The Recommended First Complementary Foods: A Review of the Literature

Abstract

During infancy, adequate nutrition is essential to warrant healthy growth and development of infants to their full potential. Nutritional deficits particularly iron, during this critical period increase the risk of illness and long-term developmental impairment. Therefore, international organizations including Health Canada recommend that infants should be primarily introduced to iron rich complementary foods (CFs) such as iron fortified cereal and meat in order to meet their iron requirements and prevent growth faltering. This review aims to provide an overview on the available research of the recommended first CFs and their effects on various health outcomes including iron. Although the studies on meat presented in this review showed inconsistent findings regarding improvement of iron status, however, consumption of meat had promising positive effects on growth and other health outcomes. Studies on the fortified cereals reported improvement of iron status and possibly growth. Further large scale, multicenter trials are needed to support the current findings and to investigate the long-term benefits of these recommended CFs.

Keywords: Complementary foods; Fortified cereal; Meat; Infant; Iron; Growth; Breastfeeding

Review Article

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Abbreviations: CFs: Complementary Foods; EBF: Exclusive Breastfeeding; ID: Iron Deficiency; RCT: Randomized Controlled Trial; WHO: World Health Organization

Introduction

During infancy, adequate nutrition is essential to warrant healthy growth and development of infants to their full potential. Nutritional deficits particularly iron, during this critical period increase the risk of illness and long-term developmental impairment [1-3]. Therefore, optimal feeding practices of exclusive breastfeeding up to six months of age followed by adequate CF introduction are highly important to ensure disease free and healthy development of the growing infant [4].

At about six months, full term EBF infants are at risk to develop iron deficiency (ID) because of the high demand of iron needed for growth and the low iron concentration in the breast milk [5-7]. Reliance on these reasons, Health Canada recommends that infants should be primarily introduced to iron rich foods in order to meet their iron requirements [8]. The statement reinforced the introduction of iron-fortified infant cereals as well as meat and meat alternatives. Iron-fortified cereals were the most common first CFs while meats were the least CFs introduced to Canadian infants [9]. It is widely known that iron-fortified cereals provide non-heme iron with a rate of absorption of <5% and that heme iron available from meats are better absorbed (>35%) [10]. In addition to iron, there are other nutrients that need to be obtained from these first CFs to assure normal development of the infants, thus, it is of highly importance to understand how efficient are these first foods in satisfying the developmental needs for this age group. Therefore, the aim of the following literature review is to provide an overview on the existing research on infant complementary feeding, focusing on fortified cereal and meat, in relation to iron status and other health outcomes.

Materials and Methods

In the present review, we provide an overview of the available publications related to complementary feeding in infancy focusing on the first recommended CFs; fortified cereal and meat. We performed an electronic MEDLINE database search for the related studies and reviewed the results with a focus on interventional studies.

Results and Discussion

Meat as first complementary food

Meat is a good source of bioavailable iron and zinc as well as vitamins B6 and B12 and has been recommended as an appropriate early CF by Health Canada [11,12]. However, in a Canadian survey by Friel et al. [13], it was indicated that less than 10% of 6 to 9 months old infants consume meats [13]. In the US, data from the Infant Feeding Practices II indicated that meat consumption was the least common first solid food introduced to the infants [14]. In another survey conducted in four sites; Guatemala, Democratic Republic of Congo, Zambia, Pakistan; Krebs et al. [15] had found that less than 25% of breastfed infants consumed meat regularly [15]. In Germany, it was found that only 15% of infants received mashed meat as first CF [16]. Indeed, there is an increasing agreement around the health and growth advantages of benefits of meat as first CF [15]. Looking at the literature, there have been few studies conducted to examine the potential benefit of meat introduction as CF. The studies varied significantly in terms of the age of the studied population (ranged from 4 months to 24 months), mode of feeding (human milk Vs formula) and the outcome measures (iron status, growth, microbiome etc).

Observational studies

The benefits of meat introduction have been reported in a number of studies in the developing and developed countries.

For example, in a cross sectional survey conducted on 12 to 24 months old Indian children, there was a positive association between length-for-age scores and parental education and meat consumption [17]. In another study conducted on breastfed infants and toddlers in Peru, the results indicated that the linear growth was positively associated with the intake of meats [18]. In a prospective cohort study conducted in the UK, 144 full term infants were recruited at 4 months and followed up to 24 months of age. Meat consumption of 28.3 g/day from 4 to 12 months was positively associated with weight gain ($p<0.05$), and with psychomotor development ($p<0.02$) [19]. Similar observation was noted in Denmark, between high protein intake and weight gain ($p=0.03$) [20]. In contrast, in another 198 cohorts, iron status parameters, hemoglobin and zinc concentrations were not significantly associated with the intake of meat. However, when the relation between these parameters and the diet groups was further explored using the chi-squared test, significant inverse relationship was observed between low serum iron and meat intake at 12 months of age ($p<0.023$) [21]. In the cross sectional study by Krebs et al. [15], meat consumption was associated with a reduced likelihood of stunning (odds ratio = 0.64; 95% CI, 0.46-0.90) [15]. In a retrospective study, the results of data from the China Food and Nutrition Surveillance System had indicated an attributable risk of no consumption of animal source food to stunning was 28.2% and to underweight was 11.7% [22].

In the multi-country prospective cohort study (the Global Exploration of Human Milk) three hundred and sixty five breast fed infants from the US (Cincinnati), Mexico (Mexico City) and China (Shanghai) were followed up from birth to two years of age to examine the growth and health outcomes in relation to breast milk and CF consumption. High protein foods (meat, eggs, legumes) were significantly introduced earlier among Chinese infants (4.8 months) than among Mexican infants (7.0 months) and American infants (9.3 months; $p=0.0001$). Infants in Shanghai had significant higher increase in their anthropometric measurements (weight-for age Z-score, length-for age Z-score, weight-for-length Z-score, BMI-for-age Z-score, head circumference-for-age Z-score) at one year of age than the infants in Cincinnati and Mexico City ($p<0.001$). However, the results indicated no association between earlier high protein food introduction and anthropometric scores at 1 year of age with the exception of longer duration of exclusive breastfeeding, which was associated with lower weight-for age Z-score ($p<0.05$) [23]. Although the authors concluded that specific feeding practices do not explain the differences in growth measurement, one should keep in mind the limitation of this type of studies in confirming causality between the variables and the outcomes.

Interventional studies

There are number of nutritional intervention trials that have been conducted to target the improvement and diversification of complementary feeding practices through nutritional education provided to caregivers. For example, in Peru conveying a message to introduce liver, eggs, and fish resulted in significant reduction of stunning [24]. In a recent RCT, eighty five EBF Colombian infants were randomly assigned either to a group in which caregivers received recommendations that emphasized on meat consumption of 3 times per week (new guidelines group) or to a group in which caregivers received usual advice on solid introduction (control group). At 12 months of age, there was a significant higher increase in hemoglobin and hematocrit at 12 months among the group who received meat consumption recommendation ($p=0.01$, $p=0.03$ respectively). However, there were no significant differences between the groups in linear growth and zinc level [25]. A clinical study in Denmark randomized 8 months old breastfed infants either to low or high meat feeding groups for 8 weeks. Infants in the high meat group had higher serum hemoglobin concentration than infants in the low meat group [26]. Another trial in the US randomized 88 EBF infants at 4 months of age to receive either pureed meat or iron-fortified cereal. Infants in the meat group showed higher increase in head circumference than infants in the cereal group. There was a 16-fold increase in zinc absorption from a test meal in the meat group than in the cereal group [27]. Table 1 illustrates the clinical feeding interventions of meat as CF conducted on infants. Over all, the studies have suggested positive effects as well as acceptability of meat consumption as first CF.

Iron fortified cereal as first complementary food

With the increasing knowledge of the high requirements of iron in infants, iron fortification of infant cereal has become an important vehicle to meet iron needs of the growing infant [32]. Regardless of fortification, cereal is considered a low fat and a low energy dense diet and contains phytate, which affects iron bioavailability [33]. Iron fortified cereal has been the typical first CF offered to infants in Canada and other countries [13,34]. Fruits and vegetables are also commonly introduced after cereal, despite being a poor source of iron. At the end of first year of life, protein sources are introduced gradually. This complementary feeding practice for the breastfed infant is not only unique to Canada but also common in both developed and developing countries [34]. The typical unfortified plant-based cereal may pose a risk of iron and zinc deficiency if consumed alone without supplements [35]. Homemade plant-based cereals introduction is a common practice in various African and Asian countries due to its affordability; however, these foods such as maize porridges, are low in iron, zinc and vitamin A [33,36]. Therefore, the fortification of these low nutrient density foods have been assessed to be adapted as a strategy to tackle the problem of micronutrients deficiency and malnutrition in the developing countries. In the developed countries, fortification of food is the primary strategy to overcome the problem of micronutrient deficiency in infants which has met the goals with documented improvements of rate of anemia and growth [37].

In 2003, a joint statement between the Pan American Health Organization and the WHO was published as a result of the need of consistent child feeding guidelines [35]. The guidelines included principles on exclusive breastfeeding duration and age of introduction of solids, breastfeeding maintenance, responsive feeding, preparation and storage of CFs, amount of CF, CF consistency, feeding frequency and energy density, nutrient content of CF, vitamin and mineral supplements and fortified food use for mothers and infants, and feeding throughout and after illness. Regarding the guidelines on CFs, it was recommended that the breastfed infants living in industrialized countries to consume energy of 130 kcal/day at 6-8 months, 310 kcal/day at 9-11 months, and 580 kcal/day at 12-23 months of age. Gradual increase in food consistency, variety and frequency as the infant gets older was also recommended. Consumption of meat, poultry, fish, eggs, fruits and vegetables on a daily basis was further emphasized in the guidelines. The guidelines supported the use of fortified CFs for the infant as needed.

Table 1: Summary of the clinical feeding interventions of meat

Author/ Year	Country	N	Age Mo	Duration Mo	Mode of Feeding	Intervention	Outcome Measures	Results
Dube et al. [28]	Germany	132	6-Apr	4	Predominantly BF	Low meat (8% by weight of the study food) Vs high meat (12% by weight of the study food)	Iron status parameters: Hb, hematocrit, mean cell volume, mean cell Hb, ferritin, transferrin receptors zinc protoporphyrin, serum iron	- No sig differences founded between the groups in all iron status parameters
Engelmann et al. [26]	Denmark	41	8	2	Partially BF	Low meat (10 g/d) Vs high meat (27 g/d)	Iron status parameters, serum zinc, growth, illness	- Sig difference in the decline of Hb in the low meat group (-4.9 g/l, p<0.001)
								- No sig decline in the Hb of the high meat group
								- No sig differences in the other iron status parameters, serum zinc, growth parameters, illness
Jalla et al. [29]	US	18	6-May	1	EBF	Iron fortified cereal Vs pureed beef	Zinc absorption	Absorbed zinc was sig higher from beef than from cereal (p<0.001)
Krebs et al. [30]	DR of Congo, Zambia, Guatemala, Pakistan	1062	6	12	EBF	Micronutrient fortified-cereal Vs meat	Growth, micronutrient status, dietary diversity, neurocognitive development, occurrence of infectious disease	- The linear growth (primary outcome) did not differ sig between the groups.
								- Sig more consumption of food groups among infants in meat group.
								-No sig differences between the groups in infectious disease occurrence.
								- No sig differences in Bayley Scales of infant development were observed.
								- ID was significantly lower in the cereal group (p=0.001). - Sig higher zinc intake for the meat and zinc-iron-fortified cereal groups than for iron-fortified group.

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Table 1: Summary of the clinical feeding interventions of meat(cont.)

Krebs et al. [31]	US	45	6	5	EBF	Zinc-iron-fortified cereal Vs organic whole grain iron fortified cereal Vs pureed meat	Zinc status bio-chemical markers: fractional absorption of zinc, total absorbed zinc, exchangeable zinc pool size	-Sig higher total absorbed zinc amount was observed for the meat group than the other groups (p<0.027). - Sig association between exchangeable zinc pool size and both zinc intake and total absorbed zinc (r=0.43, p<0.01; r=0.54, p<0.001 respectively). - Sig higher fractional absorption of zinc from CF in the iron-fortified cereal group than in the other groups (p=0.003).
Krebs et al. [27]	US	88	5	2	EBF	Iron fortified cereal Vs pureed beef	Growth, iron status, zinc level, Bayley Scales of Infant Development.	- Sig higher increase in head circumference among infants in meat group (p=0.02). - No sig differences in the other anthropometric measurements between the groups. - No sig difference in iron and zinc status between the groups. - Developmental scores did not differ between the groups.

BF: Breast Fed; CF: Complementary Food; EBF: Exclusively Breast Fed; Hb: Haemoglobin; ID: Iron Deficiency; mo: Month; Sig: Significant

Observational studies

There are a handful number of studies that investigated infant feeding practices and the factors that influence these practices such as maternal education, formula introduction and breastfeeding initiation [38-40]. In the developing countries, most of the observational studies had looked at and examined the association between the common complementary feeding practices in relation to growth parameters and stunting. In a cross sectional study conducted on breastfed Malawian children, the feeding practices and the nutritional quality of CF were evaluated. More than 70% of the total energy intake of infants at age of 6 months was from cereals and only 2-4% of energy intake was from meats. It was shown that the intakes of iron, niacin, zinc and calcium at all bioavailability levels were all inadequate. The study reported a prevalence of at least 25% of low anthropometric scores across the infants in all age groups. No correlation tests were conducted between growth, micronutrient status and complementary feeding [41].

Several other observational studies have documented the relationship between feeding micronutrient fortified CF and iron status, zinc status, anemia rate, growth and morbidity. For example, in a cohort of seventy-six full term Swedish infants, iron, zinc status and hemoglobin were evaluated following feeding iron and zinc rich foods [42]. Iron depletion was prevalent in 26% of the infants and 36% had low zinc concentration. Although there was no association between feeding pattern and iron depletion, the author suggested that the high cereal intake as first CF might have affected the bioavailability of both iron and zinc. Moreover, in two hundreds Iranian infants cohorts, it was reported that there were no significant differences in weight and length gain between EBF infants and infants who received CF. It was also found that infants who were EBF had lower rate of occurrence of gastrointestinal and respiratory illnesses [43].

Interventional studies

Looking at the literature, iron was supplemented through different routes including oral, parenteral, iron-fortified infant formula and iron-fortified cereal. Interventions have been taken mostly in developing countries where the prevalence of ID and stunting are high [44]. Table 2 shows a summary of the clinical feeding interventions of iron-fortified cereal as CF in infants. The

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trials varied in the population size, age group, duration, and in the measured outcome variables focusing mainly on the effect of the fortified cereal on iron status parameters and growth. The studies showed no relevant effect of iron-fortified cereal on weight gain, length gain and other growth parameters, which may be due to the short follow-up period. Other possible explanations of inconsistency of the results are the differences in the iron compounds and the amount. Most of the interventions showed significant positive effect of iron-fortified cereal consumption on the iron status parameters, however, it is worthy of mention that some interventions used multiple micronutrients CF which made establishing a cause-effect relationship between iron consumption and iron status improvement questionable.

Table 2: Summary of clinical feeding interventions of iron fortified cereal.

Author/ Year	Country	N	Age	Duration	Mode of Feeding	Intervention	Outcome Measures	Results
Faber et al. [50]	South Africa	361	12-Jun	6 months	Predominantly BF	Fortified porridge (27.5 mg/d iron) Vs unfortified porridge	Hb, serum retinol, zinc, ferritin, motor development, growth	- Sig intervention effect for ferritin (9.4 mg/L) and for Hb (9 g/L) among the fortified porridge group - Sig decrease in proportion of anaemic infants from 45% to 17% in the fortified porridge group - Sig higher motor development score achievement (15.5 points) in fortified porridge group than the control group (14.4 points) (*p=0.007*) - No sig differences between the groups in growth parameters
Gibson et al. [51]	Zambia	743	6	12	Predominantly BF	Fortified porridge (5.36 mg/d iron) Vs unfortified porridge	Iron status parameters, micronutrients deficiency, prevalence of anaemia	- Sig treatment effect on serum Hb, ferritin, transferrin receptor ($p<0.001$), and selenium ($p=0.009$) - No treatment effect on serum zinc - Consumption of fortified porridge reduced the odds of anaemia by 63%, elevated transferrin receptor by 79%, low ferritin by 72% and IDA by 82%
Javaid et al. [52]	Pakistan	86	12-Jun	8	Predominantly BF	Fortified milk cereal with ferrous fumerate Vs fortified milk cereal with ferric pyrophophate Vs unfortified milk cereal	Iron status parameters, growth, morbidity	- Sig higher Hb and ferritin levels in the iron fortified cereal groups than unfortified group - Sig higher weight gain in the iron-fortified cereal groups - Sig lower incidence of malnutrition among infants in the iron-fortified cereal groups - Sig lower incidence of acute diarrhoea in both iron fortified groups than in unfortified group ($p<0.05$) - No sig differences in incidence of infections between the groups

Table 2: Summary of clinical feeding interventions of iron fortified cereal.(cont.)

Lartey et al. [53]	Ghana	208	12-Jun	5	Partially BF	3 Fortified porridge groups Vs unfortified porridge group	Iron status parameters, serum zinc, erythrocyte riboflavin, vitamin A, growth, morbidity	- No sig differences between the groups in growth parameters - No sig differences between the groups in iron parameters, serum zinc, erythrocyte riboflavin - Sig higher plasma retinol level among infants in the vitamins + minerals fortified porridge group - Sig improvement in all growth parameters in the combined intervention groups compared with non-intervention group (p<0.001)
Lind et al. [54]	Sweden	300	12-Jun	12	Formula fed & BF	Commercial milk-based porridge Vs phytate-reduced porridge Vs formula-based porridge	Growth, Bayley scales of infant development, morbidity	- No sig differences between the groups in growth, development and morbidity - 77% higher risk of diarrhoea among infants in the formula-based porridge group
Lind et al. [55]	Sweden	300	12-Jun	6	Formula fed & BF	Commercial milk-based porridge Vs phytate-reduced porridge Vs formula-based porridge	Iron and zinc status parameters	- Sig higher Hb level in the phytate-reduced porridge group (p=0.012) - Lower prevalence of anaemia among phytate-reduced porridge group - No sig differences in the other iron and zinc parameters between the groups
Mamiro et al. [56]	Tanzania	137	6	6	Predominantly BF	Processed cereal (to increase E density & Fe solubility & to decrease phytate) Vs unprocessed cereal	Iron status parameters, Fe intake, zinc protoporphyrin, growth	- No significant differences in Hb level between the groups - No sig differences in iron intake between the groups - No sig differences in zinc protoporphyrin and in growth z-scores between the groups were found
Menon et al. [57]	Haiti	415	24-Sep	7	Predominantly BF	Fortified wheat-soy blend (sprinkles) Vs unfortified wheat-soy blend	Iron status parameters	- Sig increase in Hb level among infants in the fortified wheat-soy blend group (p<0.001). - Sig decline in anaemia rate in infants in the fortified wheat-soy blend group (54% to 14%, p<0.05)

Table 2: Summary of clinical feeding interventions of iron fortified cereal.(cont.)

Oelofse et al. [58]	South Africa	60	6	6	Partially BF	Fortified porridge (0.8 mg/d iron) Vs normal diet	Iron status parameters, zinc level, retinol level, growth, psychomotor development	- Sig higher retinol level among infants in the fortified porridge group (p<0.005) - No sig difference in the Hb and total iron level between the groups - No sig differences were detected in growth parameters and psychomotor development scores between the groups - No sig difference in zinc level between the groups
Owino et al. [59]	Zambia	150	6	3	Predominantly BF	Fortified porridge Vs fortified porridge + amylase Vs control	Iron status parameters, growth, breast milk intake	- Sig increase in Hb level among infants in the iron-fortified groups compared to control. - Sig lower rate of anaemia in iron-fortified groups - No differences in breast milk intake between the groups - No sig differences in weight and length z-scores between the groups
Pham et al. [60]	Vietnam	426	5	6	Predominantly BF	2 fortified gruel Vs unfortified gruel	Growth	- Sig higher growth parameters scores in the fortified gruel groups compared to the unfortified gruel group
Walter et al. [61]	Chile	515	4	11	EBF	Fortified cereal Vs unfortified cereal	Iron status parameters	- Sig differences between the groups in Hb level - No sig differences in ferritin level between the groups

BF: Breast Fed; CF: Complementary Food; E: Energy; EBF: Exclusively Breast Fed; Hb: Haemoglobin; Mo: Month; Sig: Significant

In the systematic review Eichler et al. [44] a meta-analysis was performed to weigh the evidence for the effects of the fortified infant formula combined with cereal foods on infants and children [44]. A clinically relevant increase in serum hemoglobin levels was reported (mean increase of 0.6 g/dL; 95% CI: 0.34 to 0.89) for children consumed iron fortified formula and cereal. Similarly, iron fortification increased the mean ferritin level by 11.3 µg/L (95% CI: 3.3 to 19.2) compared to the control groups. It was also documented that iron fortification of formula and cereal may reduce the risk of suffering from anemia by %50 (risk ratio = 0.05, 95% CI: 0.33 to 0.75). Although the meta-analysis results showed promising effects of iron fortification on functional health outcomes, one should keep in mind that the data was pooled from both iron-fortified formula and cereal interventions. In another systematic review, a broader overview of the interventions and the programs aimed at enhancing biological and clinical outcomes with CFs was given [45]. However, no meta-analysis of the effects of these foods on the outcomes was performed in lieu, the results were presented as averaged effect sizes.

The interventions included in this systematic review targeted mainly breastfed children within the age group six to twenty four months. The strategies of the reviewed interventions included education about complementary feeding, provision of CF with extra energy, provision of CF combined with education, provision of fortified CF, increased nutrient bioavailability and energy density of CF by simple technology. The studies of the iron-fortified complementary interventions that measured iron status parameters showed an average impact increase of mean hemoglobin of 6 g/land a 17 percentage points reduction in the prevalence of anemia. On the other hand, the results of the impact of the iron-fortified complementary feeding studies on growth were inconsistent with an overall mean effect size of 0.60 for weight and 0.47 for linear growth. The authors concluded that the provision of iron-fortified foods along with educational messages can substantially improve iron status, growth and behavioral development and lower morbidity. Other reviews had also combined the data from iron supplementation and CF fortifications studies in their analyses or included studies on children as well as adult women [46-49].

Conclusion

Optimal complementary feeding is a desired goal for health care providers and caregivers to ensure optimal growth and development of the infants. Micronutrients such as iron and zinc need to be derived from CFs to complement breast milk. The traditional CFs (fortified cereals) provides non heme iron with less absorption rate. While meats (newly recommended) are rich in heme iron with favorable absorption rate as well as other essential nutrients. Limited number of interventional studies on meat is available and showed inconsistent findings in regards to improvement of iron status, however, the results of the studies have suggested other beneficial health outcomes. The current review also shows that the consumption of fortified cereals resulted in improvement of iron status and possibly growth. Furthermore, these findings support the current complementary feeding recommendations by WHO and Health Canada of the introduction of fortified cereal and meat as first CFs for infants. Further large scale, multicenter trials are needed to support the current findings and to investigate the long-term benefits of these recommended CFs.

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