Title page

Title: Nutritional aspects of commercially prepared infant foods in developed countries: a narrative review

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Abstract

Nutritional intake during infancy is a critical aspect of child development and health that is of significant public health concern. Although there is extensive research on breastfeeding and timing of solid food introduction, there is less evidence on types of solid foods fed to infants, specifically commercially prepared infant foods. The consumption of commercially prepared infant foods is very prevalent in many developed countries, exceeding the consumption of homemade foods in some situations. Although these food products may have practical advantages, there are concerns about their nutritional composition, sweet taste, bioavailability of micronutrients, diversity of ingredients and long term health effects. The extent that the manufacturing, fortification and promotion of these products are regulated by legislation varies between countries and regions. The aim of this narrative review is to investigate, appraise and summarise these aspects. Overall there are very few studies directly comparing homemade and commercial infant foods and a lack of longitudinal studies to draw firm conclusions on whether commercial infant foods are mostly beneficial or unfavourable to infant health.

Introduction

It is well established that infancy is a critical time for the development of health in later life and that early nutrition plays a significant role in physical and cognitive development [1,2]. Specifically there is considerable concern that exposure to and consumption of sweet foods early in life will have metabolic consequences on children's health [3]. The World Health Organisation (WHO) recommends exclusive breastfeeding until six months, with introduction of solid food at six months [1]. Following on from a milk-based diet, the introduction of solid food to infants' diets, known as complementary feeding, enables infants to meet their nutritional requirements, whilst continuing to provide exposure to new tastes and introduction of textures. This period is an important developmental milestone. Ideally, it should provide a gradual transition progressing from a solely milk-based diet to a varied diet, providing foods that are both nutritious and safe. The use of home-prepared baby foods is encouraged by several international organizations [4–8].

Complementary feeding has been debated extensively over the past few decades, specifically the most appropriate age of introduction of solid food and allergenic foods [9–11], timeframes for the introduction of different tastes and textures [12,13], use of organic foods [14] and baby-led weaning [15,16]. The use of homemade versus commercially produced infant foods is implicated in all of these aspects. Commercially prepared infant foods, also known as "readymade" infant foods, are typically mass produced and purchased in a pre prepared format requiring minimal, if any, cooking or heating before consumption. In comparison, homemade infant foods are generally prepared in households by parents/carers, using fresh ingredients. Tracking of eating behaviours and preferences throughout life has been demonstrated[17–19]. Specifically it has also been shown that consumption of commercially prepared baby food at age 6 months is associated with consumption of ready to eat foods at 2 years of age [20], underlying the significance of this topic.

Traditionally baby foods were made at home, typically pureed or mashed with mass production first reported to have occurred in 1928 [21]. Advice regarding infant feeding changed from the late nineteenth to the mid-twentieth centuries, meaning solids were introduced at earlier ages, at approximately 4-6 weeks old in the 1950s [21]. This change in advice, combined with an increasing birth rate in the post-world war II era, led to a growth in the mass production of commercial baby foods by manufacturers as part of the canned good industry, particularly in the United States

(US) [21]. Although initially commercially produced infant foods were a means to provide fruit and vegetables year around, over the years products have diversified significantly. Currently a broad range of commercially prepared products exist across a number of categories according to stage/age range and type of food (e.g. cereal products, baby snacks, desserts). To illustrate the number of products now available, recent studies of commercial infants foods identified 479 different products in the United Kingdom (UK) market [22] and 657 in the US market [23]. Although there are an extensive number of products available, it is difficult to say whether the *variety* of ingredients used has changed over time.

Concerns have been raised regarding commercially produced infant food, specifically diversity of ingredients used [24], the taste profile [25], nutritional content [23,26], bioavailability of micronutrients [27–29] and toxicity [28]. Together these factors cumulatively create a significant change in early food exposure, with potential implications for the development of non-communicable diseases, namely allergy [30,31] and obesity [32]. There are also concerns generally regarding the role of infant feeding practices in the development of early tooth decay [33,34], although there is no evidence that commercial infant food in particular contributes to this issue. Additionally there are claims that commercially produced infant foods may displace or reduce the duration of breastfeeding [35].

Given the widespread availability of commercial baby food in developed countries and debate regarding the impact this could have on infant diet and long-term health outcomes, a summary of the evidence is warranted. The present review aims to address and critically appraise the literature regarding nutritional implications of commercial infant food consumption, in addition to broader aspects such as taste, ingredient variety and parental perception. Figure 1 illustrates the factors which will be discussed. The review will not include the wider topics of complementary feeding in developing countries, studies that include toddler foods [23,36–38] or infant beverages; which are considered outside the remit.

Usage of commercial infant foods internationally

The usage of commercial infant foods has been reported by national feeding and cohort studies in several developed countries, although dietary collection methods, sampling and timeframes differ between studies so direct comparison is not always possible. Additionally, as the focus of these studies is often breast and formula feeding practices and the age of introduction of solid food, not all published research specifically differentiates between commercially prepared and homemade infant food, so precise data is not always available.

National feeding data from the UK indicates that when questioned about the previous day's dietary intake, a greater proportion of infants aged 4-6 months had been fed commercially prepared baby food than homemade baby food (38% compared to 28%) [(39)]. In addition, almost half (45%) of mothers of 8–10-month-old infants use commercially prepared baby foods at least once a day [(39)]. Differences were observed according to maternal occupational status and ethnicity [(39)], with those in the "managerial/professional" job categories and the "Chinese and other" ethnic groups less likely to use commercially prepared infant foods. However in contrast, research from a large infant cohort study in the South of England that used principal component analyses to analyse food frequency data found clear differences in preference for wet and dry commercial infant food at age 6 months, but the pattern was not associated with many of the maternal and family characteristics considered [(40)]. The heterogenous results reported are likely due to the differences in population sampling, dietary collection and statistical analysis methods used.

Similar trends are evident in other European countries. In Ireland, a birth cohort study found that 63.2% of six month old infants consumed a sweetened commercially produced cereal for breakfast, with 30-31% consuming commercially prepared products at lunch and evening times [(41)]**.** Another Irish birth cohort study reported that 49% of foods eaten by infants in the first six weeks of weaning were homemade [(42)]**.** In France commercial infant foods are estimated to account for 27-28% of energy intake at ages 6-11 months, the majority of parents (63%) offer their child commercially prepared baby foods 4-7 days/week, with only 24% never using them [(43)]. In a German birth cohort study, analysis of all food diaries completed indicated that 94.4% of infants consumed at least one commercially prepared baby food produce within a three day period, whereas homemade complementary food was eaten exclusively by only 5.6% of participants [(44,45)]. Participants with higher commercial infant food consumption were significantly older, breastfed for a shorter duration and were more likely to have mothers with a lower educational status. In Italy, a birth cohort study of 400 infant and mother pairs reported that commercially prepared infant foods were consumed in significantly higher quantities by infants who were breastfed than non breastfed [(46)]. By using an estimated food diary approach, this study was able to quantify that commercial baby foods contributed a higher energy content than that of homemade foods. However it must be stated that of these three studies, only one recruited [43] a cross-sectional nationally representative sample.

From an economic and availability perspective, sales of commercial infant food in the 27 countries of the European Union (EU) were reported to be 1271 million Euro in 2011 [47]. In Germany, the number of commercial infant products on sale increased between 2010 and 2012 from 276 to 309 jarred vegetable-potato-meat meals, demonstrating increased availability of products.

In developed countries outside of Europe, there is a similar pattern of consumption. Although the national infant feeding survey in Australia focused on breast and formula feeding and did not specifically collect data on commercial infant food [48], the baby and toddler food market is reported to have grown by a rate of 4.8% a year in the last 5 years [36]. In the US, 73-95% of infants between the ages of 4-12 months consumed commercially produced baby foods when a national cross sectional feeding survey was conducted in 2002 [49]. When repeated in 2008, the five most frequently consumed vegetables by infants aged 4-9 months were commercially prepared, rather than fresh [50]. Although the proportion of infants aged 6- 9 months consuming commercially prepared fruit products decreased from 66.4 to 50.2%, between 2004 and 2008 respectively, four of the top five most frequently consumed fruits were commercially prepared rather than fresh in 2008 [50]. A limitation of this study however is that the data was collected using a 24 hour recall, which may not be reflective of food group intake over a longer time period. Looking at sales figures in the US, they have risen from 36.7 to 55 billion US dollars per annum from 2010 to 2015 [51].

Perceptions of commercial infant foods

Studies assessing maternal perceptions of commercial infant foods have taken place in developed countries including Scotland [52,53], England [54,55], France [56–58], USA [59], Australia [60] Germany, Italy, Spain and Sweden [53]. All of these studies, with the exception of Kim et al. [59], used a focus group or structured interview approach, which enables in depth analysis of opinions and attitudes.

Perceptions of infant feeding and commercial baby food are influenced by educational level, parity, previous experience of weaning and cultural factors [54,56,58], with second time mothers and those from lower socioeconomic groups more likely to perceive commercially prepared infant foods positively than first time mothers or those from higher socioeconomic groups [54]. Homemade foods are generally viewed as the ideal food by most mothers, due to the freshness of ingredients, taste [53], "avoidance of chemical in jars" [52] and low cost, however there is disagreement whether fresh or commercially prepared products are cheaper [60]. In most studies commercial baby foods are perceived negatively; as "bland" and "unauthentic" [57] or only used in "an emergency" [55], with some participants saying they felt "a bit guilty" using prepared foods to feed their baby [52]. Similarly a questionnaire based-study in the US indicated that many mothers have a preference for fresh fruits and vegetables over jarred baby foods, with mothers of older infants (9-11 months) reporting a significantly higher preference than mothers of younger infants [59]. However, the study by Kim et al. [59] recruited a sample of low income mothers who received supplemental food package and overall 83.7% of respondents were "very satisfied" with the jarred fruit and vegetables received.

Several of the same studies have also noted positive perceptions of commercial infant food by some participants. Perceived advantages of commercially produced infant foods are portability and convenience, with preparation of homemade food viewed as laborious and wasteful by some [52,53,57]. This is in agreement with the overall trend towards increased reliance on readymade foods across all ages generally [61]. Access to fresh fruit and vegetables, leading to availability and perishability concerns is also noted to differ depending on urban or rural location [60]. Betoko et al. [56] reported that increased use of commercially prepared vegetables and fruit purees was explained by an awareness of nutritional advice about infant feeding, coupled with a lack of time and culinary skills to implement the advice. Indeed, some research has reported that commercial infant foods are perceived as superior to homemade foods by some mothers, describing them as "safer" and possibly composed of better ingredients [54]. This is especially applicable to organic foods, which are viewed as "natural" [52]. Commercially prepared infant foods are also seen as providing an opportunity to try out new foods that the family would not normally consume (e.g. pumpkin) [52].

Two European studies [53,58] that recruited mothers and infants from different countries enabled exploration of cultural influences on commercial infant foods. Maier et al. [58] conducted structured interviews with two groups of mothers of infants aged 4-9 months:, one group in Dijon , France, the other group in Aalen , Germany. Clear between- and within-group differences in weaning practices were found, with 68% of Aalen mothers reported to prepare baby food at home greater than once/week compared to 46% of Dijon mothers. Distinct cultural differences were also reported by Synnott et al. [53] who compared mothers from five different European countries. For example, all of the Italian participants chose to prepare homemade food for their infants compared to Swedish parents who were more likely to supplement home-prepared foods with commercially prepared foods. The study also highlighted that different factors were influential per country when purchasing food for the infant. In Germany, Scotland and Sweden, health was considered the most important issue, followed by taste and organic ingredients. In Italy, the priorities were health, followed by method of production and brand compared to Spain, where the three most important factors were health, taste and brand.

Limitations of these studies are that they generally have used a small sample size, due to the qualitative approach. With the exception of Hoddinott et al. [52], the cited studies have only included mothers as participants, rather than fathers or other caregivers and as with all health related studies, selection bias and/or social desirability bias cannot be ruled out, with only those interested in infant feeding and nutrition likely to have taken part. However, overall these studies do provide rich insight into reasons why commercially prepared infant food is used so broadly, as well as the perceived disadvantages, such as taste and nutritional content.

Taste and variety of ingredients used in commercial infant foods

By incorporating a wide variety of fresh foods, ideally complementary feeding should provide a platform for establishment of balanced taste preferences. It is known that new born infants have an innate preference for sweet tastes and innate rejection to bitter tastes, which has developed from an evolutionary perspective to seek out calories and reject toxins [62]. However these innate preferences can be manipulated with exposure to different tastes in the early stages of weaning, hence why it is recommended that bitter tasting vegetables may need to be offered several times before acceptance is achieved [63,64]. The exposure effect has been described as consistent, powerful and universal [65]. A landmark study demonstrated that repeated exposure to similar foods in the early stages of complementary feeding can increase preference within a period of ten days [66], although this study used banana and peas, rather than commercially prepared foods.

Research in the UK by Garcia et al. [22,25] reported that nearly two thirds of the 329 commercial baby foods studied were sweet, with a distinct lack of bitter vegetables. The six most common fruit and vegetables used were sweet (apple banana, tomato, mango, carrot and sweet potato), with green vegetables such as such as broccoli or spinach rarely incorporated into products. In total, fruit juice was added to 18% of products and 8.5% of savory products had added fruit, giving them a sweet taste. This ubiquitious use of sweet flavors to mask the taste of bitter vegetables may be due to commercial pressure to manufacture instantly palatable foods [25].

It is unclear whether increased reliance on commercial infant foods reduces or increases the diversity of foods introduced during the weaning period. In theory, consumption of a varied diet should reduce the risk of developing a deficiency or excess of any particular nutrient [67], with dietary variety shown to correlate strongly with dietary adequacy in toddlers [68]. Less food diversity, defined broadly as the consumption of narrow range of foods [67], in early life has also been associated with increased risk of any asthma, atopic asthma, wheeze, and allergic rhinitis in a large birth cohort study [69].

A German study investigating food diversity in commercial infant foods reported that homemade infant meals used 26 different vegetables, compared to 17 different vegetables used in commercially prepared food, with the majority of meals based on carrot [24], a finding also reported in a UK study [38]. Despite this, there was no difference in variety of vegetables consumed at 6 or 9 months of age. Indeed by 12 months of age, those fed commercial meals consumed a greater variety of vegetables. This was attributed to maternal confusion around infant feeding guidelines and that for practical food preparation reasons, infants who are fed homemade food, may be fed the same homemade meal on three consecutive days, due to food being prepared in bulk.

Similarly, in a low income sample of mothers and infants from the US, infants aged 6-12 months who received commercial baby foods consumed a greater variety of fruits and vegetables, than those who did not [70], even when adjusting for infant age, maternal education and ethnicity. Looking at longer term outcomes, a longitudinal UK study reported that feeding home-cooked fruit or vegetables during infancy was associated with increased uptake and variety of fruit and vegetables eaten at the age of seven years, whereas feeding commercially prepared fruit and vegetables during infancy was not [71]. A proposed explanation for this was that commercially prepared fruit and vegetables are likely to have a uniform taste and texture, whereas those cooked at home or eaten raw will vary according to the whether it is in season and the cooking method. It is also possible that the specific combination of ingredients in commercially prepared baby food may mask or interfere with learning about the particular flavor of single vegetables [55]. A German study found no association between commercially prepared food intake in infancy and fruit and vegetable variety intake at preschool age in girls, however in boys there was an association with reduced vegetable variety score [45]. The reason for this was unclear.

In summary, the existing research base underlines the fact that the development of dietary variety and taste preference is complex and multifactorial and it is not yet clear what role commercial infant food plays in either the short or long term.

Meat and fish content of commercial infant foods

Looking more broadly at food groups other than fruit and vegetables, concerns have also been raised about the limited inclusion of fish in commercially prepared infant foods [24]. A study in Scotland highlighted the lack of infant seafood based foods in the UK, finding that of 341 main meals available, only 3.8% were seafood based, compared to 30.2% poultry, 35.5% meat based and 30.5% vegetable based [72]. This is seen as an important issue as underexposure to the distinctive taste of fish may lead to reduced preference in child and adulthood. When the study was updated in 2015, the proportion of meals containing seafood had increased to 6.3%. However it must be noted that this study only focused on one country and availability of seafood-based meals in different parts of the world may be different and influenced by cultural preferences.

Fish, specifically oily fish, is of particular nutritional relevance in infancy due to the iodine [73] and long chain polyunsaturated fatty acids (LCPUFA) content and associated health outcomes [74,75]. Although the iodine content of infant formula milk is regulated, there is no recommendation regarding minimum iodine fortification of commercial infant food in the EU [6,76]. In terms of essential fatty acids, the concern regarding a lack of sufficient LCPUFA in commercial infant food was noted more recently by Loughrill & Zand (2016) [(77)]. The contribution of fish based meals to essential fatty acid intake was found to be low, providing only 19.9% and 3.41% of of requirements for eicosapentaenoic acid and docosahexaenoic acid respectively, which may be because the meals analysed were only composed of approximately 10% of fish by weight [(77)].

On the contrary, it could also be argued that non-consumption of fish is common in all infants and young children, regardless of whether they are fed predominantly homemade or prepared baby food. National UK dietary data reported that after disaggregation of composite dishes, mean consumption of fish from all sources ranged from 1g per day for children aged 4 to 6 months to 6g per day for those aged 12 to 18 months. The proportion of infants and young children consuming fish and fish products increased with age from 13% at 4 to 6 months to 53% at 12 to 18 months. This delayed introduction may be due to confusion and change in infant feeding guidelines for allergy prevention [(24)].

Red meat is also a source of LCPUFAs, with lamb often recommended as a first meat for infants in some countries, including Italy [(78)]. A study comparing the omega 3 PUFA content of fresh lamb to a lamb-containing commercially prepared infant meal found a threefold higher content in fresh lamb. This may be due to the common use of vegetable oil as an ingredient in homogenised infant meat products which modifies the fatty acid composition, or due to the origin of lamb meat used in commercially prepared products [(78).] Of note, the quantity of LCPUFAs in lamb based commercially prepared foods was higher than that previously identified in beef-based products.

In terms of quantifying the amount of meat in an infant food product, an EU directive (1996) states that if meat, poultry or fish, are mentioned first in the name of the product, whether or not the product is presented as a meal, then the named meat, poultry or fish, shall constitute not less than 10% by weight of the total product. If meat, poultry or fish are mentioned, but not first in the name of the product, then it shall constitute not less than 8 % by weight of the total product. Following on from this stipulation, a German study concluded that the low meat composition of many commercial infant meals may increase the risk of marginal iron status in older infants who were breastfed for 4-6 months [(79).] In Australia, Mauch et al. [(80)] reported that commercial infant foods were the most common source of meat/meat alternatives consumed at age 5.5 months, but by 14 months mixed meals such as bolognese were more common. The study concluded that parents should encourage meat "in a recognisable form" and as one of the first complementary foods.

Nutritional content of commercial infant foods

Tables 1 and 2 provide a summary of studies that have investigated the nutritional content of commercial infant foods from 1997-2016. Studies were heterogenous in design, assessing different types and numbers of food (main meals, desserts, snacks), obtained from several different countries. The studies have been divided into two tables, broadly dependent on the objectives of the study.

Contrasting methods have been used dependent on the objective of the study, which limits the ability to directly compare results and generalize findings. The majority of the studies investigating energy, sugar and salt content relied on nutritional content information provided by food labels [(22,67)], which could be subject to substantial error, depending on the accuracy of the labeling information provided. Research investigating micronutrient, trace element or toxicity levels undertook independent laboratory analysis of samples [(27–29,81–84)], which although is arguably more objective, methods, criteria and analysis standards may differ between studies. Overall there is noted to be a paucity of studies directly comparing the nutritional content of commercial and homemade infant foods, with only two studies identified that directly compared equivalent products using laboratory analysis [(85,86)]. The same conclusion was reached by a recent report, which reported that the overall evidence on nutritional composition was of low quality and direct comparison of commercially prepared infant foods with homemade foods was often lacking [(35)]. In recognizing the paucity of studies that directly compare commercially prepared infant to homemade infant foods, it must be highlighted that infant eating patterns are not necessarily dichotomous i.e. that infants may be fed a combination of commercially prepared and homemade products and the proportion of each may vary at different developmental stages. Additionally, there are ethical concerns regarding infant feeding studies and therefore randomized controlled trials are probably not a suitable or practical study design to implement.

Sugar, salt and fat content

Several studies have focused on the “healthy eating” aspect of infant nutrition, assessing either sugar, salt or fat content. Some studies specified added sugar content [23,87], whereas others reported only total sugar content [22,86], which makes comparisons problematic. In terms of sugar, the overall trend was that products had an inappropriately high sugar content compared to nationally recognized standards and recommendations [22 ,86,87], however this claim is difficult to disentangle as fruit, and therefore fructose, was a primary ingredient in many of the products investigated. Both total and added sugar are an essential factor to consider, given the recently published recommendations regarding reducing consumption of added sugars [89].

In contrast to sugar and added sugar, few products had sodium levels of concern according to information provided on the food label [87]. In support of this viewpoint, Maalouf et al. [90] determined that only 2.2% of dietary sodium was derived from commercial baby food using nationally representative data in infants aged 0-6 months in the US, which increased to 8.8% in infants aged 6-12 months. However this study relied on data using a 24-hour recall method, therefore may not necessarily be reflective of usual daily intake. One study that conducted laboratory analysis reported sodium content exceeded the maximum permitted level [27]. As commercially prepared infant foods are widely used, the sodium content is important as salt preference may be established due to exposure in infancy [91].

There was disagreement whether overall the nutritional composition of infant food was acceptable. A UK study concluded that total daily intake of fat from the consumption of commercial complementary food may be in excess of the recommended guidelines if the intake of dessert and snacks are incorporated [92]. In terms of caloric intake, van den Boom et al. [85] reported that homemade foods have a lower energy density than commercially prepared, however this was later contradicted by Garcia et al.[22] although different methods were used by each study.

Micronutrient content and adequacy

Studies of micronutrient content overall did not reach a consensus whether homemade or commercially prepared baby food had a nutritionally superior content. This may in part be due to different regulations on micronutrient fortification in different countries. A summary of studies is shown in Table 2.

Mineral & trace element content

Concentration of iron, zinc and calcium in commercially prepared infant foods were raised as a concern by some studies [27,28,85]. Overall a systematic review found no evidence that commercially prepared infant foods improved anaemia or micronutrient status, but only two studies were included in the review, which were deemed to have a moderate risk of bias [35]. In contrast to the systematic review, Melo et al. [81] reported that a diet based solely on commercially prepared foods would provide a sufficient intake of calcium, copper, iron, potassium, magnesium and zinc for a 6 month old infant, whether breast or formula fed. However, this conclusion was drawn based on nutritional analysis of a sample menu recommended by an infant food manufacturer and therefore may be subject to bias. By using dietary pattern scores the Avon Longitudinal Study of Parents and Children study, a large prospective study in the UK, demonstrated that between 6-8 months of age, calcium and iron intakes increased across infants who scored highly in the commercially prepared baby food patterns. This could be because in the 1990s when the study took place, most commercially prepared infant foods were fortified with ferrous sulphate, unlike current times when many unfortified organic products are available [93].

Looking at subtypes of commercial infant foods, no difference was found in iron, zinc, magnesium and potassium levels between vegetable and meat meals [83]. Overall trace elements were at acceptable levels when compared to available national and international guidelines [27,28,83], although baby rice contained excessive lead, arsenic, nickel and chromium in some countries [28].

Vitamin content

Few studies evaluated vitamin content, although Randhawa et al. [86] reported that mean vitamin B1, B2 and vitamin C contents were comparable across commercial, laboratory prepared and homemade recipes. One study identified vitamin C as the most commonly fortified micronutrient [36]. More recently, Loughrill et al. [84] have suggested that commercial infant food may supply excess levels of vitamin A in infants, however this calculation was made on the basis of a theoretical daily menu consisting of only commercially prepared foods in formula, so cautious interpretation is required.

Limitations of review

Although this article has aimed to appraise the current literature, there are limitations and restrictions to this review. As set out in the introduction, the review has focused on complementary infant feeding in children under the age of one year old in developed countries. We have not included studies related to infant beverages, including infant formula or juice, as the remit would have been too broad. There is also varying degrees of legislation governing the composition, fortification and marketing of commercial infant foods in different countries therefore findings and summaries reported may not be relevant to other countries. As previously mentioned, a wide range of categories of foods are available, which may have changed over time. Some of the studies cited have calculated the nutritional content of commercially prepared foods based on theoretical daily intakes using estimated portion sizes, however the use and consumption of commercial and homemade foods is not dichotomous. There is also a paucity of data regarding the contribution of energy, macro and micronutrients from commercial and home made foods. Fundamentally infant feeding practices are complicated by confounding variables including socioeconomic and cultural factors, beliefs, attitudes and maternal diet, therefore it is not always possible to explain dietary patterns. As this is a narrative review, rather than a systematic review, it cannot be guaranteed that all the existing literature has been explored, however an extensive literature search was undertaken.

Conclusion and future research needs

It is clear that usage of commercially prepared infant foods is very pervasive in many developed countries. Research has highlighted concerns about the altered nutritional intake, sweet taste, food diversity and toxicity of commercial infant food and the effect this could have on long-term dietary intake and health, although the evidence base is unequivocal and complicated by different regulations between countries and a lack of randomised controlled trials. Commercially prepared baby foods have practical advantages and may improve nutritional intake and dietary variety in some situations and population groups. Overall there are very few studies directly comparing homemade and commercial infant foods and a lack of longitudinal studies to draw firm conclusions on whether commercial infant foods are predominantly beneficial or unfavourable to infant health. It is therefore important for further high quality research to be conducted.

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Table 1. Summary of studies on macronutrient composition with emphasis on sugar, fat and salt content.

Author (year)	Objective	Country	Method	Criteria	Outcome
Hilbig et al. (2015) (87)	To compare the composition of home made and commercial infant foods eaten by German infants aged 6-12 months by analysis of 1083 3 day food diaries from 396 participants.	Germany	Nutritional analysis of homemade and commercial foods based on food labels.	• Complementary meals defined as semisolid pureed or mashed foods. Solid snack foods and drinks not included in analysis.	• Of 8226 meals analysed, 74% comprised commercial meals or a mixture of commercial and homemade. • Median portion size of commercial and homemade meals was the same. • Added sugars found in less than ¼ of meals. • 24% of commercial savoury meals prepared with discretionary salt, compared to 0.7% of homemade meals.
Zand et al. (2015) (94)	To analyse the macronutrient content of 8 popular baby meals for 6-9 month old infants purchased in the UK between November 2010 and May 2011 in order to ascertain their nutritional suitability and adequacy.	UK	Laboratory analysis	• Laboratory analysis of energy, protein, fat, carbohydrate, and fibre. • Compared to EU commission directive 2006/125/EC.	• Average energy density was at recommended level of 0.6 kcal/gram. • All products were good sources of protein. Meat dishes provided 23.4% RNI compared to 16.8% by vegetable dishes. • Average fat content of both meat and vegetable meals were compliant with maximum permitted levels, but two of the vegetarian dishes were higher than the recommended level of 31%. • No difference in fibre content between meat and vegetable dishes.
Garcia et al. (2013) [22]	To describe the types of commercial infant foods available in the UK and provide an overview of their taste, texture and nutritional content	UK	Nutritional content based on food labels.	• 479 infant foods produced by main 4 UK manufacturers. Products classified as sweet or savoury using name and product description. Classified into 4 groups: readymade, breakfast cereals, powdered meals and dry finger foods.	• 65% of products targeted at 4+ months of age were sweet. • 1/3 of sweet products consisted of fruit only. For 2/3 of sweet products, fruit content not stated. • 26% of all products had total sugar content > 10%. • 8.5% of savoury products had added

				• Nutritional analysis per 100g compared to breast milk, formula milk and homemade meals.	fruit.
Van den Boom et al. (1997) (85)	To analyse 50 samples of meat-based home prepared meals for infants in Spain, compared to 15 home prepared meals from the UK and commercially available infant meals.	Spain and UK	Laboratory analysis of homemade samples	• Laboratory analysis of macronutrients, sodium, calcium, magnesium, iron and zinc.	• Home prepared meals had a lower energy density (50kcal/100g) and a higher protein content than commercial meals. • Homemade English meals had a higher mean sodium content than Spanish homemade meals. • All meals made a poor contribution to calcium and iron needs.

RNI, reference nutrient intake.

Table 2. Summary of studies on micronutrient and trace element composition

Author (year)	Objective	Country	Method/Criteria	Outcome
Loughrill et al. (2016) (84)	To evaluate the vitamin A and E contents of commercial infant foods targeted at 6-9 month old infants, including 4 meat and 4 vegetable based meals.	UK	• Laboratory analysis of vitamin A (retinyl acetate, retinyl palmitate, beta carotene and total carotenoid) and vitamin E (alpha-tocopherol and gamma tocopherol) contents.	• No significant difference in vitamin A or E components between vegetable and meat based meals. • Using a standardised daily menu, including formula feeding, the infant diet would exceed the RNI for vitamin A by 497%. • Considering beta carotene only, commercial meals contribute 58.3% to the RNI using a daily standardised menu. • Using a standardised daily menu, only 18.9% of vitamin E is derived from commercial infant foods.
Mir-Marques (2015) [27]	To profile the mineral content of commercial infant foods in Spain and their contribution to nutritional intake, including 35 jars, from 4 different brands, containing meat, fish, vegetables and fruit.	Spain	• Laboratory analysis of 14 essential and trace elements: aluminium, barium, cadmium, calcium, chromium, copper, potassium, magnesium, manganese, nickel, sodium, iron, lead and zinc.	• Levels of iron, zinc and calcium were inadequate to meet the needs of infants aged 6-12 months. • Iron provided by commercial baby food was only 5-20% of EAR, however none of the foods were fortified. • Sodium content exceeded maximum permitted level of 200mg/100g food. • The concentration of toxic elements was low.
Carbonell-Barrachina et al. (2012) [28]	To analyse the mineral and trace element content of gluten free and gluten containing cereals, and pureed infant foods containing meat/fish from Spain, UK, China and USA.	Spain, UK, China and USA.	• Laboratory analysis of calcium, iron, copper, zinc, manganese, selenium, chromium, cobalt, nickel, arsenic, lead, cadmium, mercury and sodium.	• Most baby rice and cereals were fortified with iron, zinc and calcium, however not all fortification is clearly indicated on labelling. • Estimated daily intakes of Ca, Fe, Cu and Zn were below recommended values established by WHO/UNICEF. • Calcium intakes were higher in baby rice and cereals (1.42g/kg) than pureed infant foods containing meat/fish (0.16g/kg). • Iron content was higher in baby cereals (6.58mg/100g) than rice (4.7mg/100g). • Zinc content was higher in cereals and rice (0.7mg/100g) than meat/fish foods (0.23mg/100g) • Mercury and cadmium levels were low enough to guarantee safety, however baby rice contained too much lead, arsenic,

				nickel and chromium in certain countries.
Zand et al. (2012) (83)	To establish the concentration of 20 essential and non essential elements in a representative range of commercial infant foods targeted at 6-12 month old infants in the UK.	UK	• Laboratory analysis of 20 essential and non-essential elements (calcium, iron, magnesium, sodium, potassium, zinc, selenium, molybdenum, cobalt, copper, chromium, manganese, arsenic, barium, nickel, cadmium, antimony, lead, mercury and aluminium).	• 4 poultry and 4 fish based meals, including both organic and halal were analysed. • Organic chicken brands were higher n essential and trace elements. • Chicken based meals provided a mean of 10% of RNI values. Fish based meals provided 17% of RNI values. • The concentration of toxic elements were not of concern.
Randhawa et al. (2012) (86)	To analyse the nutritive value, pesticide levels and microbial safety of 30 samples of baby food (10 commercial, 10 lab-made and 10 homemade: all prepared using the same recipe)	Canada	• Laboratory analysis of nutritive value and microbial safety of all samples. • Nutritional content consisted of: energy, protein, fat, carbohydrate, vitamin A, Vitamin C, thiamine, niacin, riboflavin, iron, calcium and zinc. • Pesticide residues measured in fruit and vegetable products.	• Average thiamine, riboflavin, vitamin C, iron and calcium contents were comparable among the three groups of samples. Zinc content was higher in homemade samples. • Homemade samples had a higher mean aerobic colony count that those made in the lab or commercially. • Homemade food had the fewest numbers of samples with pesticides, but levels in all three groups were below maximum residue levels.
Zand et al. (2011) (82)	To examine nutritive values of commercial infant foods in the UK market for 6-9 month olds compared to nutritional requirements.	UK	• Laboratory analysis of calcium, copper, magnesium, iron, zinc, potassium, sodium and selenium	• 8 products from 4 brands including 4 meat and 4 vegetable based meals were analysed • No significant differences in iron, zinc, magnesium, potassium and sodium contents between meat and vegetable meals. • With the exception of potassium, all samples provided less than 20% of RNI. Selenium not detected in any samples.
Melo et al. (2008) (81)	To determine the concentration of major minerals and trace elements in 74 commercial infant foods available in Norway (porridge, fruit puree and dinners).	Norway	• Laboratory analysis of 14 essential and trace elements: aluminium, arsenic, chromium, copper iron, mercury, potassium, manganese, molybdenum, sodium, nickel, lead and zinc.	• A diet based solely on commercially prepared foods would provide a sufficient intake of calcium, copper, iron, potassium, magnesium, sodium and zinc, for a 6 month old infant, whether breast or formula fed. • All products were within upper tolerable limit for minerals. • None of the products contained arsenic, cadmium, mercury or lead in amounts that present a health hazard. • Some minor discrepancies existed for declared and analysed

				values for some of the elements.
Bosscher et al. (2002) [29]	To determine calcium, iron and zinc availability from 8 weaning meals obtained from supermarkets: 4 vegetable based and 4 fruit based products.	Belgium	• Laboratory analysis of calcium, iron and zinc availability. • Vitamin C, macronutrient and other mineral content derived from manufacturer information.	• Mean calcium content was 33.6mg/100g. Calcium availability was 39.2% and 31.7% for fruit and vegetables respectively. • Mean iron content was 0.35mg/100g. Availability was 13% in vegetables and 10.2% in fruit purees. • Mean zinc content was 0.24mg/100g. Availability was 52% in fruits and 22% in vegetables.

RNI, reference nutrient intake

Figure 1. Current issues regarding commercial infant food intake in developed countries (see attached pdf)