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

Maslin, Kate

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1 **Title page**

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

4

5 **Authors:** Kate Maslin¹ & Carina Venter²

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7 1. School of Health Sciences and Social Work, University of Portsmouth,
8 Portsmouth, United Kingdom.

9 2. Division of Allergy and Immunology, Cincinnati Children's Hospital Medical
10 Center, Cincinnati, OH 45229, USA.

11

12 **Corresponding author:** Kate Maslin, Senior Research Fellow, School of Health
13 Sciences and Social Work, James Watson West Building, University of Portsmouth,
14 Portsmouth, PO1 2FR, United Kingdom.

15 Telephone: +44 2392 844401. Email: kate.maslin@port.ac.uk

16

17 **Shortened title:** Commercial infant food.

18

19 **Key words:** infant feeding, baby food, complementary feeding, weaning foods.

20

21

22 **Abstract**

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

38

39

40

41 **Introduction**

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

55 Complementary feeding has been debated extensively over the past few
56 decades, specifically the most appropriate age of introduction of solid food and
57 allergenic foods ⁽⁹⁻¹¹⁾, timeframes for the introduction of different tastes and textures
58 ^(12,13), use of organic foods ⁽¹⁴⁾ and baby-led weaning ^(15,16). The use of homemade
59 versus commercially produced infant foods is implicated in all of these aspects.
60 Commercially prepared infant foods, also known as "readymade" infant foods, are
61 typically mass produced and purchased in a pre prepared format requiring minimal, if
62 any, cooking or heating before consumption. In comparison, homemade infant foods
63 are generally prepared in households by parents/carers, using fresh ingredients.
64 Tracking of eating behaviours and preferences throughout life has been
65 demonstrated⁽¹⁷⁻¹⁹⁾. Specifically it has also been shown that consumption of
66 commercially prepared baby food at age 6 months is associated with consumption of
67 ready to eat foods at 2 years of age ⁽²⁰⁾, underlying the significance of this topic.

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

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

84 Concerns have been raised regarding commercially produced infant food,
85 specifically diversity of ingredients used ⁽²⁴⁾, the taste profile ⁽²⁵⁾, nutritional content
86 ^(23,26), bioavailability of micronutrients ^(27–29) and toxicity ⁽²⁸⁾. Together these factors
87 cumulatively create a significant change in early food exposure, with potential
88 implications for the development of non-communicable diseases, namely allergy ^(30,31)
89 and obesity ⁽³²⁾. There are also concerns generally regarding the role of infant feeding
90 practices in the development of early tooth decay ^(33,34), although there is no evidence
91 that commercial infant food in particular contributes to this issue. Additionally there
92 are claims that commercially produced infant foods may displace or reduce the
93 duration of breastfeeding ⁽³⁵⁾.

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

103

104 **Usage of commercial infant foods internationally**

105 The usage of commercial infant foods has been reported by national feeding and
106 cohort studies in several developed countries, although dietary collection methods,
107 sampling and timeframes differ between studies so direct comparison is not always
108 possible. Additionally, as the focus of these studies is often breast and formula

109 feeding practices and the age of introduction of solid food, not all published research
110 specifically differentiates between commercially prepared and homemade infant food,
111 so precise data is not always available.

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

126 Similar trends are evident in other European countries. In Ireland, a birth
127 cohort study found that 63.2% of six month old infants consumed a sweetened
128 commercially produced cereal for breakfast, with 30-31% consuming commercially
129 prepared products at lunch and evening times⁽⁴¹⁾. Another Irish birth cohort study
130 reported that 49% of foods eaten by infants in the first six weeks of weaning were
131 homemade⁽⁴²⁾. In France commercial infant foods are estimated to account for 27-
132 28% of energy intake at ages 6-11 months, the majority of parents (63%) offer their
133 child commercially prepared baby foods 4-7 days/week, with only 24% never using
134 them⁽⁴³⁾. In a German birth cohort study, analysis of all food diaries completed
135 indicated that 94.4% of infants consumed at least one commercially prepared baby
136 food produce within a three day period, whereas homemade complementary food was
137 eaten exclusively by only 5.6% of participants^(44,45). Participants with higher
138 commercial infant food consumption were significantly older, breastfed for a shorter
139 duration and were more likely to have mothers with a lower educational status. In
140 Italy, a birth cohort study of 400 infant and mother pairs reported that commercially
141 prepared infant foods were consumed in significantly higher quantities by infants who
142 were breastfed than non breastfed⁽⁴⁶⁾. By using an estimated food diary approach, this

143 study was able to quantify that commercial baby foods contributed a higher energy
144 content than that of homemade foods. However it must be stated that of these three
145 studies, only one recruited ⁽⁴³⁾ a cross-sectional nationally representative sample.

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

151 In developed countries outside of Europe, there is a similar pattern of
152 consumption. Although the national infant feeding survey in Australia focused on
153 breast and formula feeding and did not specifically collect data on commercial infant
154 food ⁽⁴⁸⁾, the baby and toddler food market is reported to have grown by a rate of 4.8%
155 a year in the last 5 years ⁽³⁶⁾. In the US, 73-95% of infants between the ages of 4-12
156 months consumed commercially produced baby foods when a national cross sectional
157 feeding survey was conducted in 2002 ⁽⁴⁹⁾. When repeated in 2008, the five most
158 frequently consumed vegetables by infants aged 4-9 months were commercially
159 prepared, rather than fresh ⁽⁵⁰⁾. Although the proportion of infants aged 6- 9 months
160 consuming commercially prepared fruit products decreased from 66.4 to 50.2%,
161 between 2004 and 2008 respectively, four of the top five most frequently consumed
162 fruits were commercially prepared rather than fresh in 2008 ⁽⁵⁰⁾. A limitation of this
163 study however is that the data was collected using a 24 hour recall, which may not be
164 reflective of food group intake over a longer time period. Looking at sales figures in
165 the US, they have risen from 36.7 to 55 billion US dollars per annum from 2010 to
166 2015 ⁽⁵¹⁾.

167

168 **Perceptions of commercial infant foods**

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

174 Perceptions of infant feeding and commercial baby food are influenced by
175 educational level, parity, previous experience of weaning and cultural factors ^(54,56,58),
176 with second time mothers and those from lower socioeconomic groups more likely to

177 perceive commercially prepared infant foods positively than first time mothers or
178 those from higher socioeconomic groups ⁽⁵⁴⁾. Homemade foods are generally viewed
179 as the ideal food by most mothers, due to the freshness of ingredients, taste ⁽⁵³⁾,
180 “avoidance of chemical in jars” ⁽⁵²⁾ and low cost, however there is disagreement
181 whether fresh or commercially prepared products are cheaper ⁽⁶⁰⁾. In most studies
182 commercial baby foods are perceived negatively; as “bland” and “unauthentic” ⁽⁵⁷⁾ or
183 only used in “an emergency” ⁽⁵⁵⁾, with some participants saying they felt “a bit guilty”
184 using prepared foods to feed their baby ⁽⁵²⁾. Similarly a questionnaire based-study in
185 the US indicated that many mothers have a preference for fresh fruits and vegetables
186 over jarred baby foods, with mothers of older infants (9-11 months) reporting a
187 significantly higher preference than mothers of younger infants ⁽⁵⁹⁾. However, the
188 study by Kim et al. ⁽⁵⁹⁾ recruited a sample of low income mothers who received
189 supplemental food package and overall 83.7% of respondents were “very satisfied”
190 with the jarred fruit and vegetables received.

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

207 Two European studies ^(53,58) that recruited mothers and infants from different
208 countries enabled exploration of cultural influences on commercial infant foods.
209 Maier et al. ⁽⁵⁸⁾ conducted structured interviews with two groups of mothers of infants

210 aged 4-9 months:, one group in Dijon , France, the other group in Aalen , Germany.
211 Clear between- and within-group differences in weaning practices were found, with
212 68% of Aalen mothers reported to prepare baby food at home greater than once/week
213 compared to 46% of Dijon mothers. Distinct cultural differences were also reported
214 by Synnott et al. ⁽⁵³⁾ who compared mothers from five different European countries.
215 For example, all of the Italian participants chose to prepare homemade food for their
216 infants compared to Swedish parents who were more likely to supplement home-
217 prepared foods with commercially prepared foods. The study also highlighted that
218 different factors were influential per country when purchasing food for the infant. In
219 Germany, Scotland and Sweden, health was considered the most important issue,
220 followed by taste and organic ingredients. In Italy, the priorities were health, followed
221 by method of production and brand compared to Spain, where the three most
222 important factors were health, taste and brand.

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

231

232 **Taste and variety of ingredients used in commercial infant foods**

233 By incorporating a wide variety of fresh foods, ideally complementary feeding should
234 provide a platform for establishment of balanced taste preferences. It is known that
235 new born infants have an innate preference for sweet tastes and innate rejection to
236 bitter tastes, which has developed from an evolutionary perspective to seek out
237 calories and reject toxins ⁽⁶²⁾. However these innate preferences can be manipulated
238 with exposure to different tastes in the early stages of weaning, hence why it is
239 recommended that bitter tasting vegetables may need to be offered several times
240 before acceptance is achieved ^(63,64). The exposure effect has been described as
241 consistent, powerful and universal ⁽⁶⁵⁾. A landmark study demonstrated that repeated
242 exposure to similar foods in the early stages of complementary feeding can increase

243 preference within a period of ten days ⁽⁶⁶⁾, although this study used banana and peas,
244 rather than commercially prepared foods.

245 Research in the UK by Garcia et al. ^(22,25) reported that nearly two thirds of the
246 329 commercial baby foods studied were sweet, with a distinct lack of bitter
247 vegetables. The six most common fruit and vegetables used were sweet (apple
248 banana, tomato, mango, carrot and sweet potato), with green vegetables such as such
249 as broccoli or spinach rarely incorporated into products. In total, fruit juice was added
250 to 18% of products and 8.5% of savory products had added fruit, giving them a sweet
251 taste. This ubiquitous use of sweet flavors to mask the taste of bitter vegetables may
252 be due to commercial pressure to manufacture instantly palatable foods ⁽²⁵⁾.

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

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

271 Similarly, in a low income sample of mothers and infants from the US, infants
272 aged 6-12 months who received commercial baby foods consumed a greater variety of
273 fruits and vegetables, than those who did not ⁽⁷⁰⁾, even when adjusting for infant age,
274 maternal education and ethnicity. Looking at longer term outcomes, a longitudinal
275 UK study reported that feeding home-cooked fruit or vegetables during infancy was

276 associated with increased uptake and variety of fruit and vegetables eaten at the age of
277 seven years, whereas feeding commercially prepared fruit and vegetables during
278 infancy was not ⁽⁷¹⁾. A proposed explanation for this was that commercially prepared
279 fruit and vegetables are likely to have a uniform taste and texture, whereas those
280 cooked at home or eaten raw will vary according to the whether it is in season and the
281 cooking method. It is also possible that the specific combination of ingredients in
282 commercially prepared baby food may mask or interfere with learning about the
283 particular flavor of single vegetables ⁽⁵⁵⁾. A German study found no association
284 between commercially prepared food intake in infancy and fruit and vegetable variety
285 intake at preschool age in girls, however in boys there was an association with
286 reduced vegetable variety score ⁽⁴⁵⁾. The reason for this was unclear.

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

291 **Meat and fish content of commercial infant foods**

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

303 Fish, specifically oily fish, is of particular nutritional relevance in infancy due
304 to the iodine ⁽⁷³⁾ and long chain polyunsaturated fatty acids (LCPUFA) content and
305 associated health outcomes ^(74,75). Although the iodine content of infant formula milk
306 is regulated, there is no recommendation regarding minimum iodine fortification of
307 commercial infant food in the EU ^(6,76). In terms of essential fatty acids, the concern

308 regarding a lack of sufficient LCPUFA in commercial infant food was noted more
309 recently by Loughrill & Zand (2016) ⁽⁷⁷⁾. The contribution of fish based meals to
310 essential fatty acid intake was found to be low, providing only 19.9% and 3.41% of of
311 requirements for eicosapentaenoic acid and docosahexaenoic acid respectively, which
312 may be because the meals analysed were only composed of approximately 10% of
313 fish by weight ⁽⁷⁷⁾.

314 On the contrary, it could also be argued that non-consumption of fish is
315 common in all infants and young children, regardless of whether they are fed
316 predominantly homemade or prepared baby food. National UK dietary data reported
317 that after disaggregation of composite dishes, mean consumption of fish from all
318 sources ranged from 1g per day for children aged 4 to 6 months to 6g per day for
319 those aged 12 to 18 months. The proportion of infants and young children consuming
320 fish and fish products increased with age from 13% at 4 to 6 months to 53% at 12 to
321 18 months. This delayed introduction may be due to confusion and change in infant
322 feeding guidelines for allergy prevention ⁽²⁴⁾.

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

332 In terms of quantifying the amount of meat in an infant food product, an EU
333 directive (1996) states that if meat, poultry or fish, are mentioned first in the name of
334 the product, whether or not the product is presented as a meal, then the named meat,
335 poultry or fish, shall constitute not less than 10% by weight of the total product. If
336 meat, poultry or fish are mentioned, but not first in the name of the product, then it
337 shall constitute not less than 8 % by weight of the total product. Following on from
338 this stipulation, a German study concluded that the low meat composition of many
339 commercial infant meals may increase the risk of marginal iron status in older infants
340 who were breastfed for 4-6 months ⁽⁷⁹⁾. In Australia, Mauch et al. ⁽⁸⁰⁾ reported that

341 commercial infant foods were the most common source of meat/meat alternatives
342 consumed at age 5.5 months, but by 14 months mixed meals such as bolognese were
343 more common. The study concluded that parents should encourage meat “in a
344 recognisable form” and as one of the first complementary foods.

345 **Nutritional content of commercial infant foods**

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

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

372 *Sugar, salt and fat content*

373 Several studies have focused on the “healthy eating” aspect of infant nutrition,
374 assessing either sugar, salt or fat content. Some studies specified added sugar content
375 ^(23,87), whereas others reported only total sugar content ^(22,86), which makes
376 comparisons problematic. In terms of sugar, the overall trend was that products had an
377 inappropriately high sugar content compared to nationally recognized standards and
378 recommendations ^(22,86,87), however this claim is difficult to disentangle as fruit, and
379 therefore fructose, was a primary ingredient in many of the products investigated.
380 Both total and added sugar are an essential factor to consider, given the recently
381 published recommendations regarding reducing consumption of added sugars ⁽⁸⁹⁾.

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

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

399 *Micronutrient content and adequacy*

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

404 *Mineral & trace element content*

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

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

426 *Vitamin content*

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

435 **Limitations of review**

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

455

456 **Conclusion and future research needs**

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

469

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474

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477

478

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787

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.	<ul style="list-style-type: none"> Complementary meals defined as semisolid pureed or mashed foods. Solid snack foods and drinks not included in analysis. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Laboratory analysis of energy, protein, fat, carbohydrate, and fibre. Compared to EU commission directive 2006/125/EC. 	<ul style="list-style-type: none"> 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.	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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

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	<ul style="list-style-type: none"> • Nutritional analysis per 100g compared to breast milk, formula milk and homemade meals. • Laboratory analysis of macronutrients, sodium, calcium, magnesium, iron and zinc. 	<p>fruit.</p> <ul style="list-style-type: none"> • 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.
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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	<ul style="list-style-type: none"> Laboratory analysis of vitamin A (retinyl acetate, retinyl palmitate, beta carotene and total carotenoid) and vitamin E (alpha-tocopherol and gamma tocopherol) contents. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Laboratory analysis of 14 essential and trace elements: aluminium, barium, cadmium, calcium, chromium, copper, potassium, magnesium, manganese, nickel, sodium, iron, lead and zinc. 	<ul style="list-style-type: none"> 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.	<ul style="list-style-type: none"> Laboratory analysis of calcium, iron, copper, zinc, manganese, selenium, chromium, cobalt, nickel, arsenic, lead, cadmium, mercury and sodium. 	<ul style="list-style-type: none"> 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,

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	<ul style="list-style-type: none"> 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). 	<p>nickel and chromium in certain countries.</p> <ul style="list-style-type: none"> 4 poultry and 4 fish based meals, including both organic and halal were analysed. Organic chicken brands were higher in 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	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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 than 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	<ul style="list-style-type: none"> Laboratory analysis of calcium, copper, magnesium, iron, zinc, potassium, sodium and selenium 	<ul style="list-style-type: none"> 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. 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
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	<ul style="list-style-type: none"> Laboratory analysis of 14 essential and trace elements: aluminium, arsenic, chromium, copper iron, mercury, potassium, manganese, molybdenum, sodium, nickel, lead and zinc. 	<ul style="list-style-type: none"> 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

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	<ul style="list-style-type: none"> • Laboratory analysis of calcium, iron and zinc availability. • Vitamin C, macronutrient and other mineral content derived from manufacturer information. 	<p>values for some of the elements.</p> <ul style="list-style-type: none"> • 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.
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RNI, reference nutrient intake

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