brand names of commercially produced foods eaten, which were then entered into FoodWorks® as a new food.

The completed 4dWFR was then emailed, or posted, back to the main researcher. Each individual record was checked upon completion to ensure accuracy of the data and account for any missing information.

Participants were informed that they may be contacted via email, after handing in the diary, to help provide any further clarification where needed.

3.9 Study Overview



Appendix B: Supplementary Results

Supplementary Table 1

Mean contribution of food and beverage sources to total sugar intake from complementary food intakes[a]

Food groups and foods[d]	N (total %)[b]	Percentage contribution to energy from complementary foods		
		Mean[c] ± SD	Minimum	Maximum
Fruit	**93 (98)**	**45.2 ± 21.0**	**4.4**	**82.3**
Bananas	82 (86)	18.5 ± 15.0	0.1	57.4
Apples	51 (54)	6.6 ± 12.2	0.4	76.9
Pears	46 (48)	4.5 ± 7.0	0.1	27.1
Mandarin	45 (47)	4.1 ± 6.2	0.3	25.9
Kiwifruit	31 (33)	2.6 ± 4.7	1.3	18.3
Berries	34 (36)	1.8 ± 4.5	0.02	32.3
Grapes	22 (23)	1.6 ± 4.2	1.3	24.0
Oranges	18 (19)	1.4 ± 3.7	0.1	18.8
Pineapple	5 (5)	0.5 ± 2.2	6.2	14.6
Feijoa	14 (15)	1.1 ± 3.7	0.3	23.0
Stone Fruits	6 (6)	0.98 ± 4.6	7.6	37.9
Tinned Fruits	10 (11)	0.6 ± 2.6	0.5	20.9
Mango	6 (6)	0.5 ± 2.6	1.3	18.3
Melon	11 (12)	0.4 ± 1.7	0.2	14.5
Vegetables	**94 (99)**	**14.9 ± 13.9**	**0.1**	**73.0**
Kumara	53 (56)	3.7 ± 5.5	0.6	23.3
Carrots	69 (73)	3.3 ± 4.3	0.13	28.1
Pumpkin	51 (54)	2.7 ± 4.8	0.14	32.5
Beans/peas	44 (46)	1.2 ± 1.8	0.02	9.8
Tomatoes	40 (42)	0.8 ± 1.4	0.1	6.5
Broccoli and cauliflower	48 (51)	0.8 ± 1.4	0.1	8.0
Onions	41 (43)	0.7 ± 1.8	0.1	9.8
Frozen vegetables	24 (25)	0.6 ± 1.3	0.03	6.2
Parsnip	9 (10)	0.3 ± 1.0	0.2	6.7
Sweet Corn	28 (30)	0.5 ± 1.2	0.1	5.9
Potatoes	48 (51)	0.3 ± 0.4	0.02	2.7
Root vegetables	8 (8)	0.2 ± 1.2	0.2	9.8
Cucumber	22 (23)	0.2 ± 0.4	0.04	2.6
Cabbage (incl. Brussel sprouts)	7 (7)	0.1 ± 0.6	0.3	4.7
Courgette	9 (10)	0.1 ± 0.5	0.02	4.7
Capsicum	19 (20)	0.1 ± 0.3	0.02	1.5
Avocado	18 (19)	0.1 ± 0.3	0.05	2.2
Silver beet	3 (3)	0.02 ± 0.2	0.1	1.7

Commercial infant foods	**73 (77)**	**14.7 ± 19.8**	**0.2**	**85.2**
Puree/pouch products	57 (60)	12.3 ± 19.0	0.1	85.1
Infant cereals (incl. baby rice)	22 (23)	1.5 ± 5.1	0.1	36.9
Infant biscuits/crackers	45 (47)	1.0 ± 2.7	0.1	23.5
Dairy/dairy-free alternatives	**80 (84)**	**9.7 ± 9.9**	**0.03**	**37.6**
Yoghurt	57 (60)	5.7 ± 7.8	0.1	37.6
Milk	52 (55)	3.0 ± 5.4	0.04	25.0
Dairy-free alternatives	13 (14)	0.9 ± 4.4	0.03	35.4
Cheese	16 (17)	0.1 ± 0.4	0.04	3.4
Cream and butter	22 (23)	0.02 ± 0.1	0.01	0.6
Discretionary foods and beverages	**75 (79)**	**8.3 ± 10.1**	**0.2**	**36.1**
Dried fruit	27 (28)	2.0 ± 4.4	0.4	28.5
Custard/mouse	11 (12)	1.1 ± 3.4	2.0	20.1
Muesli bars	11 (12)	1.1 ± 4.2	2.3	28.4
Sugar	18 (19)	0.8 ± 3.2	0.2	23.51
Cakes/pastries	16 (17)	0.7 ± 4.8	0.1	46.1
Jams	11 (12)	0.6 ± 2.5	0.8	19.0
Biscuits	11 (12)	0.6 ± 2.0	1.5	10.8
Juice	9 (10)	0.4 ± 2.5	0.01	20.5
Sauces	21 (22)	0.4 ± 1.6	0.01	10.1
Takeaways	10 (11)	0.2 ± 1.0	0.2	7.0
Yeast spreads (Vegemite and Marmite)	26 (27)	0.2 ± 0.4	0.1	2.4
Chocolate	5 (5)	0.2 ± 0.2	1.0	11.2
Honey	2 (2)	0.1 ± 0.7	4.0	5.51
Confectionery	1 (1)	0.03 ± 0.3	3.0	3.0
Potato chips	4 (4)	0.03 ± 0.2	0.1	1.3
Breads and cereals	**91 (96)**	**5.6 ± 6.7**	**0.2**	**36.1**
Bread	87 (92)	2.8 ± 3.2	0.2	18.1
Cereals	54 (57)	1.7 ± 4.3	0.1	33.6
Pasta	31 (33)	0.5 ± 1.8	0.04	12.1
Crackers	36 (38)	0.5 ± 1.6	0.02	10.8
Rice	18 (19)	0.1 ± 0.3	0.02	3.1
Popcorn	1 (1)	0.0 ± 0.0	0.1	0.1
Meat/meat-substitutes	**71 (74)**	**0.9 ±1.3**	**0.02**	**6.8**
Nuts, seeds and nut butters	13 (14)	0.2 ± 0.7	0.01	5.2
Legumes/plant-based meat substitutes	22 (23)	0.2 ±0.6	0.1	4.5
Meat (Beef, chicken, lamb, pork)	22 (23)	0.2 ± 0.5	0.1	3.3
Eggs	30 (32)	0.2 ± 0.3	0.02	1.5
Fish	18 (19)	0.1 ± 0.2	0.03	1.1

Appendix C: Four-day weighed food record (4dWFR)

Feeding Babies Study

Weighed Food Diary

To be completed by infants' primary carer(s)

Date started

DD	MM	YY

Instructions for completing food diary:

- This diary requires **all** the foods and fluids your infant consumes to be weighed and recorded on **four** non-consecutive days, including **one** weekend day. E.g. Monday, Wednesday, Friday, Sunday.
- Please try not to change what you give your child as a result of keeping a food diary!

Instructions for using food scales

Weigh EVERYTHING (food and liquids) in gram (g) amounts with weighing scales

Step 1: Turn on the scales

- Firstly, set scales up on a flat surface such as kitchen bench.
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g"
- If the unit is in "oz", change to "g" on the back of the scales

Step 2: Place plate or bowl on scales

- Place the EMPTY plate or bowl you intend to serve the food or liquid in on the scale.
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g" with the plate on the scale

Step 3: Weigh the plate or bowl with food (before eating)

- Add first food to the scale and record the weight in the "Amount" column.
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g" with the plate on the scale and first food
- Add second food to the scale and record the weight in the "Amount" column.
- Repeat for as needed.

Step 4: Weigh the plate or bowl with leftover food (after eating)

- Place the EMPTY plate or bowl you intend to serve the food or liquid in on the scale.
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g" with the plate on the scale
- Record the weight of the first food left over in the "weight of food leftover column"
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g" with the plate on the scale
- Record weight of second food left over in the "weight of food leftover column"
- Repeat as needed.

Step 5: Estimate the leftovers unable to be weighed

- For any foods that may have been spilt on the floor, or on the infant estimate as accurately as possible amounts and record in "leftovers column" (e.g. 2tsp apple puree)

How to estimate amounts of food and drink when you can't weigh them?

If unable to weigh and estimate the amounts, please record this in the "weight of all meals and snacks"

- Household measures – cups, tablespoons and teaspoons. Be specific whether it's heaped or level.
- Weights marked on packages – weights on packaged foods. E.g. ½ of a 110g tin of Watties baby food apple and pear puree.
- Bread – number and size of the slices. E.g. 1/2 slice homebrand multigrain, toast slice.
- Fruit – infants palm size used to estimate portion size. E.g. 4 green grapes, ¼ banana, ¼ granny smith apple.
- Takeaway foods – record the amount consumed and the corresponding weight of the food using the weights in the pictures of "the commonly consumed takeaway food" pictures provided

KEEP IN MIND: We are not looking for a "HEALTHY" diet, we want to know what your infant eats!

EXAMPLE A: How to describe recipes Day: Monday Date: 22/08/15

Food diary: Filled out by the primary carer(s) of the infant

Step 1		Step 2			Step 3	Step 4			Milk before solids Or Solids before milk
Time	Meal or snack	Name of food or drink	Brand of food or drink	Cooking method	Weight of each food or drink	Leftovers: Weight of food left over	Leftovers: Estimation of food leftover	Child fed (C) parent fed (P) or both (B)	
7:00am	Meal	Breastfed - 10minutes							Milk before solids
		1 slice wholegrain toast	Tip Top		25g		Almost all		
		Apple, blueberry, muesli	Heinz for baby	Microwaved	45g	13g	2 tsp		
10:00am	Snack	Banana	Bobby banana		¼ banana – palm size				
		Chocolate cake	Homemade		50g				
12:00pm	Meal	4 Chicken nuggets	Tegal	Baked	70g				Solids before milk
		Potato	Agria washed	Oven roasted	20g	6g	1tsp		
		Whole baby carrots frozen	Signature range	Steamed	28g		none		
3:00pm	Snack	Breastfeed – 15minutes							
6:00pm	Meal	Spaghetti bolognaise	Homemade – see recipe		60g		none		Solids before milk
8:00pm	Snack	Infant formula	Karicare – stage 2		200ml		none		

Please record sandwich or toast slice bread

Please weigh total amount of food leftover

If having fruit, and don't have scales, you can estimate using infants palm

Of total amount leftover that is unable to be weighed, please estimate each food, e.g. half banana, ¼ muesli

Record homemade recipes separately

EXAMPLE B: How to record recipes

Step 1	Step 2	Step 3	Step 4	Step 5
Name of recipe	Amount of each ingredient including any water added (e.g. 3 medium carrots, 500g lean mince, 1 medium onion, 60mL water etc)	Cooking method	Proportion or recipe served to your child	Time of day
Home-made spaghetti bolognaise	300g lean beef mince (1Tbsp olive oil to brown) 50g, diced onion 50g, carrot diced 1 clove garlic, minced 60g, beef stock (Campbells) 30g tomato paste (Watties) 50g, frozen mixed vegetables (signature range) 60g water 5g white flour (homebrand) 400g dried spaghetti (budget)	Mince was shallow fried in a pan. Spaghetti was boiled in a pot	One tenth (1/10)	6pm

Day: _____ Date: _____

Food diary: Filled out by the primary carer(s) of the infant ***Please state any supplements your infant is having e.g. Vitadol C***

Step 1		Step 2			Step 3	Step 4			Milk before solids Or Solids before milk
Time	Meal or snack	Name of food or drink	Brand of food or drink	Cooking method	Weight of each food or drink	Leftovers: Weight of food left over	Leftovers: Estimation of food leftover	Child fed (C) parent fed (P) or both (B)	

Recording recipes

Step 1	Step 2	Step 3	Step 4	Step 5
Name of recipe	Amount of each ingredient including any water added (e.g. 3 medium carrots, 500g lean mince, 1 medium onion, 60mL water etc)	Cooking method	Proportion or recipe served to your child	Time of day

References

Abeshu, M. A., Lelisa, A., & Geleta, B. (2016). Complementary feeding: review of recommendations, feeding practices, and adequacy of homemade complementary food preparations in developing countries–lessons from Ethiopia. *Frontiers in Nutrition, 3*, 41.

Ahern, S. M., Caton, S. J., Bouhlal, S., Hausner, H., Olsen, A., Nicklaus, S., Møller, P., & Hetherington, M. M. (2013). Eating a rainbow. Introducing vegetables in the first years of life in 3 European countries. *Appetite, 71*, 48-56.

Alexy, U., Kersting, M., Sichert-Hellert, W., Manz, F., & Schöch, G. (1999). Macronutrient intake of 3-to 36-month-old German infants and children: results of the DONALD Study. *Annals of Nutrition and Metabolism, 43*(1), 14-22.

Alexy, U., Sichert-Hellert, W., & Kersting, M. (2003). Associations between intake of added sugars and intakes of nutrients and food groups in the diets of German children and adolescents. *British Journal of Nutrition, 90*(2), 441-447.

Alles, M., Eussen, S., and Van Der Beek, E. (2014). Nutritional challenges and opportunities during the weaning period and in young childhood. *Annals of Nutrition and Metabolism,* **64**(3-4): 284-293.

Alvisi, P., Brusa, S., Alboresi, S., Amarri, S., Bottau, P., Cavagni, G., Corradini, B., Landi, L., Loroni, L., and Marani, M. (2015). Recommendations on complementary feeding for healthy, full-term infants. *Italian Journal of Pediatrics,* **41**(1): 36.

Alm, A., Wendt, L.-K., Koch, G., Birkhed, D., & Nilsson, M. (2012). Caries in adolescence–influence from early childhood. *Community Dentistry and Oral Epidemiology, 40*(2), 125-133.

Amoutzopoulos, B., Steer, T., Roberts, C., Cole, D., Collins, D., Yu, D., Hawes, T., Abraham, S., Nicholson, S., and Baker, R. (2018). A Disaggregation Methodology to Estimate Intake of Added Sugars and Free Sugars: An Illustration from the UK National Diet and Nutrition Survey. *Nutrients,* **10**(9): 1177.

Andersen, L. F., Lande, B., Arsky, G. H., & Trygg, K. (2003). Validation of a semi-quantitative food-frequency questionnaire used among 12-month-old Norwegian infants. *European Journal of Clinical Nutrition, 57*(8), 881-888. https://doi.org/10.1038/sj.ejcn.1601621

Andreyeva, T., Chaloupka, F. J., & Brownell, K. D. (2011). Estimating the potential of taxes on sugar-sweetened beverages to reduce consumption and generate revenue. *Preventive Medicine, 52*(6), 413-416. https://doi.org/10.1016/j.ypmed.2011.03.013

Arnold, D. L., Moodie, C. A., Stavric, B., Stoltz, D. R., Grice, H. C., & Munro, I. C. (1977). Canadian Saccharin Study. *Science, 197*(4301), 320-320. https://doi.org/10.1126/science.197.4301.320

Baird, J., Fisher, D., Lucas, P., Kleijnen, J., Roberts, H., & Law, C. (2005). Being big or growing fast: systematic review of size and growth in infancy and later obesity. *British Medical Journal, 331*(7522), 929-931. https://doi.org/10.1136/bmj.38586.411273.E0

Barends, C., de Vries, J., Mojet, J., & de Graaf, C. (2013). Effects of repeated exposure to either vegetables or fruits on infant's vegetable and fruit acceptance at the beginning of weaning. *Food Quality and Preference, 29*(2), 157-165. https://doi.org/10.1016/j.foodqual.2013.03.008

Bates, B., Lennox, A., & Swan, G. (2010). National diet and nutrition survey: headline results from year 1 of the rolling programme (2008/2009). *London: Food Standards Agency*.

Beauchamp, G., & Mennella, J. (2009). Early flavor learning and its impact on later feeding behavior. *Journal of Pediatric Gastroenterology and Nutrition, 48*, S25-S30.

Bell, A. C., Kremer, P. J., Magarey, A. M., & Swinburn, B. A. (2005). Contribution of 'noncore' foods and beverages to the energy intake and weight status of Australian children. *European Journal of Clinical Nutrition, 59*(5), 639-645. https://doi.org/10.1038/sj.ejcn.1602091

Bener, A., Al Darwish, M. S., Tewfik, I., & Hoffmann, G. F. (2013). The impact of dietary and lifestyle factors on the risk of dental caries among young children in Qatar. *The Journal Of The Egyptian Public Health Association, 88*(2), 67-73.

Bialostosky, K., Wright, J. D., Kennedy-Stephenson, J., McDowell, M., & Johnson, C. L. (2002). Dietary intake of macronutrients, micronutrients, and other dietary constituents: United States, 1988-94: data from the National Health Examination Survey, the National Health and Nutrition Examination Surveys, and the Hispanic Health and Nutrition Examination Survey.

Birch, L. L., & Doub, A. E. (2014). Learning to eat: birth to age 2 y. *American Journal of Clinical Nutrition, 99*(3), 723S-728S. https://doi.org/10.3945/ajcn.113.069047

Birch, L. L., Gunder, L., Grimm-Thomas, K., & Laing, D. G. (1998). Infants' consumption of a new food enhances acceptance of similar foods. *Appetite*.

Black, R. E., Makrides, M., & Ong, K. K. (2017). *Complementary Feeding: Building the Foundations for a Healthy Life: 87th Nestle Nutrition Institute Workshop, Singapore, May 2016.* Karger Medical and Scientific Publishers.

Bresson, J.-L., Flynn, A., Heinonen, M., Hulshof, K., Korhonen, H., Lagiou, P., Løvik, M., Marchelli, R., Martin, A., & Moseley, B. (2009). Review of labelling reference intake values Scientific Opinion of the Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the review of labelling reference intake values for selected nutritional elements. *EFSA J, 1008*, 1-14.

Burt, B. A., & Pai, S. (2001). Sugar consumption and caries risk: a systematic review. *Journal of Dental Education, 65*(10), 1017-1023.

Butte, N. F., Fox, M. K., Briefel, R. R., Siega-Riz, A. M., Dwyer, J. T., Deming, D. M., & Reidy, K. C. (2010). Nutrient Intakes of US Infants, Toddlers, and Preschoolers Meet or Exceed Dietary Reference Intakes. *Journal of the American Dietetic Association, 110*(12), S27-S37. https://doi.org/10.1016/j.jada.2010.09.004

Butte, N., Wong, W., Hopkinson, J., Heinz, C., Mehta, N., and Smith, E. (2000). Energy requirements derived from total energy expenditure and energy deposition during the first 2 y of life. *The American Journal of Clinical Nutrition,* **72**(6): 1558-1569.

Caballero, B. (2001). Early nutrition and risk of disease in the adult. *Public Health Nutrition, 4*(6a), 1335-1336.

Campoy, C., Campos, D., Cerdo, T., Diéguez, E., and García-Santos, J. (2018). Complementary feeding in developed countries: the 3 W's (When, What, and Why?). *Annals of Nutrition and Metabolism,* **73**: 27-36.

Cantoral, A., Tellez-Rojo, M. M., Ettinger, A. S., Hu, H., Hernandez-Avila, M., & Peterson, K. (2016). Early introduction and cumulative consumption of sugar-sweetened beverages during the pre-school period and risk of obesity at 8-14 years of age. *Pediatric Obesity, 11*(1), 68-74. https://doi.org/10.1111/ijpo.12023

Caton, S. J., Blundell, P., Ahern, S. M., Nekitsing, C., Olsen, A., Møller, P., Hausner, H., Remy, E., Nicklaus, S., & Chabanet, C. (2014). Learning to eat vegetables in early life: the role of timing, age and individual eating traits. *PLoS ONE, Public Library of Science, 9*(5).

Chaffee, B. W., Feldens, C. A., Rodrigues, P. H., & Vitolo, M. R. (2015). Feeding practices in infancy associated with caries incidence in early childhood. *Community Dentistry and Oral Epidemiology, 43*(4), 338-348. https://doi.org/10.1111/cdoe.12158

Chaffee, B. W., Rodrigues, P. H., Kramer, P. F., Vitolo, M. R., & Feldens, C. A. (2017). Oral health-related quality-of-life scores differ by socioeconomic status and caries experience. *Community Dentistry and Oral Epidemiology, 45*(3), 216-224. https://doi.org/10.1111/cdoe.12279

Chambers, L., Hetherington, M., Cooke, L., Coulthard, H., Fewtrell, M., Emmett, P., Lowdon, J., Blissett, J., Lanigan, J., Baseley, C., & Stanner, S. (2016). Reaching consensus on a 'vegetables

first' approach to complementary feeding. *Nutrition Bulletin, 41*(3), 270-276. https://doi.org/10.1111/nbu.12220

Chan, L., Magarey, A. M., & Daniels, L. A. (2011). Maternal Feeding Practices and Feeding Behaviors of Australian Children Aged 12-36 Months. *Maternal and Child Health Journal, 15*(8), 1363-1371. https://doi.org/10.1007/s10995-010-0686-4

Cogswell, M., Gunn, J., Yuan, K., Park, S and Merritt, R. (2015). Sodium and sugar in complementary infant and toddler foods sold in the United States. *Pediatrics,* **135**(3): 416-423.

Committee on Medical Aspects of Food Policy. (1989). *Report on Health and Social Subjects: Dietary Sugars and Human Disease: Report of the Panel of Dietary Sugars* (Vol. 37). London: HMSO.

Conn, J. A., Davies, M. J., Walker, R. B., & Moore, V. M. (2009). Food and nutrient intakes of 9-month-old infants in Adelaide, Australia. *Public Health Nutrition, 12*(12), 2448-2456. https://doi.org/10.1017/s1368980009005552

Coulthard, H., Harris, G., & Emmett, P. (2010). Long-term consequences of early fruit and vegetable feeding practices in the United Kingdom. *Public Health Nutrition, 13*(12), 2044-2051. https://doi.org/10.1017/s1368980010000790

Coulthard, H., Harris, G., & Fogel, A. (2014). Exposure to vegetable variety in infants weaned at different ages. *Appetite, 78*, 89-94. https://doi.org/10.1016/j.appet.2014.03.021

Cornwell, T. and McAlister, A. (2011). Alternative thinking about starting points of obesity. Development of child taste preferences. *Appetite,* **56**(2): 428-439.

Cowbrough, K. (2010). Complementary feeding for infants 6 to 12 months. *The Journal of Family Health Care*: 33.

Cowin, I., P. Emmett and ALSPAC Study Team (2007). Diet in a group of 18-month-old children in South West England, and comparison with the results of a national survey. *Journal of Human Nutrition and Dietetics*, **20**(3): 254-267.

Crawley, H., & Westland, S. (2017). *Baby foods in the UK: A review of commercially produced jars and pouches of baby foods marketed in the UK*. First Steps Nutrition Trust.

Cummings, J., & Stephen, A. (2007). Carbohydrate terminology and classification. *European Journal of Clinical Nutrition, 61*(1). S5-S18.

Darling, J. C., Bamidis, P. D., Burberry, J., & Rudolf, M. C. (2020). The First Thousand Days: early, integrated and evidence-based approaches to improving child health: coming to a population near you? *Archives of Disease in Childhood*.

de Ruyter, J. C., Olthof, M. R., Seidell, J. C., & Katan, M. B. (2012). A trial of sugar-free or sugar-sweetened beverages and body weight in children. *New England Journal of Medicine, 367*(15), 1397-1406.

Dewey, K. (2003). Guiding Principles for Complementary Feeding of the Breastfed Child. World Health Organization Washington: Pan American Health Organization.

Dennison, B. A., Edmunds, L. S., Stratton, H. H., & Pruzek, R. M. (2006). Rapid infant weight gain predicts childhood over-weight. *Obesity, 14*(3), 491-499. https://doi.org/10.1038/oby.2006.64

DiMeglio, D. P., & Mattes, R. D. (2000). Liquid versus solid carbohydrate: effects on food intake and body weight. *International Journal of Obesity, 24*(6), 794-800. https://doi.org/10.1038/sj.ijo.0801229

Do, L. G., & Spencer, A. (2007). Oral health-related quality of life of children by dental caries and fluorosis experience. *Journal of Public Health Dentistry, 67*(3), 132-139.

Duangthip, D., Gao, S. S., Chen, K. J., Lo, E. C. M., & Chu, C. H. (2020). Oral health-related quality of life and caries experience of Hong Kong preschool children. *International Dental Journal, 70*(2), 100-107. https://doi.org/10.1111/idj.12526

EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). (2010). Scientific opinion on dietary reference calues for carbohydrates and dietary fibre. *EFSA Journal.* 2010, 8(3), 1462.

Eid, E. (1970). Follow-up study of physical growth of children who had excessive weight gain in first six months of life. *Br Med J, 2*(5701), 74-76.

Elia, M., & Cummings, J. H. (2007). Physiological aspects of energy metabolism and gastrointestinal effects of carbohydrates. *European Journal of Clinical Nutrition, 61*, S40-S74. https://doi.org/10.1038/sj.ejcn.1602938

Elliott, C. D. (2011). Sweet and salty: nutritional content and analysis of baby and toddler foods. *Journal of Public Health, 33*(1), 63-70.

Erickson, J., Sadeghirad, B., Lytvyn, L., Slavin, J., and Johnston, B. (2017). The scientific basis of guideline recommendations on sugar intake: a systematic review. *Annals of Internal Medicine*, **166**(4): 257-267.

Erickson, L. W., Taylor, R. Y., Haszard, J. J., Fleming, E. A., Daniels., L., Morison, B. J., Leong, C., Fangupo, L. J., Wheeler, B. J., Taylor, B. J., Te Morenga, L., McLean, R. M., Heath, A. L. M. (2018) Impact of a Modified Version of Baby-Led Weaning on Infant Food and Nutrient Intakes: The BLISS Randomized Controlled Trial. *Nutrients, 10*(6). https://doi.org/10.3390/nu10060740

Eriksson, J., Forsen, T., Osmond, C., & Barker, D. (2003). Obesity from cradle to grave. *International Journal of Obesity, 27*(6), 722-727. https://doi.org/10.1038/sj.ijo.0802278

Erkkola, M., Kronberg-Kippila, C., Kyttala, P., Lehtisalo, J., Reinivuo, H., Tapanainen, H., Veijola, R., Knip, M., Ovaskainen, M. L., & Virtanen, S. M. (2009). Sucrose in the diet of 3-year-old Finnish children: sources, determinants and impact on food and nutrient intake. *British Journal of Nutrition, 101*(8), 1209-1217. https://doi.org/10.1017/s0007114508057619

Escobar, M. A. C., Veerman, J. L., Tollman, S. M., Bertram, M. Y., & Hofman, K. J. (2013). Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. *BMC Public Health, 13*(1), 1072.

Faldella, G., Corvaglia, L., Lanari, M., and Salvioli, G. (2003). Iron balance and iron nutrition in infancy. *Acta Paediatrica* **92**: 82-85.

Fidler Mis, N., Braegger, C., Bronsky, J., Campoy, C., Domellöf, M., Embleton, N., Hojsak, I., Hulst, J., Indrio, F., and Lapillonne, A. (2017). Sugar in infants, children and adolescents: a position paper of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition. *Journal of Pediatric Gastroenterology and Nutrition*, **65**(6): 681-696.

Filstrup, S. L., Briskie, D., Da Fonseca, M., Lawrence, L., Wandera, A., & Inglehart, M. R. (2003). Early childhood caries and quality of life: child and parent perspectives. *Pediatric Dentistry, 25*(5), 431-440.

Finn, S., Culligan, E. P., Snelling, W. J., & Sleator, R. D. (2018). Early life nutrition. *Science Progress, 101*(4), 332-359.

Fisher, J. O., Butte, N. F., Mendoza, P. M., Wilson, T. A., Hodges, E. A., Reidy, K. C., & Deming, D. (2008). Overestimation of infant and toddler energy intake by 24-h recall compared with weighed food records. *American Journal of Clinical Nutrition, 89*(3), 928-928. https://doi.org/10.3945/ajcn.2008.27309

Forshee, R. A., Storey, M. L., & Anderson, P. A. (2009). Sugar-sweetened beverages and BMI in children and adolescents: reanalyses of a meta-analysis Reply. *American Journal of Clinical Nutrition, 89*(1), 439-440. https://doi.org/10.3945/ajcn.2008.27089

Foterek, K., Buyken, A. E., Bolzenius, K., Hilbig, A., Nothlings, U., & Alexy, U. (2016). Commercial complementary food consumption is prospectively associated with added sugar intake in childhood. *British Journal of Nutrition, 115*(11), 2067-2074. https://doi.org/10.1017/s0007114516001367

Fox, M. K., Pac, S., Devaney, B., & Jankowski, L. (2004). Feeding infants and toddlers study: what foods are infants and toddlers eating? *Journal of the American Dietetic Association, 104*, 22-30.

Fox, M. K., Reidy, K., Novak, T., & Ziegler, P. (2006). Sources of energy and nutrients in the diets of infants and toddlers. *Journal of the American Dietetic Association, 106*(1), S28-S42. https://doi.org/10.1016/j.jada.2005.09.034

Frencken, J. E., Sharma, P., Stenhouse, L., Green, D., Laverty, D., & Dietrich, T. (2017). Global epidemiology of dental caries and severe periodontitis–a comprehensive review. *Journal of Clinical Periodontology, 44*, S94-S105.

Food Standards Australia New Zealand. 2002. *Australia New Zealand Food Standards Code*. Canberra: Food Standards Australia New Zealand. Retrieved 12 January 2020 from http://www.foodstandards.gov.au/thecode/foodstandardscode.cfm (accessed 25 January 2020).

Garcia, A. L., McLean, K., & Wright, C. M. (2016). Types of fruits and vegetables used in commercial baby foods and their contribution to sugar content. *Maternal and Child Nutrition, 12*(4), 838-847. https://doi.org/10.1111/mcn.12208

Gibney, M., Sigman-Grant, M., Stanton Jr, J. L., & Keast, D. R. (1995). Consumption of sugars. *The American Journal of Clinical Nutrition, 62*(1), 178S-194S.

Gibson, R. S. (2005). *Principles of nutritional assessment*. Oxford university press, USA.

Gluckman, P. D., & Hanson, M. A. (2008). Developmental and epigenetic pathways to obesity: an evolutionary-developmental perspective. *International Journal of Obesity, 32*, S62-S71. https://doi.org/10.1038/ijo.2008.240

Grant, A. M., Ferguson, E. L., Toafa, V., Henry, T. E., & Guthrie, B. E. (2004). Dietary factors are not associated with high levels of obesity in New Zealand Pacific preschool children. *The Journal of Nutrition, 134*(10), 2561-2565.

Grindefjord, M., Dahllöf, G., Nilsson, B., & Modéer, T. (1996). Stepwise Prediction of Dental Caries in Children up to 3.5 Years of Age. *Caries Research, 30*(4), 256-266. https://doi.org/10.1159/000262333

Hagman, U., Bruce, Å., Persson, L. A., Samuelson, G., & Sjölin, S. (1986). Food habits and nutrient intake in childhood in relation to health and socio-economic conditions. A Swedish Multicentre Study 1980-81. *Acta paediatrica Scandinavica. Supplement, 328*, 1-56.

Harris, G. (2008). Development of taste and food preferences in children. *Current Opinion in Clinical Nutrition & Metabolic Care, 11*(3), 315-319.

Harris, R., Nicoll, A. D., Adair, P. M., & Pine, C. M. (2004). Risk factors for dental caries in young children: a systematic review of the literature. *Community Dental Health, 21*(1), 71-85.

Hayes, J. E., & Johnson, S. L. (2017). Sensory aspects of bitter and sweet tastes during early childhood. *Nutrition Today, 52*(2), S41-S51.

Hepper, P. G. (1988). Adaptive fetal learning: prenatal exposure to garlic affects postnatal preferences. *Animal Behaviour, 36*(3), 935-936.

Herbst, A., Diethelm, K., Cheng, G., Alexy, U., Icks, A., & Buyken, A. E. (2011). Direction of Associations between Added Sugar Intake in Early Childhood and Body Mass Index at Age 7 Years May Depend on Intake Levels. *Journal of Nutrition, 141*(7), 1348-1354. https://doi.org/10.3945/jn.110.137000

Hur, Y. I., Park, H., Kang, J. H., Lee, H. A., Song, H. J., Lee, H. J., & Kim, O. H. (2016). Associations between Sugar Intake from Different Food Sources and Adiposity or Cardio-Metabolic Risk in Childhood and Adolescence: The Korean Child-Adolescent Cohort Study. *Nutrients, 8*(1), Article 20. https://doi.org/10.3390/nu8010020

Jardi, C., Aranda, N., Bedmar, C., Ribot, B., Elias, I., Aparicio, E., Arija, V., Voltas, N., Hernandez, C., Canals, J., Escribano, J., Jimenez, R., Barroso, J. M., & Grp Investigador, D. (2019). Consumption of free sugars and excess weight in infants. A longitudinal study. *Anales De Pediatria, 90*(3), 165-172. https://doi.org/10.1016/j.anpedi.2018.03.018

Johnson, L., van Jaarsveld, C. H., Llewellyn, C. H., Cole, T. J., & Wardle, J. (2014). Associations between infant feeding and the size, tempo and velocity of infant weight gain: SITAR analysis of the Gemini twin birth cohort. *International Journal of Obesity, 38*(7), 980-987.

Johnson, S. L., & Hayes, J. E. (2017). Developmental readiness, caregiver and child feeding behaviors, and sensory science as a framework for feeding young children. *Nutrition Today, 52*(2), S30-S40.

Joyce, T., & Gibney, M. (2008). The impact of added sugar consumption on overall dietary quality in Irish children and teenagers. *Journal of Human Nutrition and Dietetics, 21*(5), 438-450.

Judd, A. L., Beck, K. L., McKinlay, C., Jackson, A., & Conlon, C. A. (2020). Validation of a Complementary Food Frequency Questionnaire to assess infant nutrient intake. *Maternal and Child Nutrition, 16*(1), Article e12879. https://doi.org/10.1111/mcn.12879

Karaolis-Danckert, N., Buyken, A. E., Bolzenius, K., de Faria, C. P., Lentze, M. J., & Kroke, A. (2006). Rapid growth among term children whose birth weight was appropriate for gestational age has a longer lasting effect on body fat percentage than on body mass index. *American Journal of Clinical Nutrition, 84*(6), 1449-1455.

Karjalainen, S., Soderling, E., Sewon, L., Lapinleimu, H., & Simell, O. (2001). A prospective study on sucrose consumption, visible plaque and caries in children from 3 to 6 years of age. *Community Dentistry and Oral Epidemiology, 29*(2), 136-142. https://doi.org/10.1034/j.1600-0528.2001.290208.x

Kassebaum, N. J., Smith, A. G. C., Bernabe, E., Fleming, T. D., Reynolds, A. E., Vos, T., Murray, C. J. L., & Marcenes, W. (2017). Global, Regional, and National Prevalence, Incidence, and Disability-Adjusted Life Years for Oral Conditions for 195 Countries, 1990-2015: A Systematic Analysis for the Global Burden of Diseases, Injuries, and Risk Factors. *Journal of dental research, 96*(4), 380-387. https://doi.org/10.1177/0022034517693566

Kelder, S. H., Perry, C. L., Klepp, K.-I., & Lytle, L. L. (1994). Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. *American Journal of Public Health, 84*(7), 1121-1126.

Kelishadi, R., & Farajian, S. (2014). The protective effects of breastfeeding on chronic non-communicable diseases in adulthood: A review of evidence. *Advanced Biomedical Research, 3*, 3. https://doi.org/10.4103/2277-9175.124629

Klesges, R. C., Klesges, L. M., Eck, L. H., & Shelton, M. L. (1995). A longitudinal analysis of accelerated weight gain in preschool children. *Pediatrics, 95*(1), 126-130.

Koletzko, B., Brands, B., Poston, L., Godfrey, K., & Demmelmair, H. (2012). Early nutrition programming of long-term health. *Proceedings of the Nutrition Society, 71*(3), 371-378.

Koplin, J. J., Kerr, J. A., Lodge, C., Garner, C., Dharmage, S. C., Wake, M., & Allen, K. J. (2019). Infant and young child feeding interventions targeting overweight and obesity: A narrative review. *Obesity Reviews, 20*, 31-44. https://doi.org/10.1111/obr.12798

Kramer, P. F., Feldens, C. A., Ferreira, S. H., Bervian, J., Rodrigues, P. H., & Peres, M. A. (2013). Exploring the impact of oral diseases and disorders on quality of life of preschool children. *Community Dentistry and Oral Epidemiology, 41*(4), 327-335. https://doi.org/10.1111/cdoe.12035

Kramer, M. S., & Shapiro, S. H. (1984). Scientific Challenges in the Application of Randomized Trials. *Journal of American Medical Association, 252*(19), 2739-2745. https://doi.org/10.1001/jama.1984.03350190041017

Kranz, S., Smiciklas-Wright, H., & Francis, L. A. (2006). Diet quality, added sugar, and dietary fiber intakes in American preschoolers. *Pediatric Dentistry, 28*(2), 164-171.

Krebs, N. F., Hambidge, K. M., Mazariegos, M., Westcott, J., Goco, N., Wright, L. L., Koso-Thomas, M., Tshefu, A., Bose, C., Pasha, O., Goldenberg, R., Chomba, E., Carlo, W., Kindem, M., Das, A., Hartwell, T., McClure, E., & Complementary Feeding Study, G. (2011). Complementary feeding: a Global Network cluster randomized controlled trial. *BMC Pediatrics, 11*, Article 4. https://doi.org/10.1186/1471-2431-11-4

Krebs-Smith, S. M., Graubard, B. I., Kahle, L. L., Subar, A. F., Cleveland, L. E., & Ballard-Barbash, R. (2000). Low energy reporters vs others: a comparison of reported food intakes. *European Journal of Clinical Nutrition, 54*(4), 281-287. https://doi.org/10.1038/sj.ejcn.1600936

Krisdapong, S., Sheiham, A., & Tsakos, G. (2009). Oral health-related quality of life of 12-and 15-year-old Thai children: findings from a national survey. *Community Dentistry and Oral Epidemiology, 37*(6), 509-517. https://doi.org/10.1111/j.1600-0528.2009.00503.x

Kunz, C., Rodriquez-Palmero, M., Koletzko, B., & Jensen, R. (1999). Nutritional and biochemical properties of human milk, Part I: General aspects, proteins, and carbohydrates. *Clinics in Perinatology, 26*(2), 307-333.

Kwak, S. G., & Kim, J. (2017) Central Limit Theoram: the cornerstone of modern statistics. *Korean Journal of Anesthesiologu, 70*(2), 144-156. https://doi.org/10.4097/kjae.2017.70.2.144

Lamberti, L. M., Walker, C. L. F., Noiman, A., Victora, C., & Black, R. E. (2011). Breastfeeding and the risk for diarrhea morbidity and mortality. *BMC public health, 11*(3), S15.

Lange, C., Visalli, M., Jacob, S., Chabanet, C., Schlich, P., & Nicklaus, S. (2013). Maternal feeding practices during the first year and their impact on infants' acceptance of complementary food. *Food quality and preference, 29*(2), 89-98.

Li, Y., & Wang, W. (2002). Predicting caries in permanent teeth from caries in primary teeth: An eight-year cohort study. *Journal of dental research, 81*(8), 561-566. https://doi.org/10.1177/154405910208100812

Libuda, L., & Kersting, M. (2009). Soft drinks and body weight development in childhood: is there a relationship? *Current Opinion in Clinical Nutrition & Metabolic Care, 12*(6), 596-600.

Liem, D. G., & Mennella, J. A. (2002). Sweet and sour preferences during childhood: role of early experiences. *Developmental Psychobiology: The Journal of the International Society for Developmental Psychobiology, 41*(4), 388-395.

Lioret, S., McNaughton, S. A., Spence, A. C., Crawford, D., & Campbell, K. J. (2013). Tracking of dietary intakes in early childhood: the Melbourne InFANT Program. *European Journal of Clinical Nutrition, 67*(3), 275-281. https://doi.org/10.1038/ejcn.2012.218

Lustig, R. H., Schmidt, L. A., & Brindis, C. D. (2012). The toxic truth about sugar. *Nature, 482*(7383), 27-29. https://doi.org/10.1038/482027a

Lytle, L. A., Seifert, S., Greenstein, J., & McGovern, P. (2000). How do children's eating patterns and food choices change over time? Results from a cohort study. *American Journal of Health Promotion, 14*(4), 222-228.

Maier, A. S., Chabanet, C., Schaal, B., Leathwood, P. D., & Issanchou, S. N. (2008). Breastfeeding and experience with variety early in weaning increase infants' acceptance of new foods for up to two months. *Clinical Nutrition, 27*(6), 849-857.

Male, C., Persson, L., Freeman, V., Guerra, A., and Van't Hof, M. (2001). Prevalence of iron deficiency in 12-mo-old infants from 11 European areas and influence of dietary factors on iron status (Euro-Growth study). *Acta Paediatrica* **90**(5): 492-498.

Marriott, L., Robinson, S., Poole, J., Borland, S., Godfrey, K., Law, C., Inskip, H., & Southampton Women's Survey Study Group. (2008). What do babies eat? Evaluation of a food frequency

questionnaire to assess the diets of infants aged 6 months. *Public Health Nutrition, 11*(7), 751-756.

Marriott, L. D., Inskip, H. M., Borland, S. E., Godfrey, K. M., Law, C. M., Robinson, S. M., & Southampton Women's Survey Study Group. (2009). What do babies eat? Evaluation of a food frequency questionnaire to assess the diets of infants aged 12 months. *Public health nutrition, 12*(7), 967-972. https://doi.org/10.1017/S1368980008003388

Martin, C. R., Ling, P. R., & Blackburn, G. L. (2016). Review of Infant Feeding: Key Features of Breast Milk and Infant Formula. *Nutrients, 8*(5), Article 279. https://doi.org/10.3390/nu8050279

Mattila, M.-L., Rautava, P., Paunio, P., Ojanlatva, A., Hyssälä, L., Helenius, H., & Sillanpää, M. (2001). Caries experience and caries increments at 10 years of age. *Caries Research, 35*(6), 435-441.

Maunder, E. M., Nel, J. H., Steyn, N. P., Kruger, H. S., & Labadarios, D. (2015). Added sugar, macro- and micronutrient intakes and anthropometry of children in a developing world context. *PLoS One, 10*(11).

Mejare, I., Stenlund, H., Julihn, A., Larsson, I., & Permert, L. (2001). Influence of approximal caries in primary molars on caries rate for the mesial surface of the first permanent molar in Swedish children from 6 to 12 years of age. *Caries Research, 35*(3), 178-185. https://doi.org/10.1159/000047453

Mellbin, T., & Vuille, J. C. (1973). Physical development at 7-years of age in relation to velocity of weight-gain in infancy with special reference to incidence of overweight. *British Journal of Preventive & Social Medicine, 27*(4), 225-235.

Mennella, J. (2007). The chemical senses and the development of flavor preferences in humans. *Textbook on human lactation. Amarillo, TX: Hale Publishing*, 403-414.

Mennella, J. A. (2014). Ontogeny of taste preferences: basic biology and implications for health. *The American journal of clinical nutrition, 99*(3), 704S-711S.

Mennella, J. A., & Beauchamp, G. K. (2002). Flavor experiences during formula feeding are related to preferences during childhood. *Early Human Development, 68*(2), 71-82, Article Pii s0378-3782(02)00008-7. https://doi.org/10.1016/s0378-3782(02)00008-7

Mennella, J. A., & Beauchamp, G. K. (2010). The role of early life experiences in flavor perception and delight. In *Obesity prevention* (pp. 203-217). Elsevier.

Mennella, J. A., Bobowski, N. K., & Reed, D. R. (2016a). The development of sweet taste: From biology to hedonics. *Reviews in Endocrine & Metabolic Disorders, 17*(2), 171-178. https://doi.org/10.1007/s11154-016-9360-5

Mennella, J. A., Johnson, A., & Beauchamp, G. K. (1995). Garlic ingestion by pregnant women alters the odor of amniotic fluid. *Chemical senses, 20*(2), 207-209.

Mennella, J. A., Lukasewycz, L. D., Castor, S. M., & Beauchamp, G. K. (2011). The timing and duration of a sensitive period in human flavor learning: a randomized trial. *The American journal of clinical nutrition, 93*(5), 1019-1024.

Mennella, J. A., Reed, D. R., Mathew, P. S., Roberts, K. M., & Mansfield, C. J. (2015). "A Spoonful of Sugar Helps the Medicine Go Down": Bitter Masking by Sucrose Among Children and Adults. *Chemical senses, 40*(1), 17-25. https://doi.org/10.1093/chemse/bju053

Mennella, J. A., Reiter, A. R., & Daniels, L. M. (2016b). Vegetable and Fruit Acceptance during Infancy: Impact of Ontogeny, Genetics, and Early Experiences. *Advances in Nutrition, 7*(1), 211S-219S. https://doi.org/10.3945/an.115.008649

Mennella, J. A., & Trabulsi, J. C. (2012). Complementary foods and flavor experiences: setting the foundation. *Annals of Nutrition and Metabolism, 60*(Suppl. 2), 40-50.

Metcalf, P. A., Scragg, R. K. R., Stewart, A. W., & Scott, A. J. (2007). Design effects associated with dietary nutrient intakes from a clustered design of 1 to 14-year-old children. *European Journal of Clinical Nutrition, 61*(9), 1064-1071. https://doi.org/10.1038/sj.ejcn.1602618

Mikkila, V., Rasanen, L., Raitakari, O. T., Pietinen, P., & Viikari, J. (2005). Consistent dietary patterns identified from childhood to adulthood: The cardiovascular risk in young finns study. *British Journal of Nutrition, 93*(6), 923-931. https://doi.org/10.1079/bjn20051418

Miles, G., & Siega-Riz, A. M. (2017). Trends in Food and Beverage Consumption Among Infants and Toddlers: 2005-2012. *Pediatrics, 139*(6), Article e20163290. https://doi.org/10.1542/peds.2016-3290

Mills, A., & Tyler, H. (1992). *Food and nutrient intakes of British infants aged 6-12 months*. HMSO Publications Centre.

Ministry of Health. (2008). Food and Nutrition Guidelines for Healthy Infants and Toddlers (aged 0–2): A background paper (4th Edition) – Partially revised December 2012. Wellington: Ministry of Health.

Ministry of Health. (2018). "Baby-led Weaning." Retrieved 2 February 2020 from https://www.health.govt.nz/your-health/pregnancy-and-kids/first-year/6-12-months/feeding-your-baby/baby-led-weaning.

Ministry of Health. (2019). "Annual Data Explorer 2018/19: New Zealand Health Survey." Retrieved 2 February, 2020, from https://minhealthnz.shinyapps.io/nz-health-survey-2018-19-annual-data-explorer/

Ministry of Health (2020). "Annual Data Explorer 2019/20: New Zealand Health Survey." Retrieved 1 February, 2021, from https://minhealthnz.shinyapps.io/nz-health-survey-2019-20-annual-data-explorer/.

Moding, K. J., Ferrante, M. J., Bellows, L. L., Bakke, A. J., Hayes, J. E., & Johnson, S. L. (2018). Variety and content of commercial infant and toddler vegetable products manufactured and sold in the United States. *American Journal of Clinical Nutrition, 107*(4), 576-583. https://doi.org/10.1093/ajcn/nqx079

Monteiro, P. O. A., & Victora, C. G. (2005). Rapid growth in infancy and childhood and obesity in later life - a systematic review. *Obesity Reviews, 6*(2), 143-154. https://doi.org/10.1111/j.1467-789X.2005.00183.x

Moore, T., Arefadib, N., Deery, A., Keyes, M., & West, S. (2017). The first thousand days: an evidence

Morton, S., Atatoa-Carr, P., Grant, C., Lee, A., Bandara, D., Kinloch, J., Schmidt, J., Hedges, M., Ivory, V., & Kingi, T. (2012). Growing up in New Zealand: A longitudinal study of New Zealand children and their families. Report 2: Now we are born.

Mourao, D. M., Bressan, J., Campbell, W. W., & Mattes, R. D. (2007). Effects of food form on appetite and energy intake in lean and obese young adults. *International Journal of Obesity, 31*(11), 1688-1695. https://doi.org/10.1038/sj.ijo.0803667

Mustard, J. F. (2009). Canadian progress in early child development - putting science into action. *Paediatrics & Child Health, 14*(10), 689-690. https://doi.org/10.1093/pch/14.10.689

Naidoo, S., & Myburgh, N. (2007). Nutrition, oral health and the young child. *Maternal & Child Nutrition, 3*(4), 312-321.

National Health and Medical Research Council, Australian Government Department of Health and Ageing, New Zealand Ministry of Health. Nutrient Reference Values for Australia and New Zealand. Canberra: National Health and Medical Research Council; 2006.

Ni Mhurchu, C., Eyles, H., Genc, M., & Blakely, T. (2014). Twenty percent tax on fizzy drinks could save lives and generate millions in revenue for health programmes in New Zealand. *NZ Med J, 127*(1389), 92-95.

Nicklaus, S., Boggio, V., Chabanet, C., & Issanchou, S. (2005). A prospective study of food variety seeking in childhood, adolescence and early adult life. *Appetite, 44*(3), 289-297. https://doi.org/10.1016/j.appet.2005.01.006

Noble, S., Emmett, P., & ALSPAC Study Team. (2001). Food and nutrient intake in a cohort of 8-month-old infants in the south-west of England in 1993. *European Journal of Clinical Nutrition, 55*(8), 698-707. https://doi.org/10.1038/sj.ejcn.1601210

Ong, K. K., Emmett, P., Northstone, K., Golding, J., Rogers, I., Ness, A. R., Wells, J. C., & Dunger, D. B. (2009). Infancy Weight Gain Predicts Childhood Body Fat and Age at Menarche in Girls. *Journal of Clinical Endocrinology & Metabolism, 94*(5), 1527-1532. https://doi.org/10.1210/jc.2008-2489

Ong, K. K., & Loos, R. J. F. (2006). Rapid infancy weight gain and subsequent obesity: Systematic reviews and hopeful suggestions. *Acta Paediatrica, 95*(8), 904-908. https://doi.org/10.1080/08035250600719754

Owada, M., Aoki, K., & Kitagawa, T. (2000). Taste preferences and feeding behaviour in children with phenylketonuria on a semisynthetic diet. *European journal of pediatrics, 159*(11), 846-850.

Padarath, S., Gerritsen, S., & Mackay, S. (2020). Nutritional Aspects of Commercially Available Complementary Foods in New Zealand Supermarkets. *Nutrients, 12*(10), Article 2980. https://doi.org/10.3390/nu12102980

Palmer, C. A., Kent, R., Loo, C. Y., Hughes, C. V., Stutius, E., Pradhan, N., Dahlan, M., Kanasi, E., Vasquez, S. S. A., & Tanner, A. C. R. (2010). Diet and Caries-associated Bacteria in Severe Early Childhood Caries. *Journal of Dental Research, 89*(11), 1224-1229. https://doi.org/10.1177/0022034510376543

Pan American Health Organization. (2016). *Pan American Health Organization Nutrient Profile Model*. PAHO. https://iris.paho.org/handle/10665.2/18621

Pan, L. P., Li, R. W., Park, S. Y., Galuska, D. A., Sherry, B., & Freedman, D. S. (2014). A Longitudinal Analysis of Sugar-Sweetened Beverage Intake in Infancy and Obesity at 6 Years. *Pediatrics, 134*, S29-S35. https://doi.org/10.1542/peds.2014-0646F

Parsons, T. J., Power, C., Logan, S., & Summerbell, C. (1999). Childhood predictors of adult obesity: A systematic review. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity, 23 Suppl 8*, S1-107. https://doi.org/10.1038/sj.ijo.0801139

Peres, M. A., Macpherson, L. M., Weyant, R. J., Daly, B., Venturelli, R., Mathur, M. R., Listl, S., Celeste, R. K., Guarnizo-Herreño, C. C., & Kearns, C. (2019). Oral diseases: a global public health challenge. *The Lancet, 394*(10194), 249-260.

Perry, B. D. (2002). Childhood experience and the expression of genetic potential: What childhood neglect tells us about nature and nurture. *Brain and mind, 3*(1), 79-100.

Petersen, P. E. (2003). The World Oral Health Report 2003: continuous improvement of oral health in the 21st century - the approach of the WHO Global Oral Health Programme. *Community dentistry and oral epidemiology, 31*, 3-23. https://doi.org/10.1046/j..2003.com122.x

Pitts, N. B., Zero, D. T., Marsh, P. D., Ekstrand, K., Weintraub, J. A., Ramos-Gomez, F., Tagami, J., Twetman, S., Tsakos, G., & Ismail, A. (2017). Dental caries. *Nature reviews Disease primers, 3*(1), 1-16.

Remy, E., Issanchou, S., Chabanet, C., & Nicklaus, S. (2013). Repeated Exposure of Infants at Complementary Feeding to a Vegetable Puree Increases Acceptance as Effectively as Flavor-Flavor Learning and More Effectively Than Flavor-Nutrient Learning. *Journal of Nutrition, 143*(7), 1194-1200. https://doi.org/10.3945/jn.113.175646

Robinson, S. (2015). Infant nutrition and lifelong health: current perspectives and future challenges. *Journal of developmental origins of health and disease, 6*(5), 384-389.

Rodrigues, C. S., & Sheiham, A. (2000). The relationships between dietary guidelines, sugar intake and caries in primary teeth in low income Brazilian 3-year-olds: a longitudinal study. *International Journal of Paediatric Dentistry, 10*(1), 47-55. https://doi.org/10.1046/j.1365-263x.2000.00165.x

Rodríguez-Cano, A. M., Mier-Cabrera, J., Rodríguez-Hernández, C., Allegre-Dávalos, A. L., Munoz-Manrique, C., & Perichart-Perera, O. (2020). Complementary feeding practices and their association with adiposity indicators at 12 months of age. *Journal of developmental origins of health and disease*, 1-8.

Rosenstein, D., & Oster, H. (1988). Differential facial responses to four basic tastes in newborns. *Child Dev, 59*(6), 1555-1568.

Ruottinen, S., Karjalainen, S., Pienihakkinen, K., Lagstrom, H., Niinikoski, H., Salminen, M., Ronnemaa, T., & Simell, O. (2004). Sucrose intake since infancy and dental health in 10-year-old children. *Caries Research, 38*(2), 142-148. https://doi.org/10.1159/000075938

Ruottinen, S., Niinikoski, H., Lagström, H., Rönnemaa, T., Hakanen, M., Viikari, J., Jokinen, E., & Simell, O. (2008). High Sucrose Intake Is Associated With Poor Quality of Diet and Growth Between 13 Months and 9 Years of Age: The Special Turku Coronary Risk Factor Intervention Project. *Pediatrics, 121*(6), e1676. https://doi.org/10.1542/peds.2007-1642

Saavedra, J. M., Deming, D., Dattilo, A., & Reidy, K. (2013). Lessons from the Feeding Infants and Toddlers Study in North America: What Children Eat, and Implications for Obesity Prevention. *Annals of Nutrition and Metabolism, 62*, 27-36. https://doi.org/10.1159/000351538

Schaal, B., Marlier, L., & Soussignan, R. (2000). Human foetuses learn odours from their pregnant mother's diet. *Chemical senses, 25*(6), 729-737.

Schwarzenberg, S. J., & Georgieff, M. K. (2018). Advocacy for Improving Nutrition in the First 1000 Days To Support Childhood Development and Adult Health. *Pediatrics, 141*(2), Article e20173716. https://doi.org/10.1542/peds.2017-3716

Schwartz, C., Chabanet, C., Lange, C., Issanchou, S., & Nicklaus, S. (2011). The role of taste in food acceptance at the beginning of complementary feeding. *Physiology & Behavior, 104*(4), 646-652. https://doi.org/10.1016/j.physbeh.2011.04.061

Schwartz, C., Issanchou, S., & Nicklaus, S. (2009). Developmental changes in the acceptance of the five basic tastes in the first year of life. *British Journal of Nutrition, 102*(9), 1375-1385.

Scientific Advisory Committee on Nutrition [SACN]. (2015). *Carbohydrates and Health*. London: TSO.

Selwitz, R. H., Ismail, A. I., & Pitts, N. B. (2007). Dental caries. *The Lancet, 369*(9555), 51-59.

Sharafi, M., Hayes, J. E., & Duffy, V. B. (2013). Masking Vegetable Bitterness to Improve Palatability Depends on Vegetable Type and Taste Phenotype. *Chemosensory Perception, 6*(1), 8-19. https://doi.org/10.1007/s12078-012-9137-5

Sheiham, A., and James, W. (2015). Diet and dental caries: the pivotal role of free sugars reemphasized. *Journal of Dental Research,* **94**(10): 1341-1347.

Shonkoff, J. P., Richter, L., van der Gaag, J., & Bhutta, Z. A. (2012). An Integrated Scientific Framework for Child Survival and Early Childhood Development. *Pediatrics, 129*(2), E460-E472. https://doi.org/10.1542/peds.2011-0366

Siega-Riz, A. M., Deming, D. M., Reidy, K. C., Fox, M. K., Condon, E., & Briefel, R. R. (2010). Food consumption patterns of infants and toddlers: where are we now? *Journal of the American Dietetic Association, 110*(12), S38-S51.

Singer, M. R., Moore, L. L., Garrahie, E. J., & Ellison, R. C. (1995). The tracking of nutrient intake in young children: the Framingham Children's Study. *American Journal of Public Health, 85*(12), 1673-1677.

Singh, N., Dubey, N., Rathore, M., & Pandey, P. (2020). Impact of early childhood caries on quality of life: Child and parent perspectives. *Journal of Oral Biology and Craniofacial Research, 10*(2), 83-86.

Skeie, M. S., Raadal, M., Strand, G. V., & Espelid, I. (2006). The relationship between caries in the primary dentition at 5 years of age and permanent dentition at 10 years of age - a longitudinal study. *International Journal of Paediatric Dentistry, 16*(3), 152-160. https://doi.org/10.1111/j.1365-263X.2006.00720.x

Skinner, J. D., Carruth, B. R., Bounds, W., Ziegler, P., & Reidy, K. (2002a). Do food-related experiences in the first 2 years of life predict dietary variety in school-aged children? *Journal of Nutrition Education and Behavior, 34*(6), 310-315.

Skinner, J. D., Carruth, B. R., Bounds, W., & Ziegler, P. J. (2002b). Children's food preferences: a longitudinal analysis. *Journal of the American Dietetic Association, 102*(11), 1638-1647.

Sonneville, K. R., Long, M. W., Rifas-Shiman, S. L., Kleinman, K., Gillman, M. W., & Taveras, E. M. (2015). Juice and Water Intake in Infancy and Later Beverage Intake and Adiposity: Could Juice be a Gateway Drink? *Obesity, 23*(1), 170-176. https://doi.org/10.1002/oby.20927

Stacey, N., Mudara, C., Ng, S. W., van Walbeek, C., Hofman, K., & Edoka, I. (2019). Sugar-based beverage taxes and beverage prices: Evidence from South Africa's Health Promotion Levy. *Social Science & Medicine, 238*, Article 112465. https://doi.org/10.1016/j.socscimed.2019.112465

Steiner, J. E. (1977). Facial expressions of the neonate infant indicating the hedonics of food-related chemical stimuli. *Taste and development: The genesis of sweet preference*, 173-188.

Steiner, J. E., Glaser, D., Hawilo, M. E., & Berridge, K. C. (2001). Comparative expression of hedonic impact: affective reactions to taste by human infants and other primates. *Neuroscience & Biobehavioral Reviews, 25*(1), 53-74.

Stephen, A., Alles, M., de Graaf, C., Fleith, M., Hadjilucas, E., Isaacs, E., Maffeis, C., Zeinstra, G., Matthys, C., & Gil, A. (2012). The role and requirements of digestible dietary carbohydrates in infants and toddlers. *European Journal of Clinical Nutrition, 66*(7), 765-779. https://doi.org/10.1038/ejcn.2012.27

Stettler, N., Kumanyika, S. K., Katz, S. H., Zemel, B. S., & Stallings, V. A. (2003). Rapid weight gain during infancy and obesity in young adulthood in a cohort of African Americans. *The American Journal of Clinical Nutrition, 77*(6), 1374-1378.

Stettler, N., Zemel, B. S., Kumanyika, S., & Stallings, V. A. (2002). Infant Weight Gain and Childhood Overweight Status in a Multicenter, Cohort Study. *Pediatrics, 109*(2), 194. https://doi.org/10.1542/peds.109.2.194

Sundborn, G., Merriman, T., Thornley, S., Metcalf, P., & Jackson, R. (2014). An 'End-Game' for sugar sweetened beverages. *Pacific Health Dialog, 20*(1), 22-30.

Taveras, E. M., Rifas-Shiman, S. L., Belfort, M. B., Kleinman, K. P., Oken, E., & Gillman, M. W. (2009). Weight Status in the First 6 Months of Life and Obesity at 3 Years of Age. *Pediatrics, 123*(4), 1177-1183. https://doi.org/10.1542/peds.2008-1149

Te Morenga, L., Mallard, S., & Mann, J. (2013). Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. *British Medical Journal, 346*, Article e7492. https://doi.org/10.1136/bmj.e7492

The New Zealand Institute for Plant & Food Research Limited, Ministry of Health (2017). New Zealand Food Composition Database, New Zealand FOODfiles 2016 Version 01. Available online: https://www.foodcomposition.co.nz/foodfiles (accessed on 20 December 2020).

Thompson, F. E., & Byers, T. (1994). Dietary assessment resource manual. *The Journal of nutrition, 124*(suppl_11), 2245s-2317s.

Thornley, S., Bach, K., Bird, A., Farrar, R., Bronte, S., Turton, B., Atatoa Carr, P., Fa'alili-Fidow, J., Morton, S., & Grant, C. (2020). What factors are associated with early childhood dental caries? A longitudinal study of the Growing Up in New Zealand cohort. *International Journal of Paediatric Dentistry*.

UNICEF (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge, WHO.

United States Department of Agriculture [USDA]. (2020). *ChooseMyPlate.gov vegetable group food gallery [Internet]*. Retrieved 9 April 2020 from https://www.myplate.gov

Vanderas, A. P., Kavvadia, K., & Papagiannoulis, L. (2004). Development of caries in permanent first molars adjacent to primary second molars with interproximal caries: Four-year prospective radiographic study. *Pediatric Dentistry, 26*(4), 362-368.

Vartanian, L. R., Schwartz, M. B., & Brownell, K. D. (2007). Effects of soft drink consumption on nutrition and health: A systematic review and meta-analysis. *American Journal of Public Health, 97*(4), 667-675. https://doi.org/10.2105/ajph.2005.083782

Ventura, A. K., & Mennella, J. A. (2011). Innate and learned preferences for sweet taste during childhood. *Current Opinion in Clinical Nutrition and Metabolic Care, 14*(4), 379-384. https://doi.org/10.1097/MCO.0b013e328346df65

Ventura, A. K., & Worobey, J. (2013). Early Influences on the Development of Food Preferences. *Current Biology, 23*(9), R401-R408. https://doi.org/10.1016/j.cub.2013.02.037

Wardle, J., Cooke, L. J., Gibson, E. L., Sapochnik, M., Sheiham, A., & Lawson, M. (2003a). Increasing children's acceptance of vegetables; a randomized trial of parent-led exposure. *Appetite, 40*(2), 155-162.

Wardle, J., Herrera, M. L., Cooke, L., & Gibson, E. L. (2003b). Modifying children's food preferences: the effects of exposure and reward on acceptance of an unfamiliar vegetable. *European Journal of Clinical Nutrition, 57*(2), 341-348.

Webb, K. L., Lahti-Koski, M., Rutishauser, I., Hector, D. J., Knezevic, N., Gill, T., Peat, J. K., Leeder, S. R., & Team, C. (2006). Consumption of 'extra' foods (energy-dense, nutrient-poor) among children aged 16-24 months from western Sydney, Australia. *Public Health Nutrition, 9*(8), 1035-1044. https://doi.org/10.1017/phn2006970

Wendt, L. K., Hallonsten, A. L., Koch, G., & Birkhed, D. (1996). Analysis of caries-related factors in infants and toddlers living in Sweden. *Acta Odontologica Scandinavica, 54*(2), 131-137. https://doi.org/10.3109/00016359609006019

Weng, S. F., Redsell, S. A., Swift, J. A., Yang, M., & Glazebrook, C. P. (2012). Systematic review and meta-analyses of risk factors for childhood overweight identifiable during infancy. *Archives of Disease in Childhood, 97*(12), 1019-1026. https://doi.org/10.1136/archdischild-2012-302263

Wilson, P., & Hogan, S. (2017). Sugar taxes: A review of the evidence.

Wisker, E., & Feldheim, W. (1990). Metabolizable energy of diets low or high in dietary fiber from fruits and vegetables when consumed by humans. *The Journal of Nutrition, 120*(11), 1331-1337.

Wong, H., McGrath, C., King, N., & Lo, E. (2011). Oral health-related quality of life in Hong Kong preschool children. *Caries Research, 45*(4), 370-376.

World Health Organization (Regional Office for the Eastern Mediterranean). (2016b). *Policy statement and recommended actions for lowering sugar intake and reducing prevalence of type 2 diabetes and obesity in the Eastern Mediterranean Region*. Retrieved 13 April 2020 from http://www.emro.who.int/nutrition/strategy/policy-statement-and-recommended-actions-for-lowering-sugar-intake-and-reducing-prevalence-of-type-2-diabetes-and-obesity-in-the-eastern-mediterranean-region.html

World Health Organization (2003a). "Complementary feeding: report of the global consultation, and summary of guiding principles for complementary feeding of the breastfed child."

World Health Organization (2003b). Global strategy for infant and young child feeding, World Health Organization.

World Health Organization (2014). "Obesity and inequities: Guidance for addressing inequities in overweight and obesity." Regional office for Europe. Copenhagen: World Health Organisation. ISBN **978**(92): 890.

World Health Organization. (2015). *Guideline: sugars intake for adults and children*. World Health Organization.

World Health Organization (Regional Office for the Eastern Mediterranean) (2016a). Policy statement and recommended actions for lowering sugar intake and reducing prevalence of type 2 diabetes and obesity in the Eastern Mediterranean Region. Retrieved from http://www.emro.who.int/nutrition/strategy/policy-statement-and-recommended-actions-for-lowering-sugar-intake-and-reducing-prevalence-of-type-2-diabetes-and-obesity-in-the-eastern-mediterranean-region.html.

World Health Organisation (2016b). WHO urges global action to curtail consumption and health impacts of sugary drinks. *World Health Organization, Geneva, Switzerland*.

World Health Organization. (2017). *Sugars and dental caries*. World Health Organization.

World Health Organisation (2019). "Commercial Foods for Infants and Young Children in the WHO European Region. A study of the Availability, Composition and Marketing of Baby Foods in Four European Countries.", World Health Organization.

Wu, T. C., & Chen, P. H. (2009). Health Consequences of Nutrition in Childhood and Early Infancy. *Pediatrics and Neonatology, 50*(4), 135-142. https://doi.org/10.1016/s1875-9572(09)60051-6

Yao, M. J., & Roberts, S. B. (2001). Dietary energy density and weight regulation. *Nutrition Reviews, 59*(8), 247-258.

Yuan, W. L., Nicklaus, S., Lioret, S., Lange, C., Forhan, A., Heude, B., Charles, M. A., de Lauzon-Guillain, B., & Grp, E. M.-C. C. S. (2017). Early factors related to carbohydrate and fat intake at 8 and 12 months: results from the EDEN mother-child cohort. *European Journal of Clinical Nutrition, 71*(2), 219-226. https://doi.org/10.1038/ejcn.2016.216

Zhou, S. J., Gibson, R. A., Gibson, R. S., & Makrides, M. (2012). Nutrient intakes and status of preschool children in Adelaide, South Australia. *Medical Journal of Australia, 196*(11), 696-700. https://doi.org/10.5694/mja11.11080