COMPLEMENTARY FEEDING PRACTICES AND COMMERCIAL INFANT FOODS

Dissertation zum Erwerb des Doktorgrades der Humanbiologie an der Medizinischen Fakultät der Ludwig-Maximilians-Universität zu München

vorgelegt von
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aus Keflavík, Island
Jahr 2021

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Abbreviations

ALSPAC	Avon Longitudinal Study of Parents and Children
BLS	*Bundeslebensmittelschlüssel*
BMS	breastmilk substitute
CCF	commercial complementary foods
CF	complementary food
CI	confidence interval
CHOP	European Childhood Obesity Project
DONALD	Dortmund Nutritional and Anthropometric Longitudinally Designed
EFSA	European Food Safety Authority
EPL	energy-providing liquids
ESPGHAN	European Society for Pediatric Gastroenterology, Hepatology and Nutrition
ONE	*Office de la Naissance et de l'Enfance*
OR	odds ratio
SIAIP	Italian Society of Allergology and Pediatric Immunology
SIGENP	Italian Society of Gastroenterology, Hepatology and Pediatric Nutrition
SOP	standard operating procedures
WHO	World Health Organization

Publication list

This cumulative doctoral thesis consists of the following two publications:

Publication I:

Theurich MA, Zaragoza-Jordana M, Luque V, et al. Commercial complementary food use amongst European infants and children: results from the EU Childhood Obesity Project. *Eur J Nutr*. 2020; 59(4):1679-1692. doi:10.1007/s00394-019-02023-3

"Commercial complementary food use amongst European infants and children: results from the EU Childhood Obesity Project" is an original research article published in the peer-reviewed journal *European Journal of Nutrition* (EJON). It appeared online on July 1, 2019 and in print in June 2020. Bibliometric indicators (e.g. impact factor, ranking) for EJON include a subject-specific impact factor of 4.66 in 2019, according to the InCites Journal Citation Reports. EJON is a scientific, peer-reviewed journal ranked at place 16 of 89 journals in 2019, among the top 18% of journals in the *Nutrition and Dietetics* category.

Publication II:

Theurich, M.A.; Koletzko, B.; Grote, V. Nutritional Adequacy of Commercial Complementary Cereals in Germany. *Nutrients* 2020, *12(6), 1590;* doi.org/10.3390/nu12061590

"Nutritional adequacy of commercial complementary cereals in Germany" is an original research article, published in the peer-reviewed journal *Nutrients*. It first appeared online in May 2020. Bibliometric indicators of the journal *Nutrients*, include the subject-specific impact factor of 4.55 in 2019, according to the InCites Journal Citation Reports. *Nutrients* is an open access, peer-reviewed journal ranked at place 17 of 89 journals in 2019, among the top 19% of journals in the *Nutrition and Dietetics* category.

1. Contribution of Theurich, M. to the publications

1.1. Contribution to Publication I: "Commercial complementary food use amongst European infants and children: results from the EU Childhood Obesity Project"

The first manuscript was written as part of work conducted with data from the European Childhood Obesity Project (CHOP), at the Dr. von Hauner Children's Hospital, at the University of Munich Medical Centre in Munich in collaboration with additional European study centers in four European countries, including: the Universitat Rovira i Virgili, IISPV, in Tarragona, Spain, the Université Libre de Bruxelles, in Brussels, and the CHC St Vincent, Liège-Rocourt, the Queen Fabiola Children's University Hospital, Université Libre de Bruxelles in Brussels, Belgium, the Children's Memorial Health Institute in Warsaw, Poland, and the University of Milan in Milan, Italy. There are 11 coauthors.

The contribution of Theurich, M to the first qualifying publication include:

- conception of the study design for evaluation of CCF data
- drafting and composition of scientific content as the first author of the manuscript
- creation of a concept for the organization and statistical evaluation of data
- data cleaning, management and complementary feeding data categorization
- technical input into descriptive data presentation
- creation, design and editing of tables
- coordination and revisions to the manuscript based on input from coauthors
- preparation, submission of the manuscript to the *European Journal of Nutrition*
- technical revisions to the manuscript based on peer-reviewers' feedback, point-by-point responses to peer reviewers' comments
- copy editing revisions based on Copy Editor feedback

1.2. Contribution to Publication II: “Nutritional Adequacy of Commercial Complementary Cereals in Germany”

Work for the second manuscript was conducted at the Dr. von Hauner Children’s Hospital, at the University of Munich Medical Centre in Munich. There are 2 coauthors.

The contribution of Theurich, M to the second qualifying publication include:

- conception of study design for evaluation of commercial cereal data
- drafting and composition of scientific content as the first author of the manuscript
- creation of a template for data collection, data collection
- supervision of data collection by dietetics student
- cleaning, evaluation and checking of data
- statistical testing and analysis of nutrient data
- design of figures and tables in the manuscript
- coordination and revisions to the manuscript based on input from coauthors
- preparation and submission of the manuscript to the journal *Nutrients*
- technical revisions to the manuscript based on peer-reviewers’ feedback, responses to peer reviewers’ comments
- copy editing revisions based on Copy Editor feedback

2. Introduction

"Complementary feeding practices and commercial infant foods" summarizes scientific research conducted as part of a cumulative doctoral dissertation at the Dr. von Hauner Children's Hospital of the Ludwig-Maximilians-Universität München. It is being submitted in support of candidature for the Doctoral Degree in Human Biology (Dr. rer. biol. hum.) from the Medical Faculty of the Ludwig-Maximilians-Universität München. This cumulative doctoral dissertation consists of two publications that were published in peer-reviewed, scientific journals in 2019 and 2020.

The overarching question this doctoral thesis aims to address is: "Which types and quality of commercial complementary foods (CCF) are fed to infants and young children living in Europe, and what role do CCF play in dietary intakes?" The three main objectives of this dissertation are to:

- Describe the types of CCF fed to European infants and young children and determine socioeconomic characteristics associated with CCF use
- Quantify the contribution of CCF to daily dietary energy intakes
- Assess the nutritional adequacy of a common type of CCF (commercial baby cereals) on the German market

Types of CCF fed to European infants and young children, their role in dietary intakes and associated socioeconomic factors

In the first part of this cumulative thesis, complementary feeding data from the European Childhood Obesity Project (CHOP) is used to explore and describe the role of CCF in the dietary intakes of infants and young children living in five European countries, namely, Germany, Italy, Belgium, Poland and Spain. The first work, "Commercial complementary food use amongst European infants and children: Results from the EU Childhood Obesity Project" uses dietary data from 1088 infants at nine time points over the first two years of life. It explores which types of CCF are consumed, how they contribute to overall caloric intakes in the cohort over the first two years of life and which socioeconomic factors are associated with CCF use. The a-priori hypothesis of the EU CHOP trial tested the effect of varying levels of protein in commercial infant formula on the risk for childhood obesity. The results of these analyses are published elsewhere.[1,2]

Commercial complementary foods are thought to play a substantial role in the diets of modern European infants and children. Yet few epidemiological studies have examined the use of CCF compared to other types of foods in birth cohorts, to quantify their contribution to dietary intakes over time.[3] Knowing the proportion of infants that consume CCF over time, and the total dietary energy contribution from CCF, is relevant for studies on the relationship between CCF and childhood eating habits and ultimately, long-term child health outcomes.

Observational data from the Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) study in Germany was evaluated for the relationship between CCF use in 288 infants and their fruit and vegetables consumption in childhood.[4] Results from the DONALD cohort found that amongst boys, consuming higher levels of CCF in infancy was associated with lower intakes of vegetables in infancy and preschool, as well as lower fruit and vegetable intakes in childhood.[4] Amongst girls, higher CCF intakes in infancy were associated with lower vegetable intakes in infancy.[4] In a separate evaluation study on the DONALD cohort, it was shown that infant diets with a higher proportion of CCF were associated with a higher odds for total added sugar intakes in infants, preschool and primary school-aged children.[5] An evaluation of complementary feeding data from 7097 infants enrolled in the ALSPAC study showed that dietary patterns of 6- and 15-month old infants consuming higher levels of CCF were associated with small but persistent negative effects on IQ scores at 8 years.[6] Similarly, 6-month old infants with dietary patterns consisting of home-made meals at 6 months of age were associated with higher IQ scores in mid-childhood.[6]

Results from the first publication in this dissertation, "Commercial complementary food use amongst European infants and children: results from the EU Childhood Obesity Project;"

demonstrated that CCF contributed substantially to caloric intakes in the CHOP cohort over the first two years of life.[7] Total energy from CCF between 4 and 9 months of age was significantly higher ($p \leq 0.002$) amongst formula-fed children.[7]

It is unknown what social factors drive parental decisions to use homemade foods or CCF to feed their infants. A qualitative study of mother's experiences in England found that maternal decisions to use CCF was reportedly influenced by parity, previous experience with complementary feeding, and education.[8] In that study, CCF was considered by the majority of mothers to be convenient and was perceived as either superior or safer than homemade foods by some.[8] In the CHOP trial, we also found parental education was associated with CCF use, as well as maternal employment and maternal smoking.[7] Additionally, formula-feeding was significantly associated with CCF use and the quantity of CCF fed per day.[7] Use of CCF was also associated with factors related to the infants themselves, including infant gender and infant age.[7]

Evaluation of CCF fed to infants in the CHOP trial revealed that in all countries, pastas and cereals were the most commonly fed types of CCF, followed by pureed fruits. Commercial cereals contributed over 90% of the total average calories from grains between 6 and 9 months of age, and commercial fruit-based CCF contributed over 65% of the total average calories from fruit over the first year of life.[7]

Sweetened CCF contributed substantially to diets over two years of life. Formula-fed infants, and infants living in Spain, Italy or Poland were significantly more likely to be fed sweetened CCF.[7] Almost all infants and children fed CCF at 9 and 12 months of age (95%) were fed at least one sweetened CCF product.[9] Based on these findings, a second study was designed to evaluate the most commonly consumed type of CCF, commercial cereals, to determine their nutritional adequacy.

<u>Nutritional quality of commercial baby cereals</u>

There has been increased attention from the World Health Organization (WHO) Regional Office for Europe on the poor nutritional quality of CCF in European countries.[10,11] In 2020, the WHO Regional Office for Europe evaluated 2,634 CCF products from ten European countries including the United Kingdom, Denmark, Spain, Italy, Malta, Hungary, Norway, Portugal, Estonia and Slovenia.[12] Results showed that a third of energy from CCF came from total sugar, and that the use of added sugars (most commonly, fruit juice concentrates) was widespread.[12] In the United States, studies have found both high levels of sugar and sodium in foods marketed for infants and toddlers.[13,14]

Excessive sugar in baby foods are concerning since diets high in sugar increase the risk for overweight and obesity and dental caries, replace more nutrient-dense foods in the diet and may decrease dietary diversity.[15] In terms of longer term health effects, the consumption of diets high in sugar increases the risk of type 2 diabetes mellitus, cardiovascular disease and has other untoward metabolic health effects.[15]

Based on knowledge gained from the complementary feeding data collected during the CHOP trial that commercial grain products (pastas, cereals) were the most commonly fed CCF and were the first foods used in Italy and Spain,[7] we aimed to analyze the nutritional composition of commercial cereals to determine their nutritional quality. The second paper of this cumulative dissertation, "Nutritional adequacy of commercial complementary cereals in Germany" summarizes the nutrient composition of 164 commercial complementary cereal products in a comprehensive national survey of commercial cereal products in Germany.[9] Results of the survey demonstrated that approximately a quarter of all energy in baby cereals are from sugar and one third of German baby cereals contain added sugars (sucrose, glucose, honey, and fruit juice concentrates, etc).[9] These results coincide with a study published from the DONALD cohort that reported added sugars in commercial cereals containing fruit.[16]

In addition to the problem of added and total sugars in CCF, there is a general concern of the predominately sweet taste of CCF products in Europe, through the use of fruits and sweet vegetable ingredients.[17] The use of fruit ingredients to make CCF sweeter, is concerning since exposure to sweet foods during infancy has been shown to promote infants' innate preference for sweet taste[15] and may be linked with poor eating habits and lower fruit and vegetables intakes in childhood.[4] In a study from the United Kingdom that evaluated the types of fruits and vegetables used in 329 CCF products listing a fruit or vegetables in the product name, authors reported predominantly fruits and relatively sweet vegetables.[17] In our study of commercial cereals in Germany, we report that one-third of the cereal products surveyed contained fruit ingredients, with banana being the most commonly used ingredient.[9]

Nutritional composition of CCF may vary depending on the type of food packaging.[18] In 2019, an evaluation of 703 CCF products from the United States, showed that 397 (56%) of CCF were baby food pouches.[18] Authors reported that baby food pouches in fruit and vegetable categories were more likely to contain added sugars.[18] In Europe, the nutritional composition of baby food pouches has been criticized for the high proportion of energy from simple sugars[19] and the use of added sugars.[20] For this and other reasons, in 2019, the Deutsche Gesellschaft für Kinder und Jugendmedizin (DGKJ) released a position statement discouraging the regular use of baby food pouches.[21] In our study of commercial cereals, we found that all ready-to-eat cereal porridges in jars and pouches contained added sugars.

Baby cereals are considered to be a primary source of non-heme iron for infants.[22] However, amongst all evaluated baby cereals in Germany, few cereal products contained the key micronutrients zinc (n = 23, 14%), iron (n = 43, 26%) or iodine (n = 43, 26%).[9] In addition, none of the ready-to-eat cereals (n=33) contained iron, zinc, or iodine in appreciable amounts (defined as at least equal to 15% of daily reference values).[9] Our results coincide with a study of the mineral content of 35 CCF of various types from Spain, which reported that adequate intakes (AI) and estimated average requirements (EAR) for iron and zinc were very low (5-20%, 10-60%, respectively).[23] An evaluation of CCF compared to homemade meals in the DONALD cohort revealed that the iron content was higher in homemade meals compared to commercial composite foods and commercial cereal meals containing fruit.[16] Reports of a low average levels of micronutrients in CCF are concerning since as the results of the CHOP trial demonstrated,[7] CCF make up a significant proportion of dietary energy during the first years of life. Improvements to the nutrient composition of baby cereals are warranted in Germany and other European countries where cereals do not provide at least 15% of the daily reference values for key micronutrients and products contain substantial energy from sugar, including added sugars.

3. Summary

Background

Infants and young children require highly nutrient-dense complementary foods to meet their nutritional needs and developmental potential. It is unknown to what extent commercial complementary foods (CCF) contribute to the dietary intakes of infants and young children in Europe. Commercial cereals are one type of CCF commonly fed as a first complementary food and are important sources of non-heme iron in infancy.[22]

The objectives of this doctoral thesis are to 1) describe the contribution of CCF to the dietary intakes of European infants and children 2) describe socioeconomic factors of children fed CCF and 3) evaluate the nutritional adequacy of commercial complementary cereals in Germany.

Methods

For the first study, complementary feeding data from 3-day dietary records of 1088 infants enrolled in the EU CHOP trial (8378 weighed food protocols between 4 and 24 months of age) was evaluated to determine the overall contribution of CCF to daily dietary intakes and related socioeconomic factors of children fed CCF.[7]

For the second study, a cross-sectional national survey of commercial cereal manufacturer and distributor websites was conducted in 2019.[9] Ingredient and nutrient information of 164 products from 15 baby food brands in Germany were used to determine the levels of key micronutrients (iron, zinc and iodine), sugar and salt contents.

Results

In the CHOP cohort, CCF contributed over 75% of calories from complementary foods in early infancy (4-6 months), over 50% calories in late infancy (7 - 9 months) and around 40% of calories at 12 months in Germany, Italy, Poland and Spain.[7] Daily energy intakes from CCF during infancy (4–9 months) was significantly higher ($p \leq 0.002$) amongst formula-fed children.[7] At two years of age, 68% of the cohort were still fed at least one type of CCF.[7] Infant gender, country, age and formula-feeding, parental education, maternal employment and smoking were significantly associated with CCF use and quantity of CCF fed.[7] Families with middle- and high-levels of education fed significantly less quantities of CCF compared to families with lower education. Compared to all other ages; 9-month-old infants were fed the most CCF per day. Commercial grain products (pastas, cereals) were the most commonly reported CCF and were first foods in Italy and Spain.

Sweetened CCF played a substantial role in dietary intakes over the first two years of life. Formula-fed infants ($p \leq 0.009$), and those living in Spain, Italy or Poland were significantly more likely to be fed sweetened CCF. Over 95% of the cohort reporting CCF, consumed at least one sweetened CCF at 9 and 12 months of age.

For the second study, results of the cross-sectional national survey of commercial cereal manufacturer and distributor websites revealed that few German commercial cereals products contained zinc ($n = 23$, 14%), iron ($n = 43$, 26%) or iodine ($n = 43$, 26%).[9] Cereals had on average 14 ± 15g of total sugar (on average, 25% total energy), and one third of products contained added sugars.[9]

Conclusion

In the EU CHOP trial, CCF contributed substantially to dietary intakes. Policy makers who regulate the nutrient composition for CCF should take the substantial contribution of CCF to dietary energy into account. Parental choice to use CCF and sweetened CCF may be dependent on certain socioeconomic factors and formula-feeding.[7]

A large proportion of the CHOP cohort were fed sweetened CCF. Socioeconomic characteristics identified in this study can be useful for identifying groups at higher risk for using sweetened CCF. Further research is necessary to understand the cause for the geographic differences identified in sweetened CCF consumption between countries. Given the considerable intake of sweetened CCF in our cohort, more studies on the potential reasons for food choices are needed.

Due to the evidence of the lack of micronutrients and the presence of added sugars in commercial complementary cereals in Germany, manufacturers should aim to improve the nutritional composition of CCF products. More studies are warranted on the nutritional quality of commercial cereals in other European countries, to compare to our findings from Germany.

Given the recent reports from the WHO European office concerning high levels of sugar in European CCF,[10-12] policy makers should consider strengthening legislation around the total energy from sugar allowed and the addition of sugars to commercial baby foods. More studies are needed on the relationship between the consumption of CCF, and sweetened CCF, on child health outcomes.

4. Zusammenfassung

Hintergrund

Säuglinge und Kleinkinder benötigen stark nährstoffreiche Beikost um ihren Ernährungsbedürfnissen und ihrem Entwicklungspotential gerecht zu werden. In welchem Umfang kommerzielle Beikost (CCF) zur Nahrungsaufnahme von Säuglingen und Kleinkindern in Europa beitragen ist nicht bekannt. Kommerzielle Cerealien sind eine Art von Beikost, die üblicherweise als erste Beikost eingeführt wird und im Säuglingsalter eine wichtige Quelle für Nicht-Häm-Eisen darstellt.[22]

Ziel dieser Doktorarbeit ist es, 1) den Beitrag von CCF zur Nahrungsaufnahme europäischer Säuglinge und Kinder zu beschreiben, 2) sozioökonomische Faktoren von mit CCF gefütterten Kindern zu beschreiben und 3) die ernährungsphysiologische Angemessenheit kommerzieller Beikost-Cerealien in Deutschland zu bewerten.

Methoden

Für die erste Studie wurden Beikost Fütterungsdaten aus 3-Tages-Ernährungsprotokollen von 1088 Säuglingen aus der EU-CHOP-Studie (8378 Wiegeprotokolle zwischen 4 und 24 Monaten) ausgewertet, um den Gesamtbeitrag von CCF zur täglichen Nahrungsaufnahme und damit verbundene sozioökonomische Faktoren zu bestimmen. [7]

Für die zweite Studie wurde 2019 eine nationale Querschnittserhebung auf Websites kommerzieller Beikosthersteller und -händler durchgeführt.[9] Zur Bestimmung wichtiger Mikronährstoff- (Eisen, Zink und Jod), Zucker- und Salzgehalte wurden Inhaltsstoff- und Nährstoffinformationen von 164 Produkten von 15 Babynahrungsmarken in Deutschland verwendet.

Ergebnisse

In der CHOP-Kohorte trug CCF im frühen Säuglingsalter (4-6 Monate) über 75% der Kalorien aus Beikost bei, im späten Säuglingsalter (7 - 9 Monate) über 50% der Kalorien und nach 12 Monaten rund 40% der Kalorien in Deutschland, Italien, Polen und Spanien.[7] Die tägliche Energiezufuhr von CCF im Säuglingsalter (4–9 Monate) war bei Kindern, die mit Säuglingsnahrung gefüttert wurden, signifikant höher ($p \leq 0{,}002$).[7] Im Alter von zwei Jahren wurden 68% der Kohorte noch mit mindestens einer Art von CCF gefüttert.[7] Das Säuglingsgeschlecht, Land, Alter und Säuglingsnahrungsfütterung, Erziehung der Eltern, Beschäftigung der Mütter und Rauchen waren signifikant mit dem CCF-Gebrauch und der Menge an gefüttertem CCF assoziiert.[7] Familien mit mittlerem und hohem Bildungsniveau fütterten signifikant weniger CCF im Vergleich zu Familien mit niedrigerer Bildung. Im Vergleich zu allen anderen Altersgruppen erhielten 9-Monate alte Säuglinge das meiste CCF pro Tag. Kommerzielle Getreideprodukte (Nudeln, Cerealien) waren die am häufigsten gefütterten CCF und waren die zuerst eingeführte Beikost in Italien und Spanien.

Gesüßtes CCF spielte in den ersten zwei Lebensjahren eine substantielle Rolle bei der Nahrungsaufnahme. Säuglinge, die mit Säuglingsnahrung gefüttert wurden ($p \leq 0{,}009$) und solche die in Spanien, Italien oder Polen lebten erhielten signifikant häufiger gesüßtes CCF. Über 95% der Kohorte, die überhaupt CCF gefüttert bekamen, konsumierten im Alter von 9 und 12 Monaten mindestens ein gesüßtes CCF.

Für die zweite Studie ergaben die Ergebnisse der nationalen Querschnittserhebung auf Websites kommerzieller Beikosthersteller und -händler, dass nur wenige deutsche kommerzielle Cerealien-Produkte Zink (n = 23, 14%), Eisen (n = 43, 26%) oder Jod (n = 43, 26%) enthielten.[9] Die Cerealien hatten durchschnittlich 14 ± 15 g Gesamtzucker (durchschnittlich 25% Gesamtenergie) und ein Drittel der Produkte enthielt zugesetzten Zucker.[9]

Schlussfolgerungen

In der EU-CHOP-Studie trug CCF substantiell zur Nahrungsaufnahme bei. Politische Entscheidungsträger, die die Nährstoffzusammensetzung für CCF regulieren, sollten den substantiellen Beitrag von CCF zur Nahrungsenergie berücksichtigen. Die Entscheidung der Eltern, CCF und gesüßtes CCF zu verwenden, kann von bestimmten sozioökonomischen Faktoren und der Fütterung von Säuglingsnahrung abhängen.[7]

Ein großer Teil der CHOP-Kohorte wurde mit gesüßtem CCF gefüttert. Die in dieser Studie identifizierten sozioökonomischen Merkmale können nützlich sein, um Gruppen mit einem höheren Risiko für die Verwendung von gesüßtem CCF zu identifizieren. Weitere Untersuchungen sind erforderlich, um die Ursache für die geografischen Unterschiede zu verstehen, die beim Gebrauch von gesüßtem CCF zwischen den Ländern festgestellt wurden. Angesichts der beträchtlichen Aufnahme von gesüßtem CCF in unserer Kohorte sind weitere Studien zu den Gründen für die individuelle Auswahl von Lebensmitteln erforderlich.

Aufgrund des Mangels an Mikronährstoffen und des Vorhandenseins von zugesetzten Zuckern in kommerziellen Cerealien in Deutschland, sollten die Hersteller versuchen, die Nährstoffzusammensetzung von CCF-Produkten zu verbessern. Weitere Studien zur Ernährungsqualität von kommerziellen Cerealien in anderen europäischen Ländern sind erforderlich, um sie mit unseren Ergebnissen aus Deutschland zu vergleichen.

Angesichts der jüngsten Berichte des Europäischen Büros der WHO über einen hohen Zuckergehalt in europäischen CCFs [10-12] sollten politische Entscheidungsträger erwägen, die Gesetzgebung in Bezug auf die zulässige Gesamtenergie aus Zucker und die Zugabe von Zucker zu kommerziellen Babynahrungsmitteln zu verschärfen. Weitere Studien zum Zusammenhang zwischen der Fütterung von CCF sowie gesüßtem CCF und der späteren Kindergesundheit sind erforderlich.

5. Publication I

Theurich MA, Zaragoza-Jordana M, Luque V, et al. Commercial complementary food use amongst European infants and children: results from the EU Childhood Obesity Project. *Eur J Nutr*. 2020;59(4):1679-1692. doi:10.1007/s00394-019-02023-3

(full article begins on the following page)

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ORIGINAL CONTRIBUTION

Commercial complementary food use amongst European infants and children: results from the EU Childhood Obesity Project

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Abstract

Purpose The objective of this secondary analysis is to describe the types of commercial complementary foods (CCF) consumed by infants and young children enrolled in the European Childhood Obesity Project (CHOP), to describe the contribution of CCF to dietary energy intakes and to determine factors associated with CCF use over the first 2 years of life.

Methods The CHOP trial is a multicenter intervention trial in Germany, Belgium, Italy, Poland and Spain that tested the effect of varying levels of protein in infant formula on the risk for childhood obesity. Infants were recruited from October 2002 to June 2004. Dietary data on CCF use for this secondary analysis were taken from weighted, 3-day dietary records from 1088 infants at 9 time points over the first 2 years of life.

Results Reported energy intakes from CCF during infancy (4–9 months) was significantly higher ($p \leq 0.002$) amongst formula-fed children compared to breastfed children. Sweetened CCF intakes were significantly higher ($p \leq 0.009$) amongst formula-fed infants. Female infants were fed significantly less CCF and infant age was strongly associated with daily CCF intakes, peaking at 9 months of age. Infants from families with middle- and high-level of education were fed significantly less quantities of CCF compared to infants with parents with lower education. Sweetened CCF were very common in Spain, Italy and Poland, with over 95% of infants and children fed CCF at 9 and 12 months of age consuming at least one sweetened CCF. At 24 months of age, 68% of the CHOP cohort were still fed CCF.

Conclusions CCF comprised a substantial part of the diets of this cohort of European infants and young children. The proportion of infants being fed sweetened CCF is concerning. More studies on the quality of commercial complementary foods in Europe are warranted, including market surveys on the saturation of the Western European market with sweetened CCF products.

Keywords Complementary feeding · Commercial complementary foods · Sugar · Europe · Baby foods

Introduction

Reports from western European countries show that industrial baby foods contribute significantly to infant dietary intakes [1]. A global narrative review on the nutritional aspects of commercial complementary food (CCF) concluded that there is a deficit of studies comparing the nutritional adequacy of CCF compared to homemade complementary foods with almost no cohort studies, rendering it difficult to firmly conclude if CCF are nutritionally superior or inferior to homemade foods [2].

Recent studies from the United States have raised questions about the nutritional quality of CCF. Concerns include CCF with high levels of total sugar and sodium [3, 4] and a

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lack in variety of products offering single vegetable options [5]. Nevertheless, some studies have shown a higher variety of fruit and vegetable intakes amongst children consuming CCF [6], especially among low-income populations [7]. A study from the United Kingdom (UK) showed that CCF provided more vegetable variety per meal than home- cooked recipes and that home-cooked recipes provided 26% more energy and 44% more protein and total fat [8]. Reports from the UK have highlighted that CCF are substantially more expensive than homemade recipes [9]. There has been increasing concern about the high energy from sugar in certain CCF marketed in Europe [10, 11]. Yet few cohort studies have distinguished CCF from other complementary foods when examining dietary intakes of infants and young children living in Western Europe.

This paper examines dietary data in a large birth cohort to describe and characterize CCF intakes. Infants were recruited for the European Childhood Obesity Project (CHOP), a multicenter, randomized intervention trial in Germany, Belgium, Italy, Poland and Spain that tested the effect of varying levels of protein in infant formula on the risk for childhood obesity [12]. The objective of this second- ary analysis is to describe the types of CCF reported and their contribution to dietary energy intakes and to determine which factors are associated with CCF use over the first 2 years of life.

Methods

The CHOP trial was registered at ClinicalTrials.gov (NCT number: NCT00338689). From 2002 to 2004, 1678 healthy, singleton newborns from uncomplicated pregnancies were recruited between birth and 8 weeks of life. The study was originally planned as an intervention study looking at the effect of two types of infant formulae with differing protein content fed during the first year of life. Furthermore, an observational group of breastfed children (defined as only human milk for at least 3 months of life) was included. All children were followed until 2 years of age with on-site visits at 6, 12 and 24 months of age. Infant families were living in urban, European cities in Munich and Nuremburg, Germany, Liege and Brussels, Belgium, Milan, Italy, Warsaw, Poland, Tarragona and Reus, Spain. Sociodemographic characteristics of infant families have been previously published [13, 14].

Dietary data

Complementary feeding data were obtained using 3-day, weighed dietary records at monthly intervals from 4 to 9 months and again at 12, 18 and 24 months of age from 1088 children. Parents were instructed to record food intake on 2 weekdays and 1 weekend day and received a digital scale and detailed instructions on how to weigh and record foods. All available dietary records from infants with at least one full day of weighed dietary record were used in the analysis regardless of missing dietary protocols from other time points. No standardized dietary counseling or other intervention on complementary feeding was pro- vided to parents. All food protocols were checked by study nutritionists and if needed clarified with parents either by phone or during on-site visits.

To analyze the nutrient composition of foods, the *Bundeslebensmittelschlüssel* (BLS) or German Food Code and Nutrition Database from the Federal Institute for Risk Assessment was used. BLS was chosen because it fulfills criteria for accurate dietary assessment including regular updates and comprehensiveness and it uses a systematic classification of food items [15]. The originally used BLS II.3 was updated to BLS version 3.01 to obtain nutrient information.

When dietary data were collected, a large portion of foods could not be classified into the BLS framework since many local foods consumed Belgium, Italy, Poland and Spain are not consumed in Germany and are, therefore, not listed in the German national food composition data- base. Nutrient information from local foods was, there- fore, manually recorded from food labels, obtained directly from food companies, or was calculated using each country's respective national food database. Parents provided weighed ingredient information for homemade recipes.

For CCF, parents were instructed to record food label information and to attach food labels to dietary proto- cols. Currently, no CCF are included in food composition tables of the German national database. Therefore, a classification of CCF was created by study nutritionists and a standard operating procedure (SOP) manual was sent to nutritionists in all study centers for categorization. For the purposes of this study, industrial foods were clustered into six main groups according to a similar classification by the European Commission Directive [16]: (1) vegetable purees, (2) fruit purees, (3) cereals, (4) meat, (5) composite meals and (6) dairy.

- The 'vegetable purees' group includes CCF where the main ingredient is vegetables. Industrial composite foods called "vegetarian menus" were also included in this group. Some vegetable purees contained ingredients such as vegetable oils, grains, milk and cream.
- The 'fruit purees' group includes CCF where the main ingredient is fruit. These products include either one type of fruit or a blend of fruits. Some products also included small amounts of added yoghurt or grains (less than 5% of total weight).

- The 'cereals' group includes CCF where the main ingredient is whole grain or refined cereals, noodles or pasta requiring cooking. This group also includes dry rusks or powdered biscuits requiring reconstitution with liquids.
- The 'meat' group includes CCF where the main ingredient is meat. For simplicity all kinds of meat were grouped together including: beef, chicken, veal, lamb, pork, seafood, horse, rabbit and turkey or a combination of these. Where meat was listed as the only ingredient in the product name, it must constitute at least 40% by weight and where it's mentioned anywhere in the name of the product, it must constitute at least 25% by weight [16].
- The 'composite meals' group includes CCF composed mostly of pureed vegetables with some meat. According to EU regulations, where meat is mentioned first in the product title, it must constitute at least 10% by weight and at least 25% of total protein from all named protein sources [16]. Protein from named meat sources was not less than 4 g/100 kcal [16]. Where meat was mentioned in the product title, but not as the first name in the title, it must be at least 8% meat by weight, at least 25% of total protein of all named protein sources and at least 2.2 g/100 kcal from meat and 3 g/100 kcal from all protein sources [16]. For purposes of simplicity, all products with 8–12% meat by weight were included in this group.
- The 'dairy' group includes yoghurts, cheese and dairy desserts.

Where the ingredients list included added sugars, CCF were categorized as 'sweetened.' EU legislation regulates the amount of added sugars according to product type and added sugars must be printed on food labels [16]. For the purposes of this analysis, CCF with any sugars were dichotomously categorized as either sweetened or unsweetened. This categorization was made regardless of the quantity or type of sugars added. Ingredients such as sucrose, honey and fructose or glucose syrups listed on the ingredients lists on CCF food labels were used for this categorization.

For the purposes of this analysis on complementary foods, no liquids were considered to be CCF. Therefore, infant formula, and young child formulas ("toddler milks" or "growing-up milks"), animal milks or other milk-based beverages, juices, teas, and drinking water were excluded from the analysis.

Statistical analysis

Energy intake is displayed as means with standard deviation and medians with interquartile ranges. The standard deviation of the mean energy intake is larger in earlier months, when many infants have not yet begun complementary feeding. To test differences between breastfed and formula-fed infants in caloric intakes of complementary foods, CCF, and sweetened CCF, the Kruskal–Wallis test was used to accommodate the skewed distribution of intakes at early time points.

A special statistical model was needed to investigate socioeconomic variables associated with CCF intakes. A two-part model [17] was chosen as an approach to account for the mass of zeros, which was attributable to the large number of infants reporting no complementary food intakes at the beginning of the complementary feeding period. The first part of the two-part model was a logistic regression model (dichotomous, any CCF intake). Conditional on positive outcome, the second part of the model was a general linear regression model (GLM) with log link assuming a gamma distribution due to the positively skewed complementary feeding data. An optimal repeated measure model was not readily available for the type of data. To incorporate the intra-individual correlation of repeated measures over time, cluster-robust variance estimates were used. The model was adjusted for characteristics considered important for CCF use as listed in Table 1; only those with significant ($p < 0.05$) impact on CCF were kept in the model. As total energy intake was not available for most breastfed children, the GLM model was additionally adjusted for total CF intake. Marginal effects from the model required log retransformation. Data management and statistical analyses were carried out with the software package Stata version 15.1 (StataCorp LP, College Station, TX).

Ethics

The CHOP study was approved by ethics committees in all study centers and written informed consent was obtained from parents.

Results

Socioeconomic characteristics of infants and their families

Socioeconomic characteristics of the birth cohort are described in Table 1. About 70% of all children belonged to the intervention group and were formula-fed and 30% of children were in the breastfed group. Most children lived in Spain and Italy. Most families reported combined parental education as middle (n = 576, 52.1%) or high (N = 336; 30.5%). The majority of mothers reported being married (n = 821; 75.6%) and employed (n = 947; 91.9%). A substantial proportion of mothers reported ever smoking (n = 416; 38.3%).

Table 1 Socioeconomic characteristics of 1088 children with at least one valid food protocol between 4 and 24 months of life

Socioeconomic variable		*N* (%)
Infant characteristics		
All	Total	1088 (100)
Sex	Male	549 (50)
Milk feeding type	Formula-fed	773 (71)
	Breastfed	315 (29)
Country	Germany	206 (19)
	Belgium	39 (4)
	Italy	317 (29)
	Poland	207 (19)
	Spain	319 (29)
Birth order	1st child	629 (58)
	2nd child	352 (32)
	> 2nd child	103 (10)
Family characteristics		
Household members	2	15 (1)
	3	557 (51)
	4	339 (31)
	> 4	175 (16)
Single mother	Yes	54 (5)
Maternal pre-pregnancy BMI	< 20	191 (18)
	20–24	561 (54)
	25–29	206 (20)
	≥ 30	79 (8)
Parental education (ISCED)	No/low	189 (17)
	Middle	567 (52)
	High	336 (31)
Maternal age at birth	< 28	331 (30)
	28–32	401 (37)
	33–44	355 (33)
Maternal marital status	Married	821 (76)
Maternal employment status	Employed	947 (92)
Maternal smoking	Anytime	415 (38)

ISCED The International Standard Classification of Education

Food protocols

Complementary feeding data were obtained from 8378 food protocols, with 49517 food items between 4 and 24 months of life. 4607 different food products were used of which 1172 (25%) were commercial complementary foods. The number of food protocols at each time point, the mean energy from commercial complementary foods and the mean energy from all complementary foods is reported in Table 2. Figure 1 shows the percent of the cohort reporting at least one CCF item by food category, infant age (4, 6, 9 and 24 months) and country.

Types and quality of commercial complementary foods

There were 1172 different products of CCF reported from all 5 countries. Until 9 months of age, the proportion of infants consuming any CCF increased to almost 100% and decreased thereafter with a varying degree between countries (Fig. 1).
The proportion of children consuming any CCF was 68% at 24 months of age. The type of CCF products consumed at 24 months were mostly foods from the 'cereals' group including pasta, commercial complementary cereals, cookies and rusks, as well as other types of CCF products marketed specifically for the 2nd year of life.
Overall, commercial complementary cereals and pasta were the most commonly reported CCF, followed by industrial fruit and vegetable products. Lyophilized commercial infant meat products (Category 1, Fig. 1) were only reported in Italy. Composite meals with meat (Category 3, Fig. 1) were rarely reported in Italy, but were reported in all other countries. The way that CCF was introduced differed between countries. Whereas cereals were introduced earlier in Italy and Spain, vegetable and composite CCF were used earlier in Germany and Poland. Vegetable CCF were rarely used in Italy and Spain.

Dietary energy from commercial complementary foods

In all countries, a major portion of reported energy from complementary foods was from CCF. Over 75% of calories from all complementary foods in early infancy at 4 (23 kcal ± 54), 5 (76 kcal ± 83) and 6 (142 kcal ± 107) months of age were from CCF in Germany, Italy, Poland and Spain. In late infancy, over half of all calories from complementary foods at 7, 8 and 9 months of age were from CCF, dropping to around 40% of dietary energy at 12 months of age.

Dietary intakes from breastfed and formula-fed children

Figure 2 describes the median daily energy intakes from CCF and other complementary foods (including sweetened CCF) in breastfed and formula-fed children. Reported energy intakes from all complementary foods in formula- fed children were significantly higher ($p \leq 0.006$) over all time points during the first two years of life except at 9 ($p = 0.10$) and 12 months ($p = 0.39$) of age. Reported energy intakes from CCF during infancy (4–9 months) was significantly higher ($p \leq 0.002$) amongst formula-fed children compared to breastfed children. However, differences

Table 2 Reported number of protocols and energy (mean ± SD) from all commercial complementary food (CCF) and complementary food (CCF)

Country	Food	Age (months)								
		4	5	6	7	8	9	12	18	24
All	Protocols (*n*)	911	948	968	916	892	872	855	704	733
Energy (mean ± SD)										
	CCF(kcal)	23 ± 54	76 ± 83	142 ± 107	200 ± 121	229 ± 125	243 ± 123	235 ± 133	149 ± 124	115 ± 123
	CF (kcal)	30 ± 61	107 ± 104	215 ± 149	347 ± 177	413 ± 178	461 ± 179	594 ± 182	802 ± 211	881 ± 233
Germany	Protocols (*n*)	146	154	169	174	167	163	151	117	127
Energy (mean ± SD)										
	CCF(kcal)	16 ± 41	64 ± 85	128 ± 110	189 ± 124	234 ± 138	255 ± 141	208 ± 146	93 ± 1 29	39 ± 100
	CF (kcal)	21 ± 50	70 ± 92	150 ± 121	230 ± 141	300 ± 146	348 ± 140	499 ± 171	693 ± 182	783±208
Belgium	Protocols (*n*)	28	34	34	30	27	26	24	16	22
Energy (mean ± SD)										
	CCF (kcal)	47 ± 84	53 ± 76	92 ± 72	113 ± 62	135 ± 77	135 ± 92	195 ± 127	91 ± 74	110±113
	CF (kcal)	81 ± 67	143 ± 113	252 ± 98	337 ± 116	357 ± 89	414 ± 112	594 ± 197	718 ± 229	815±247
Italy	Protocols (*n*)	306	301	305	292	282	278	281	239	252
Energy (mean ± SD)										
	CCF(kcal)	16 ± 39	74 ± 78	173 ± 115	256 ± 117	277 ± 119	288 ± 115	286 ± 130	186 ± 123	147±115
	CF (kcal)	20 ± 48	107 ± 112	290 ± 172	463 ± 176	532 ± 169	572 ± 165	658 ± 161	793 ± 187	834±199
Poland	Protocols (*n*)	165	178	190	169	171	173	173	143	143
Energy (mean ± SD)										
	CCF(kcal)	24 ± 50	79 ± 72	109 ± 83	147 ± 83	176 ± 87	195 ± 105	190 ± 117	124 ± 119	114±152
	CF(kcal)	31 ± 56	103 ± 83	141 ± 92	223 ± 110	291 ± 130	352 ± 151	528 ± 178	857 ± 237	957±263
Spain	Protocols (*n*)	266	281	270	251	245	232	226	189	189
Energy (mean ± SD)										
CCF(kcal)		33 ± 70	86 ± 93	143 ± 103	188 ± 122	218 ± 123	230 ± 112	227 ± 121	162 ± 110	123±101
CF (kcal)		42 ± 77	123 ± 105	219 ± 129	377 ± 138	445 ± 137	494 ± 147	628 ± 175	845 ± 207	962±224

CCF commercial complementary foods (all), *CF* homemade and commercial foods for adults

between formula-fed and breastfed children were not significant during early childhood (12–24 months).

The use of sweetened CCF products in breastfed infants started later in infancy, around 7 months of age, compared to 6 months in formula-fed infants. Reported energy intakes from sweetened CCF products were significantly higher ($p \leq 0.009$) in the formula-fed group at all time points. At 18 and 24 months of age, all energy from CCF amongst formula-fed children was from sweetened CCF.

Energy from different categories of commercial foods

Compared to other types of CCF, commercial complementary cereals and dried pasta contributed the most calories during the beginning of the complementary feeding period. From 12 months of age, the CCF dairy group, including products such as yoghurt, cheese and dairy desserts contributed more calories than other categories. Table 3 shows the total dietary energy intakes (kcal/day) from different CCF categories at selected ages.

Factors associated with CCF use

Infant and familial socioeconomic factors associated with CCF use are described in Table 4. Compared to male infants, female infants had lower odds to report CCF intakes. Among CCF consumers, female infants were also fed significantly less quantities (− 18.61, CI − 26.6, − 10.6) of CCF compared to males.

There were differences in CCF consumption between countries. The odds of CCF use (OR 0.29, CI 0.2, 0.4) and daily amount of CCF consumed was significantly lower (− 14.5, CI − 27.1, − 2.0) in German infants compared to Spanish infants. The odds of CCF use were also significantly lower in Polish infants (0.63, CI 0.5, 0.8) who consumed significantly less than Spanish infants (− 23.5, CI − 35.6, − 11.4). While the odds of any CCF use amongst Italian infants were not higher than Spanish infants, Italian infants consumed significantly greater daily amounts of CCF than Spanish infants (28.9, CI 18.6, 39.2).

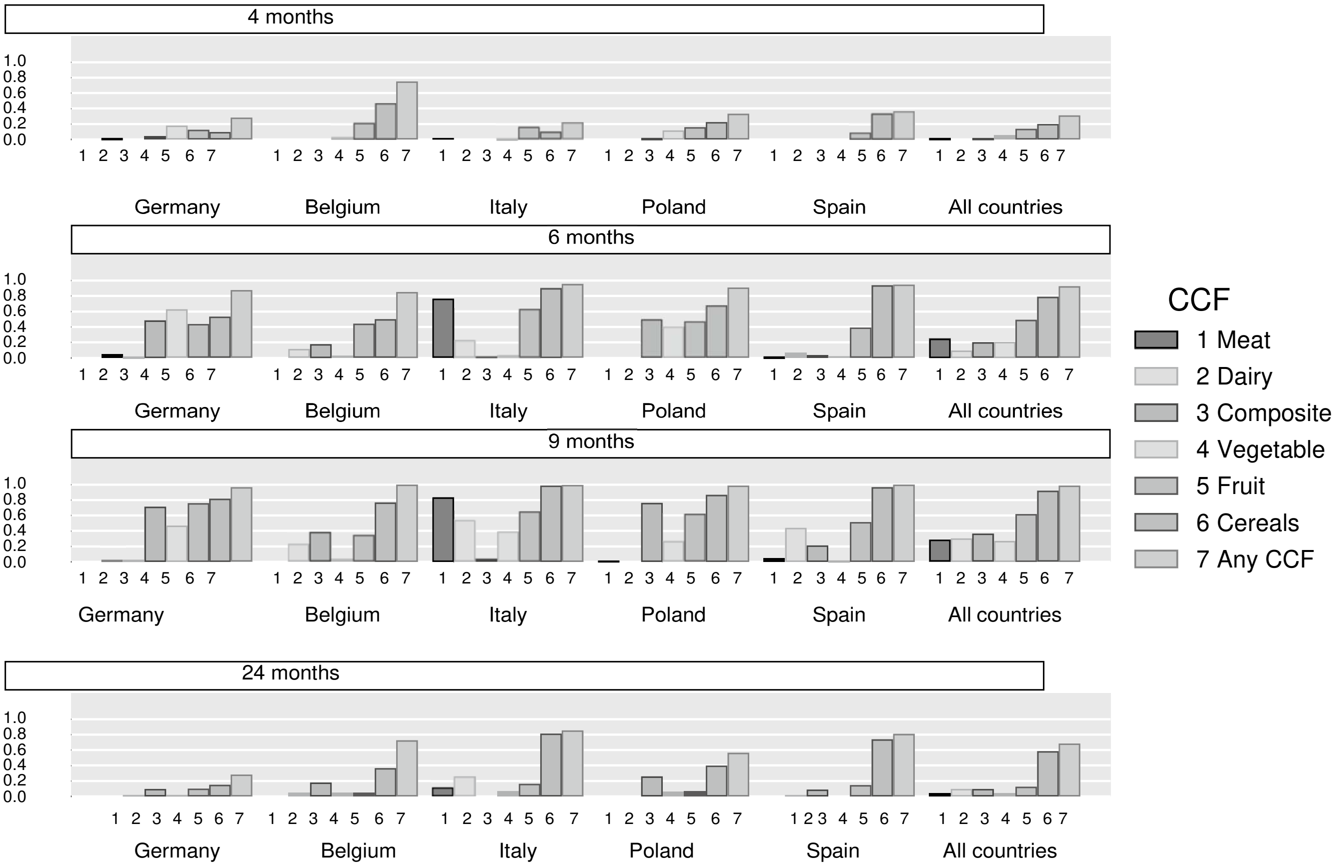

Fig. 1 Proportion of cohort reporting at least one commercial complementary food (CCF) by food category, infant age (4, 6, 9 and 24 months) and country

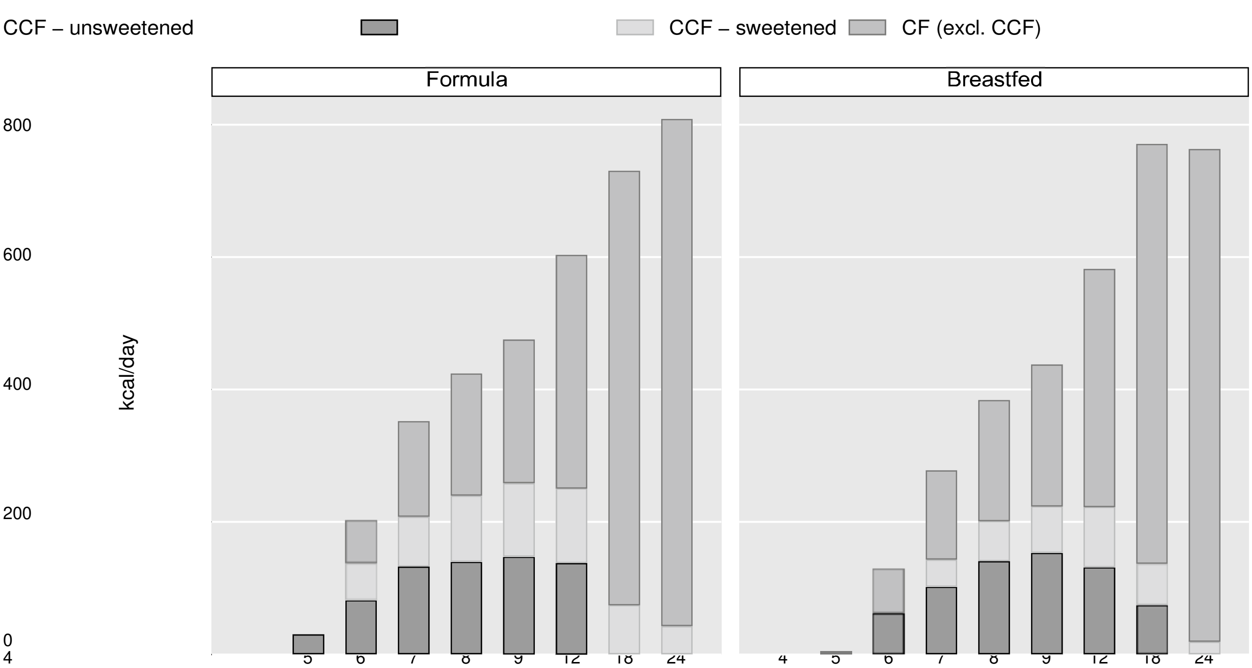

Fig. 2 Median daily energy intake (kcal) from commercial complementary foods (CCF) and complementary foods (CF) in formula-fed com- pared to breastfed children by age (months)

Table 3 Dietary energy intakes (kcal/day) by food category at selected ages

Age in months	6		8		9		12	
Number of protocols	968		892		872		855	
Category	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
CCF fruits	38 (50)	0 (0–64)	58 (60)	57 (0–96)	62 (62)	61 (0–101)	55 (65)	39 (0–96)
All fruit	57 (49)	56 (0–88)	85 (54)	78 (52–116)	90 (57)	85 (55–122)	92 (57)	86 (56–124)
CCF vegetables	12 (29)	0 (0–0)	18 (35)	0 (0–20)	19 (37)	0 (0–26)	15 (37)	0 (0–0)
All vegetables	21 (36)	0 (0–35)	43 (46)	34 (0–70)	46 (48)	40 (0–76)	50 (51)	36 (3–81)
CCF cereals	84 (79)	69 (25–126)	119 (81)	115 (58–171)	129 (82)	126 (73–177)	132 (94)	122 (63–193)
All cereals	85 (79)	70 (27–127)	126 (79)	120 (66–177)	142 (83)	137 (84–189)	179 (92)	171 (116–231)
CCF composite meals with meat	17 (36)	0 (0–0)	43 (64)	0 (0–91)	44 (69)	0 (0–98)	45 (69)	0 (0–100)
All meat	5 (18)	0 (0–22)	30 (45)	35 (0–66)	36 (47)	43 (0–69)	68 (60)	65 (36–98)
CCF dairy	7 (25)	0 (0–0)	27 (50)	0 (0–40)	28 (49)	0 (0–40)	31 (55)	0 (0–40)
All dairy	17 (37)	0 (0–17)	69 (80)	50 (0–124)	81 (83)	71 (0–130)	146 (108)	128 (68–202)

CCF commercial complementary food, *SD* standard deviation, *IQR* interquartile range

Infant age was strongly associated with CCF use, determining both the odds of CCF use and the quantities of CCF consumed. CCF intakes peaked at 9 months of age, with both younger and older infants reporting significantly less quantities of CCF compared to 9-month old infants.

Infants of mothers who were not employed were significantly less likely (OR 0.74, CI 0.5, 1.0) to report CCF. Infants with mothers who reported ever smoking were significantly more likely (OR 1.35, 95% CI 1.1, 1.6) to report CCF and were fed significantly more CCF (10.1 g/day, CI 1.1, 18.7).

Discussion

Overall CCF use in the CHOP cohort

Our findings demonstrate that CCF were used by the majority of infants and children in all countries over the first 2 years of life. These findings are consistent with the DONALD Study, which reported CCF use over the first 2 years of life in 366 German infants. Intakes were higher than home- made complementary food at 6, 9, 12, 18 and 24 months of age with 74, 98, 92, 57 and 31% of infants reporting CCF on dietary records, respectively [18]. In the CHOP cohort, German infants had higher calorie intakes from CCF than all other foods combined at 4, 5, 6, 7, 8 and 9 months of age, but CCF intakes were not higher than other foods after the first year.

Factors associated with CCF use

There were differences in general CCF use and daily intakes according to familial socioeconomic characteristics. Parental education, maternal employment and maternal smoking history were associated with total daily intakes of CCF. While the overall odds of CCF use was not predicted by parental education status, amongst infants that reported consuming CCF, daily intakes of CCF were significantly lower in infants with parents that had a middle- (*$p \leq 0.05$) or high- level (**$p \leq 0.005$), of education, compared to a low-level of education. These findings are similar to the DONALD Study which reported that infants with high intakes of CCF (≥ 62% median of dietary records with CCF) had mothers with lower educational status ($P = 0.01$), were introduced earlier to complementary foods and had shorter durations of breastfeeding compared with infants that reported lower CCF consumption. The associations found also coincide with results from the Avon Longitudinal Study of Parents and Children (ALSPAC) study. The ASLPAC study investigated sociodemographic characteristics and specific dietary patterns in infancy and showed that infants with higher scores on a CCF dietary pattern had mothers with younger maternal age, lower education and reported smoking in pregnancy [19].

Differences in complementary feeding in formula-fed and breastfed groups

There were differences in general CCF use according to primary milk feeding type (formula-feeding versus

Table 4 Factors associated with CCF use and total daily CCF intakes

Variable	Protocols with CCF, *n* (%)	Adj.[a] OR [95% CI] CCF use	Adj.[b] mean difference in CCF intakes (g) [95% CI]
Infant characteristics[c]			
Sex			
Female	3168 (81)	0.8 [0.7, 1.0]*	– 18.61 [– 26.6, – 10.6]***
Male	3223 (83)	–	–
Feeding			
Breastfed	1765 (82)	0.72 [0.6, 0.9]**	– 22.56 [– 31.7, – 13.5]***
Formula-fed	4626 (82)	–	–
Country			
Germany	1003 (73)	0.29 [0.2, 0.4]***	– 14.5 [– 27.1, – 2.0]***
Belgium	203 (84)	1.08 [0.5, 2.1]	– 40.0 [– 59.2, – 20.8]***
Italy	2126 (84)	0.96 [0.8, 1.2]	28.9 [18.6, 39.2]***
Poland	1234 (82)	0.63 [0.5,0.8]**	– 23.5 [– 35.6, – 11.4]***
Spain	1825 (85)	–	–
Age (months)			
4	282 (31)	0.0 [0.0, 0.0]***	−224.0 [−232.8, −215.3]***
5	675 (71)	0.0 [0.0, 0.0]***	−172.2 [−181.4, −163.1]***
6	898 (93)	0.15 [0.1, 0.3]***	−105.75 [−114.6, −96.6]***
7	898 (98)	0.61 [0.3, 1.1]	– 48.62 [– 56.8, – 40.4]***
8	876 (98)	0.63 [0.3, 1.1]	– 16.29 [– 23.6, – 9.0]***
9	862 (99)	–	–
12	831 (97)	0.41 [0.2, 0.8]**	– 8.50 [– 17.9, 0.9]
18	568 (81)	0.05 [0.0,0.1]***	– 93.80 [– 105.2, – 82.4]***
24	501 (68)	0.02 [0.0,0.0]***	−130.10 [−142.0, −118.2]***
Energy			
All solids	–	–	0.3 [0.3, 0.4]***
Family characteristics[d]			
Highest education			
No/low	1036 (83)	–	–
Middle	3403 (81)	0.84 [0.6, 1.1]	– 14.44 [– 26.8, – 2.1]*
High	1947 (82)	0.95 [0.7, 1.3]	– 19.74 [– 33.6, – 5.9]**
Maternal employment			
No	455 (82)	0.74 [0.5, 1.0]*	2.89 [– 13.5, 19.3]
Yes	5625 (82)	–	–
Smoking			
Yes	2432 (83)	1.35 [1.1, 1.6]**	10.11 [1.5, 18.7]*
No	3930 (81)	–	–

[a]Result of two-part model including a logit and GLM model, mutually adjusted for variables displayed in the table

[b]The mean difference is the marginal effect compared to baseline [c]Baseline: Spanish, male, formula-fed, 9-month-old infants [d]Baseline: low-education, maternal employment, non-smoker

$*p \leq 0.05$, $**p \leq 0.005$, $***p \leq 0.001$

breastfeeding). In the CHOP cohort, breastfed infants were significantly less likely to be fed CCF compared to formula-fed infants and were fed significantly less quantities of CCF. This coincides with the DONALD study which found that CCF were the predominant form of complementary foods amongst infants that were breastfed for shorter periods [20].

An earlier analysis of dietary intakes from the CHOP cohort demonstrated that complementary foods were generally introduced earlier in formula-fed infants (median 19 weeks, interquartile range 17–21) than in breastfed infants (median 21 weeks, interquartile range 19–24) [21]. Many formula-fed infants (37%) and breastfed infants (17%)

received solid foods at 4 months of age [21]. Low maternal age, low education and maternal smoking were associated with early introduction of solid foods at 3 and 4 months of age [21].

In this analysis, we report that formula-fed infants consumed generally more complementary foods, more CCF earlier in infancy, and more sweetened CCF products. Energy intakes from complementary foods in formula-fed children were significantly higher compared to breastfed infants at earlier time points, but were not significantly different at 9, 12, 18 or 24 months of age. It is known that formula-fed infants require slightly higher caloric intakes from complementary foods compared to breastfed children because of higher resting metabolic rates [22, 23]. There are some indications that the mode of milk feedings may play a role in later appetite regulation. For example, it has been shown that infants fed in early infancy with bottles containing either formula or breastmilk are more likely to empty their bottle or cup in late infancy than those directly breastfed [24]. Another study showed that infants who were directly breastfed had better appetite regulation in early childhood compared to those drinking breastmilk or formula from a bottle [25].

Dietary energy from CCF

In this cohort, CCF made up a significant portion of dietary energy intakes, contributing around half of the daily energy from all complementary foods at 7, 8 and 9 months of age. This finding is higher than that reported from France [1]. Ghisolfi et al. reported that CCF accounted for 7% of total energy intake at 4–5 months, 28% at 6–7 months, 27% at 8–11 months, 17% at 12–17 months, and 11% at 18-24 months in a cohort of French infants [1]. However, the estimation from Ghisolfi et al. excluded commercial complementary cereals, which was the most popularly consumed type of CCF in the CHOP cohort. Most infants reporting CCF intakes at 4 months of age reported consuming commercial complementary cereals (65%) or industrial fruit purees (43%). Over time, commercial complementary cereals were the most commonly reported type of CCF.

Sweetened CCF intakes

Sweetened CCF consumption in the CHOP cohort was common in all countries but was most popular in Italy, Poland and Spain. Over 95% of children consuming CCF in Spain at 9 and 12 months of age reported consuming sweetened CCF. These findings are consistent with several other studies reporting a high proportion of sweetened CCF in various European cohorts. In 2014, Garcia et al. published a nutritional evaluation of 479 CCF products on the market in the UK, and reported that 65% of them were sweet foods [26]. A later survey of CCF which had a fruit or vegetable mentioned in the product name found that fruit juice was added to 18% of CCF, which mainly consisted of fruits and relatively sweet vegetables such as carrot and sweet potato [27]. The number of children reporting consumption of sweetened CCF in the CHOP cohort is concerning and important with a view to the prevalence of childhood obesity in European countries. Spain has some of the highest childhood obesity rates in Europe, with approximately 1 in every 3 children who are overweight or obese at 2, 3 and 4 years of age [28, 29]. Reports from Italy have shown 13, 18 and 22% of children at 2, 3, and 4 years of age who are overweight or obese [28]. More research is needed to explore the relation- ship between sweetened CCF use and the risk for childhood obesity.

A study from Germany demonstrated that infants with high CCF consumption have higher total sugar intakes as well as higher odds for consuming sweetened foods during infancy [30]. Another showed that infants with high consumption of CCF have higher odds for total added sugar intake at pre-school and elementary-school ages [31]. In countries such as Spain where sweetened CCF intakes are consumed by the vast majority of the cohort, the data are suggestive that sweetened products are either very readily available or that there is not a sufficient selection of unsweetened CCF options. It is likely that differences in consumption of sweetened CCF products between the European countries could be explained by the varying types of CCF available on the market in respective countries. It, therefore, seems necessary to conduct market surveillance studies on CCF on the Western European market. In 2016, the World Health Organization (WHO) issued *Guidance on Ending the Inappropriate Promotion of Foods to Infants and Young Children*, which explicitly addresses marketing practices for CCF [32]. In an effort to curb the growing epidemic of obesity and noncommunicable diseases in childhood, the guidance discourages commercial promotion of CCF which are high in sugar or salt, low in micronutrients, or have portion sizes that encourage overeating [33]. It also discourages any promotion of CCF that would interrupt continued breastfeeding during the complementary feeding period [28]. These recommendations are important since it is known that CCF marketing affects parental belief systems as well as medical professionals' recommendations to parents [34].

Development of taste preferences in infancy

In Spain and Italy where the consumption of sweetened CCF was high, the consumption of vegetable-based CCF was simultaneously low. The complementary feeding period is a sensitive period of flavour shaping for the infant palate [35], therefore, infants and children should be exposed to a variety of foods rather than only sweet tasting foods. Some studies from Europe have highlighted the use of predominantly sweet-tasting vegetables such as carrot and sweet potato in CCF vegetable purees [27, 36]. Concerning the high use of CCF products with added sugar in the CHOP cohort, it is worth highlighting that feeding sweet CCF may negatively impact flavour learning and promote the development of non- healthy food preferences. It is known that infants have an innate preference for sweet and salty tastes, and typically reject foods which taste bitter [37, 38]. There is a sensitive period where repeated exposure to foods having a bitter or sour taste, may improve acceptance of fruits and vegetables in childhood [38–40]. Research shows that in addition to the exposure to food flavours through breastmilk, repeated expo- sure to a variety of different tasting foods during the complementary feeding period improves food acceptance [41]. Continuous exposure to sweet tasting foods in early life may, therefore, promote obesogenic food choices through hindering bitter and sour taste acceptance and hence the acceptance of healthy foods [38]. For these reasons, the 2017 ESPGHAN position statement on complementary feeding recommends timely introduction of a variety of food flavours, including bitter green vegetables, during this sensitive period [42].

Family foods and discretionary foods

In our analysis, not all children in the CHOP cohort transitioned to family foods in a timely manner, since CCF still comprised an average of 40% of dietary energy from all complementary foods at 12 months of age. In the 2nd year of life, CCF contributed 19% of dietary energy from complementary foods at 18 months of age and 13% at 2 years of age. These findings may reflect a general lack of guid- ance on when children should be fully transitioned to family foods. Guidance from the WHO states that by 12 months of age, young children should be transitioning to family foods [22, 43]. The 2017 ESPGHAN recommendations discour- age prolonged use of purees, and state that infants should be fed lumpy foods by 8–10 months of age at the latest, but do not state an age where children should be fully transitioned to family foods [42]. The earlier ESPGHAN position paper on complementary feeding from 2008 also did not specify an age for complete transition to family foods [44]. Earlier complementary feeding recommendations from Germany, however, specified that infants should transition to family foods "around the end of the first year of life." [45].

CCF are a type of convenience food which are meant to replace less-nutritious, discretionary foods in the diets of infants and young children. Intakes of discretionary foods were not evaluated in this analysis; however, findings demonstrate that many CCF with added sugars were consumed by the CHOP cohort. However, it is unclear if sweetened CCF is being used as an alternative to discretionary adult foods, or are in fact replacing more nutritious family foods. Globally, there is evidence that infants and young children are being given discretionary, nutrient-poor commercially produced snack foods at alarming rates [46–49]. The household availability of discretionary foods is also problematic within Europe, although rates vary greatly between countries [50]. There is currently little evidence on how to effectively increase the use of nutritious family foods while decreasing the use of less nutritious CCF and discretionary foods in the diets of infants and young children. Nevertheless, it seems necessary to better articulate in national and European guidance on complementary feeding that CCF with added sugars should be avoided.

Differences in complementary feeding between countries

There were considerable differences in the type of CCF used between countries. In terms of meat consumption, it has been reported that lyophilized (freeze-dried, powdered) meats are a common type of CCF consumed in Italy [34]. These meats are typically mixed with homemade foods and local ingredients [34]. The Italian CCF meat products reported in our cohort had up to 85% meat by weight. In all other countries, ready-to-eat 'menus' or 'meals,', which are a type of CCF containing a blend of vegetables, grains or other ingredients, with smaller percentages of meat by weight (8–12%) were used. In 2012, a study in Germany investigated the variety of vegetable-potato-meat or fish meals available on the baby food market. Results showed that there was a lack of CCF containing a variety of vegetables as well as fish [36]. The observation of low fish intakes in German infants has been confirmed by the same research group [51].

We hypothesize that differences in the types of CCF fed between specific countries could be due to a number of factors including product availability, sociocultural acceptance of specific types of CCF, marketing practices, national or regional policies regulating marketing, or regulations on the nutritional composition of CCF.

European and national recommendations for complementary feeding

Many European countries follow recommendations for complementary feeding issued by the European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) [42] and the European Food Safety Authority (EFSA) [52]. ESPGHAN issued a position paper on complementary feeding in 2017 which states that complementary foods should not be introduced before 4 months (16 weeks) but should not be delayed beyond 6 months (24 weeks) of age [42]. An earlier commentary from ESPGHAN from 2008 recommended that complementary foods not be introduced before 17 weeks and not later than 26 weeks of age [44]. The ESPGHAN commentary gives specific advice to avoid the addition of salt and sugar to homemade complementary foods, however, guidance does not state to avoid CCF with added sugar and salt [42]. Guidance from ESPGHAN regarding intake of free sugars state that sugars should be minimized with a desirable goal of < 5% dietary energy intake and that this level be even lower in infants and young children under 2 years of age [53]. In terms of addition of sugar and salt to complementary foods, earlier guidance stated that "offering complementary foods without added sugars and salt may be advisable not only for short-term health but also to set the infant's threshold for sweet and salty tastes at lower levels later in life." [44].

National recommendations for complementary feeding from the five countries participating in the EU CHOP trial are similar [21]. Current German national recommendations for complementary feeding are in agreement with the 2017 position paper published by ESPGHAN [42]. German complementary feeding recommendations have not substantially changed since complementary feeding data was collected in the CHOP cohort [21]. The national recommendation at the time of recruitment was to exclusively breastfeed for 4–6 months, introducing complementary foods between 5 and 7 months of age [21, 45]. In terms of recommendations on CCF, the recommendations issued by the *Netzwerk Gesund ins Leben,* a network of German national institutions, societies and associations working with young families, states that "only slightly sweet" CCF should be chosen, yet there is no specific recommendation to avoid CCF with added sugars or salt [54].

In Belgium, the *Kindengezin* issued recommendations for complementary feeding in 2012 and the *Office de la Naissance et de l'Enfance (ONE)* issued nutrition recommendations in 2016 [55, 56]. Earlier recommendations from ONE from 2009 were to not start with the introduction of complementary feeding before the age of 4 completed months [21, 57].

The national recommendation in Italy is to exclusively breastfeed for 6 months, with introduction of complementary foods and continued breastfeeding from 6 months of age [58]. Members of the Italian Society of Gastroenterol- ogy, Hepatology and Pediatric Nutrition (SIGENP) and the Italian Society of Allergology and Pediatric Immunology (SIAIP) Emilia Romagna published recommendations in 2015 stating to introduce complementary foods not before 4 months of age and not after 6 months of age [59]. These recommendations discourage the provision of sweet snacks and the addition of salt to complementary foods [59]. Earlier recommendations from the Italian Society of Neonatology from 2002 stated that term healthy babies can continue to breastfeed exclusively for 6 months, whereas introduction of complementary foods can be started at 4 or 5 months depending on individual maternal and infant circumstances [60].

Polish recommendations for complementary feeding also follow the position paper published by ESPGHAN [42]. In 2014, the Polish Society for Paediatric Gastroenterology, Hepatology and Nutrition published national complementary feeding recommendations [61], which have not changed significantly since the time the CHOP dietary data were collected. Recommendations issued in Poland from 2001 stated that complementary feeding should not start before 4 completed months of age [62, 63].

Spanish national recommendations for complementary feeding also follow the position paper published by ESPGHAN [42]. Earlier Spanish recommendations stated that complementary feeding should not start before 4 completed months of age and have not changed significantly since the time the CHOP dietary data were collected [21, 64].

Limitations

The findings of this study are a secondary analysis of dietary data from the European Childhood Obesity Project, a randomized intervention trial whose a priori hypothesis was that varying levels of protein in infant formula predict the risk for childhood obesity. Evaluation of CCF intakes and associated factors are exploratory in nature and not casual associations. The CHOP cohort is comprised of infants living in metropolitan areas in Germany, Belgium, Poland, Italy and Spain. Therefore, findings can only be generalized to European infants and young children with similar sociodemographic characteristics.

Since dietary data for this analysis was collected between 2002 and 2004, it is not clear if the types of the CCF described here accurately reflect CCF products on the market today. Little to no evidence is published on how trends in CCF use have changed over time in Western Europe, including whether or not there is an increasing or decreasing trend of sweetened CCF on the market. Data on energy-providing-liquids (EPL) were not evaluated since separate studies on EPL in the CHOP cohort have been previously published [65, 66].

In the Belgian cohort, a portion of the CCF data was entered into the nutritional composition database by study dietitians as recipe simulations, instead of direct data entry from food labels. Therefore, a portion of data entered were excluded from this analysis. Dietary analysis of the sub- sample of the Belgian cohort may, therefore, not accurately characterize CCF use.

Conclusions

In this Western European cohort, commercial complementary foods contributed a significant portion of dietary energy to the diets of infants and young children. European Commission directives on nutrient compositions for CCF should take the substantial contribution of CCF to the diets of European infants and young children into account.

Socioeconomic characteristics including infant gender, country of residence, infant age and formula-feeding were significantly associated with overall CCF use or the total daily intakes of CCF. Familial characteristics including parental education, maternal employment and maternal smoking history were also associated with total daily intakes of CCF.

The proportion of infants reporting sweetened CCF intakes is concerning since the complementary feeding period is a sensitive period of learning acceptance of new flavors and the establishment of healthy eating habits. Feeding sweetened CCF was most common in formula-fed infants and young children living in Spain, Italy and Poland. Further research is necessary to determine how marketing and availability of sweetened CCF products may influence geographic differences in sweetened CCF consumption within Europe. More research is warranted to determine the overall quality of CCF in Western Europe, including market surveys on the saturation of the market with sweetened CCF products. It seems necessary to better articulate in national and European guidance on complementary feeding that CCF with added sugars should be avoided.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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6. Publication II

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Nutritional Adequacy of Commercial Complementary Cereals in Germany

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Abstract: Commercial cereals are among the first complementary foods fed to infants in Germany and elsewhere. The purpose of this national survey is to describe the nutritional adequacy of commercial complementary cereals. A comprehensive, cross-sectional survey of cereal manufacturer websites (*n* = 15) was conducted from March to April 2019. Food labels were analyzed for iron, zinc, iodine, sodium, and sugar contents in commercial complementary cereals, and ingredient lists were evaluated for whole grains and added sugars. Preparation instructions were evaluated for the type of liquid recommended for reconstitution. Among 164 commercial complementary cereals, few contain iron (*n* = 43, 26%), zinc (*n* = 23, 14%) or iodine (*n* = 43, 26%). Sodium contents fall within EU thresholds. Most cereals were single grain, containing only wheat (*n* = 54), with half of the products (*n* = 86, 52%) containing whole grains. The average carbohydrate content of dry cereals is 69 g/100 g ± 9 g of which 14 ± 15 g is sugar. Preparation instructions for breakfast porridges and cereals recommend formula or toddler milk, while few recommend human milk (*n* = 13, 18%). Few commercial complementary cereals contain appreciable amounts (at least 15% of daily reference values) of zinc, iron, or iodine. A quarter of cereal carbohydrates are sugar and one-third of the products contain added sugars. Future directives should stipulate minimum micronutrient levels, strictly regulate sugar contents, and include human milk among preparation instructions.

Keywords: micronutrients; complementary feeding; complementary cereal; processed cereal based food; breakfast cereal; carbohydrates; sugar; Germany; Europe; infants and children

Introduction

Commercial complementary foods (CCF), also known as industrial baby foods, contribute a large proportion of the diets of infants and toddlers in high-income countries. A recent study from the WHO European Regional office [1] reports high intakes of CCF across European countries, which coincides with studies from Germany [2–4].

Data from 3274 children enrolled in the Feeding Infants and Toddlers Study (FITS) in the United States reported that 51% of infants aged four to five months, 75% of infants aged six to eight months, and 52% of infants aged nine to eleven months consume commercial complementary cereals, also known as processed cereal based food (PCBF) [5]. In Europe, an analysis of dietary intakes of 1088 infants and children enrolled in the EU Childhood Obesity Project (CHOP) demonstrated that the most commonly consumed CCF were commercial cereals [2]. In the CHOP cohort, the median (IQR) daily energy intake from commercial cereals at six months of age was 69 kcal (25 to 126) per day, peaking at 126 kcal (73 to 177) per day at nine months of age, comprising about a third of caloric energy from all complementary foods at both time points and making up almost 100% of grain intakes at 6 months of age [2]. Commercial cereals were also the most commonly reported type of CCF at 4 months of age, demonstrating that they are among the first complementary foods introduced in European infants. An earlier analysis, of 688 German infants enrolled in the DONALD Study, showed 418 different varieties of CCF and infant formula on dietary records, of which 8% were infant formula, 22% were dry cereal-based foods, and 70% were ready-to-eat baby foods [4].

Suboptimal micronutrient intakes and micronutrient deficiencies are common among infants and young children in European countries [6–8]. Iron deficiency is more prevalent in certain groups, such as infants and children born with a low birth weight [9]. Iron deficiency has been shown to affect around 14% of one- to two-year-old children in other high-income countries such as the United States [5]. Iron depletion (serum ferritin <12 ng/mL) has also been reported amongst 10-month-old German infants [10]. Dietary data from infants and children enrolled in the CHOP trial in five European countries, including Germany, showed that intakes of iron and iodine, along with various other micronutrients, were inadequate [11].

Fortified cereals are often the primary type of complementary food providing non-heme iron for infants between six and 12 months of age [5] and are an important source of key micronutrients such as iron, zinc, and iodine. Given the popularity of commercial cereals in German cohorts, accumulating international evidence of inappropriate commercial complementary foods [1,12] and evidence of inadequate micronutrient intakes in Europe, an evaluation is warranted of the nutritional adequacy of commercial complementary cereals on the market in Germany.

Only limited empirical data is available on the nutritional quality of commercial complementary cereals in European countries. This cross-sectional survey of commercial complementary cereals gives a detailed and comprehensive evaluation of products sold in Germany. The primary objective of this study is to describe the nutritional adequacy of German commercial complementary cereals. The main findings include that many commercial cereals in Germany are poor sources of iron, zinc, and iodine, have too much sugar, contain added sugars, and lack preparation instructions with human milk.

Materials and Methods

In this cross-sectional survey of commercial cereals, ingredient and nutrient information was recorded from manufacturer and distributor websites between March and April 2019. The following baby food brands (n = 15) that make up almost all commercial baby cereals in Germany were included in the survey: Alete, Alnatura, BabyDream, BabyLove, Bebivita, dmBio, Hipp, Holle, Humana, Kölln, Löwenzahn Organics, Milasan, Milupa, Nestlé, and Töpfer.

A Microsoft Excel template was created for recording nutrient information from websites, and the product information was manually entered. The template was used to record information directly from digital food labels by a qualified nutritionist. Nutrient information recorded included total energy, total carbohydrates, total sugar, sodium, salt, and selected micronutrients (iron, zinc, and iodine). For dry commercial complementary cereals, nutrient information per 100 g of powdered product was recorded. For ready-to-eat commercial complementary cereals, nutrient information per 100 g of the product was recorded.

Information on the recommended age for consumption, ingredients list, and preparation instructions were also recorded. A second qualified nutritionist double checked the recorded values against manufacturer websites for potential recording errors.

Nutrient facts labels were searched to determine the level of sodium in the cereals. If the labels only reported grams of salt but not sodium, the level of sodium was calculated by assuming there was 0.4 g of sodium in one gram of salt. Sodium values reported for 100 g of prepared cereal were used. For products that only reported sodium levels for 100 g of dry cereal (n = 33), the level of sodium was calculated for prepared cereal. This calculation was based on the manufacturer recommended preparation instructions and a reference value for sodium in whole milk (0.1 g of salt per 100 mL). For products with multiple variations of possible cereal porridge recipes (using infant formula or a mixture of whole milk and water or other combination), sodium values for a mixture of cow's milk (100 mL) and water (100 mL) were used (*Halbmilchbrei*). One manufacturer did not provide preparation instructions for three products. For these three products, a reference recipe was created using 25 g of cereal, 100 mL of cow's milk, and 100 mL of water, a portion size similar to other cereals.

Ingredient lists were used to determine if commercial complementary cereals had added sugars and to quantify the total amount of milk ingredients by weight. Ingredient lists were searched by a qualified nutritionist for added sugars. Product ingredients that included added sucrose, honey, added fructose, chocolate, fruit juice concentrates, or vegetable juice concentrate were classified as sweetened. A second nutritionist checked the ingredients lists for recording and categorization errors. Cereals which contained unconcentrated fruit juices, dried fruit (i.e., raisins), fruit powders (i.e., apple powder), fruit flakes (i.e., banana flakes), and fruit extracts (i.e., apple extract) were not classified as sweetened. Fruit ingredients from ingredients lists were flagged to determine the total number of cereals containing fruit ingredients.

Nutrient content of commercial complementary cereals in Germany are regulated under the European Commission Directive 2006/125/EC regarding processed cereal-based foods and baby foods for infants and young children, in which processed cereal-based foods are divided into four main categories, namely [13]:

1. Simple cereals which are, or have to be reconstituted, with milk or other appropriate nutritious liquids;
2. Cereals with an added high protein food which are, or have to be reconstituted, with water or other protein free liquid;
3. Pastas which are to be used after cooking in boiling water or other appropriate liquids;
4. Rusks and biscuits which are to be used either directly, or after pulverization, with the addition of water, milk, or other suitable liquids.

Products in Categories 1 and 2 were included in the survey. Dry pasta and rusks (biscuits and cookies) were not evaluated, as the purpose of this survey was to evaluate the nutritional adequacy of commercial cereal porridges commonly used as first complementary foods. Infant formulas with added grains advertised as a beverage (*Trinkbrei*, *Trinkmahlzeiten*, *Gute Nacht Fläschen*) were not evaluated.

According to the EU labeling laws, information on vitamins and minerals must be expressed as a percentage of the reference values per 100 g or 100 mL of the product as sold [13]. Where appropriate, micronutrient information is also given per specified quantity of the prepared product, as it is recommended for consumption. Micronutrient levels are only reported on food labels when they are present in appreciable amounts (defined as at least equal to 15% of daily reference values) [13].

Descriptive and inferential statistics, tables, and figures were generated using Microsoft Excel. Student's unpaired *t*-test was used to test differences between the mean caloric, carbohydrate, and sugar levels of sweetened and unsweetened cereals. The Chi-square test was used to test differences in the proportion of sweetened products by commercial cereal categories (grain porridges, milk porridges, and breakfast cereals).

Results

Nutrition and ingredient information was collected from 164 commercial cereal products from 15 brands. The following brands and number of respective cereal products, were included: Alete (n = 12), Alnatura (n = 14), BabyDream (n = 13), BabyLove (n = 5), Bebivita (n = 11), dmBio (n = 10), Hipp (n = 27), Holle (n = 13), Humana (n = 7), Kölln (n = 3), Löwenzahn Organics (n = 4), Milasan (n = 3), Milupa (n = 23), Nestlé (n = 6), and Töpfer (n = 12).

3.1. Grain Types

The majority of commercial complementary cereals (n = 108, 66%) contained one type of the following grains: millet, corn, spelt, oats, rice, or wheat. One-third of the products (n = 56, 34%) contained two or more types of grains. Among the products containing a mixture of grains, the predominate type of grain by weight was wheat or oats. Half of the commercial complementary cereals evaluated (*n* = 86, 52%) contained at least one type of whole grain flakes or whole grain cereal flours. Figure 1 shows the number and percentage of complementary cereals by grain type.

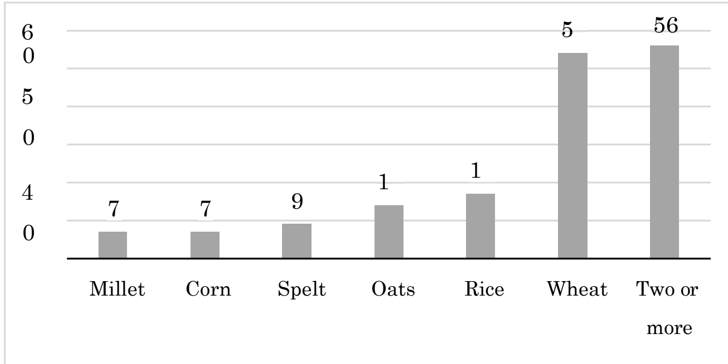

Figure 1. Number of commercial complementary cereal products by grain type.

The majority of cereals (*n* = 121, 74%) are labeled with advice to be fed from five (*n* = 61, 37%) or six months of age (*n* = 60, 37%) onwards. The remaining complementary cereals are advertised from seven (*n* = 1), eight (*n* = 15, 9%), 10 (*n* = 9, 5%), 12 (*n* = 18, 11%), or 15 months of age (*n* = 1) onwards.

3.2. *Categories of Commercial Cereals*

There were three main product categories: (1) milk porridges (*Milchbrei*), (2) grain porridges (*Getreidebrei*), and (3) breakfast cereals and porridges (*Kinder-Müsli, Kinderporridge*). There were two main types of cereals. The two types of cereals were a) dry commercial complementary cereals requiring reconstitution with liquids (*n* = 132, 80%) and b) ready-to-eat products sold in baby food jars, tubs or pouches (*n* = 33, 20%).

Milk porridges are cereal porridges with milk ingredients which are often advertised as "evening porridges" (*Abendbrei*) or "goodnight-porridges" (*Gute Nacht Brei*). Infant formula, as well as skimmed and whole animal milk powders comprise a large range of the product weight in milk porridges. Some products included percent weight of follow-on infant formula as a single ingredient in the ingredients list while other products listed individual ingredients found in formula (skimmed milk powder, plant oils, vitamins, etc.). Amongst the dry milk porridges that listed follow-on infant formula as an ingredient (*n* = 24), the percent weight for follow-on formula was on average 34% ± 10% of product weight. Among the dry milk porridges with several listed ingredients (*n* = 36), skimmed milk powder comprised an average of 18% ± 6% of product weight. In addition, some milk porridges contained whey powder (*n* = 46). Among the ready-to-eat milk porridges listing skimmed (*n* = 13) or whole milk (*n* = 20) as ingredients, milk comprised an average of 68% ± 22% and 54% ± 22% of product weight, respectively.

Grain porridges are commercial complementary cereals without animal milk components. These porridges sometimes contain fruit (*Getreide-Obst Brei*). Products in this category are marketed for infants starting from 5 months of age onwards.

Breakfast cereals and porridges for young children (*Kindermüsli, Kinderporridge, Juniormüsli*) do not contain animal milk components but can contain dried fruit. Products in this category are marketed for infants and young children 10 months of age and older.

One-third of all commercial cereals contained fruit (not including products containing only fruit juice). Banana was by far the most popular type of fruit ingredient (43 of 47 fruit-containing cereals, 91%), in the form of banana puree, banana flakes, or banana powder. Fruit was an ingredient across all three product categories.

3.3. *Preparation Instructions*

Due to the inclusion of dry milk ingredients, preparation instructions for dry milk porridges require reconstitution with water only. Instructions for dry grain porridges include reconstitution with various other types of liquids, including a mixture of 50% whole cow's milk (3.5%–3.8% fat) and 50% water (*Halbmilchbrei*), infant formula, follow-on formula, or human milk. Some manufacturers give "dairy-free" preparation instructions which include reconstitution with a combination of water, fruit puree, and vegetable oils. Of all dry grain porridges, only two manufacturers give instructions for reconstitution of dry cereals with human milk for breastfed infants (*n* = 13, 24%), whereas most give instructions for reconstitution with infant formula or toddler milk (infant formula marketed for young children) (*n* = 35, 65%).

Breakfast cereals and porridges are recommended by manufacturers to be prepared with various milk products. Preparation instructions for breakfast cereals included instructions for reconstitution with whole cow's milk (*n* = 4, 24%). Ten products (*n* = 10, 59%) recommended preparation with toddler milk. Three brands recommending preparation of cereals with formula for young children promoted their own formula brand. Breakfast cereals marketed from 10 months of age onwards (*n* = 3) included instructions for reconstitution with infant formula, cow's milk, or a "dairy-free" preparation with pureed fruit and vegetable oils. There were no breakfast cereals marketed from 10, 12 or 15 months of age that included preparation instructions with human milk.

3.4. *Key Micronutrients*

Micronutrient contents of commercial complementary cereals vary by whether cereal products were dry or ready-to-eat. According to food labels, none of the ready-to-eat products contain iron, zinc, or iodine in appreciable amounts, defined as at least equal to 15% of daily reference values.

Less than one-third of all commercial complementary cereals surveyed report the iron content on their nutrient labels (see Table 1). Most products containing iron are recommended for infants starting from five or six months of age onwards. The majority of cereals that report iron on the food label are fortified with ferric diphosphate (ferric pyrophosphate) (*n* = 35), ferrous sulfate (*n* = six), or ferrous fumarate (*n* = one).

Few cereal products surveyed report zinc on nutrient labels (see Table 1). The majority of products containing zinc are recommended for infants from five or six months of age onwards. All commercial complementary cereals containing zinc were fortified with zinc sulfate (*n* = 10) or zinc gluconate (*n* = 4). One-third of the products surveyed reported iodine on nutrient labels (see Table 1). Most products containing iodine were recommended for infants starting from five or six months of age onwards. Products containing iodine were fortified with potassium iodide (*n* = 18, 42%) or potassium iodate (*n* = 21, 48%). Three commercial cereals reported iodine on nutrient labels but did not list the source of iodine. These cereals reported follow-on formula in the ingredients list, a dietary source of iodine, according to the EU regulations which mandate between 10–50 μg iodine/100 kcal of formula. The iodine content from one cereal product, which was not fortified and did not contain follow-on formula, could not be verified by the ingredients label.

Table 1. Mean and median iron, zinc, and iodine contents of commercial complementary cereals as reported on food labels [a].

Age	Products	Iron			Zinc			Iodine		
month	*n* (%)	*n*	mean [f] (SD) [b]	median [g] (Q1, Q3) [b]	*n*	mean [f] (SD) [c]	median [g] (Q1, Q3) [c]	*n*	mean [f] (SD) [d]	median [g] (Q1, Q3) [d]
5	61 (37)	13	5.5 (2.5)	6.5 (3.5, 7.3)	8	3.6 (1.2)	3.4 (2.7, 4.0)	13	68 (24)	62 (50, 70)
6	59 (36)	24	4.9 (2.3)	4.6 (0.1, 8.5)	11	3.1 (1.0)	2.8 (2.6, 3.0)	23	70 (27)	57 (50, 104)
7	1 (0)	1	0	0	1	0	0	1	0	0
8	15 (9)	7	5.5 (1.9)	5.3 (4.2, 7.3)	2	2.6 (0.2)	2.6 (2.4, 2.6)	7	76 (40)	65 (54, 110)
10	9 (5)	1	0	0	0	0	0	1	0	0
12	18 (11)	1	0	0	1	0	0	1	0	0
15	1 (0)	0	0	0	0	0	0	0	0	0
Total	164 (100)	47	5.4 (2.3)	5.3 (3.5, 7.3)	23	3.2 (1.0)	2.8 (2.6, 3.4)	46	70 (28)	59 (50, 104)

[a] includes intrinsic and added iron, zinc, and iodine; [b] mg iron per 100 g dry product; [c] mg zinc per 100 g dry product [d] μg iodine per 100 g dry product; [f] mean of products reporting iron, zinc, or iodine on the food label; [g] median of products reporting iron, zinc, or iodine on the food label.

3.5. *Sodium*

The average sodium content of all dry commercial complementary cereals, when reconstituted as instructed by the manufacturer, was 27 ± 7.0 mg/100 kcal. The sodium content of ready-to-eat cereals was 39 ± 11 mg/100 kcal.

3.6. *Carbohydrates and Sugars*

The average carbohydrate content of dry commercial cereals was 69 ± 9 g/100 g, with 14 ± 15 g from total sugar. Most sweetened cereals products contained sucrose or fruit juice concentrates. Table 2 shows the number of sweetened products by the type of added sugar.

Table 2. Number of sweetened cereals by type of added sugar as reported on food labels.

Type of Added Sugar	Number of Products (*n* (%)
Sucrose	30 (58)
Fruit juice concentrates	6 (12)
Chocolate powder (cacao, sucrose)	5 (10)
Vegetable juice concentrates	4 (8)
Fructose	4 (8)
Glucose	2 (4)
Honey	1 (2)
Total	52 (100)

One-third of the commercial cereals evaluated (n = 52, 32%) contained added sugars. The milk porridges category had significantly more sweetened products ($p < 0.001$) as compared with grain porridges and breakfast cereal categories. Figure 2 shows the proportion of sweetened products in each product category.

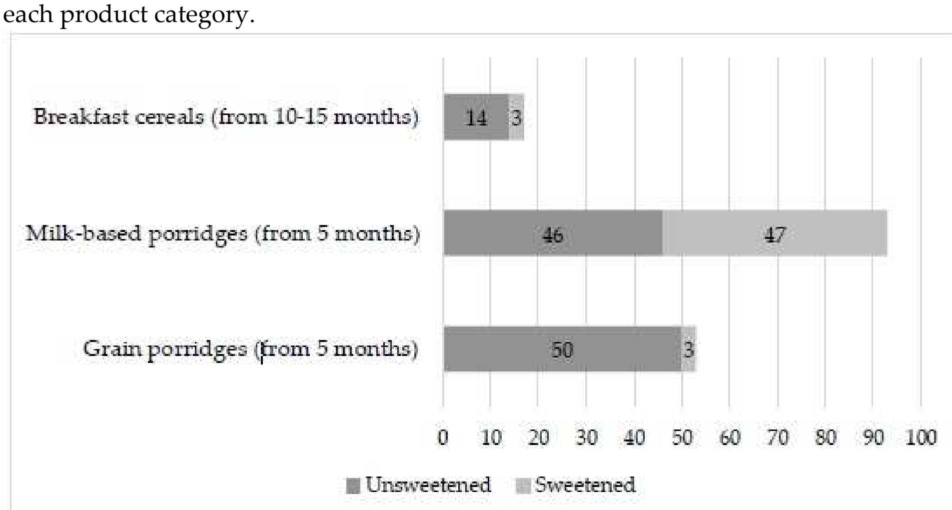

Figure 2. Proportion of sweetened commercial cereals by category.

Total energy and carbohydrate contents of commercial complementary cereals differed depending on whether cereals had been sweetened with added sugars. Table 3 shows the mean energy, as well as carbohydrate and sugar contents of sweetened and unsweetened dry cereals (n = 80).

A comparison with unsweetened dry cereals showed that sweetened dry cereals provided, on average, significantly more calories ($p < 0.001$, mean difference = 21 kcal/100 g), more carbohydrates (mean difference = 1.8 g/100 g), and significantly more sugar ($p < 0.001$, mean difference = 5.5 g/100 g).

Sweetened ready-to-eat cereals provided significantly more carbohydrates ($p < 0.001$) and sugar ($p < 0.001$) than unsweetened ready-to-eat cereals. Table 4 shows the mean energy, carbohydrate and sugar contents by cereal category (sweetened or unsweetened) for ready-to-eat cereals ($n = 33$).

Table 3. Mean energy, carbohydrate and sugar content of commercial cereals by category

Category	Total products *n* (%)	Energy (*kcal*) per 100g powder (mean ± SD)	Carbohydrates (*g*) per 100g powder (mean ± SD)	Carbohydrates (g) from sugar per 100g powder (mean ± SD)
Dry cereals				
sweetened	28 (17)	415 ± 23	70 ± 3	29 ± 10
unsweetened	103 (63)	393 ± 33	69 ± 9	15 ± 15
Ready-to-eat cereals				
Category	Total products *n* (%)	Energy (kcal) per portion (100g) (mean ± SD)	Carbohydrates (*g*) per portion (mean ± SD)	Carbohydrates (*g*) from sugar per portion (mean ± SD)
sweetened	24 (15)	79 ± 7	12 ± 1	7 ± 1
unsweetened	9 (5)	65 ± 29	8 ± 4	3 ± 1

Discussion

3.7. *Preparation Instructions*

The nutritional value of dry grain cereals depends on the liquids used to reconstitute them. We found a wide range of liquids recommended for reconstitution in the manufacturers' preparation instructions for commercial complementary cereals. Recipes for homemade complementary cereals in Germany advise, as one option, to include up to 200 mL/day of cow's milk, whereas human milk or infant formula are also indicated as options to prepare cereals [14]. Of note, commercial milk porridges, in contrast to homemade milk porridges, cannot be prepared with human milk because they contain dried whole or skimmed animal milk or infant formula, and therefore require reconstitution with water only.

3.8. *Key Micronutrients*

German national infant feeding advice [15] recommends introducing foods high in critical micronutrients such as iron, zinc, and iodine as first complementary foods. A blend of vegetables, potato, and meat or fish (*Gemüse-Kartoffel-Fleischbrei*) is recommended as a first complementary food because of its high content of bioavailable micronutrients [15]. Subsequently, milk porridges should be introduced starting from five months of age (20 weeks) and fruit-grain porridges (*Getreide-Obst Brei*) are recommended from six months (24 weeks) of age [15].

Iron, zinc, and iodine are important for infant health and complementary foods should be good sources of these micronutrients to ensure adequate growth and development. During the first years of life, dietary iron is important for infants' neurological and cognitive development. Commercial complementary cereals are considered to be important non-heme sources of iron for infants during the complementary feeding period [5]. To ensure sufficient intakes of iron in infancy, fortified complementary cereals are useful for the provision of iron. In our study, commercial complementary cereals with the highest amounts of iron were fortified. However, we found that the majority of commercial complementary cereals sold in Germany are not fortified and are poor dietary sources of iron (containing less than 15% of recommended daily intakes). Similarly, commercial baby food jars evaluated in Spain that contained meat, fish, vegetables and fruit, and also had low iron contents contributing only about 5%–20% of adequate intakes [16]. Data from 3274 children enrolled in the Feeding Infants and Toddlers Study (FITS) in the United States showed that infants and toddlers who consumed fortified commercial complementary cereals had higher iron intakes as compared with non-consumers [5].

The European Commission issued a directive in 2006 that established maximum, but not minimum levels, for iron, zinc, and iodine in commercial complementary cereals [13]. The Codex Alimentarius Guideline on Formulated Complementary Foods for Older Infants and Young Children [17] gives reference values as a guide for the amounts of vitamins and minerals to be added to complementary foods, including cereal-based porridges. For infants aged six to 12 months with an average body weight of 9 kg, the WHO and FAO-recommended nutrition intake (RNI) for iron is 18.6 mg and 9.3 mg at 5% and 10% dietary iron bioavailability, respectively [18]. For children aged 12 months to three years with an average body weight of 13 kg, the RNI is 11.6 mg and 5.8 mg at 5% and 10% dietary iron bioavailability, respectively [18]. Therefore, the WHO and FAO suggested levels of iron contained in a daily ration of complementary cereal should be 4.7–9.3 mg for older infants, and 2.9–5.8 mg for young children [18]. Among all the cereals included in this survey, only 26% provided at least 15% of the RDI for iron. Manufacturers should ensure that commercial cereals are good sources of iron.

Zinc is important for adequate development of an infant's immune system. Fortified cereals can contribute to an adequate zinc intake. A randomized study of 45 five-month-old breastfed infants in the United States demonstrated that zinc requirements are unlikely to be met without regular consumption of meat or zinc-fortified foods [19]. For infants aged six months to one year, the average individual normative requirements are 0.3 mg/kg/d and 0.186 mg/kg/d at moderate (30%) and high (50%) zinc bioavailability, respectively [18]. For children aged one to three years, the average individual normative requirements are 0.23 mg and 0.14 mg at moderate and high zinc bioavailability, respectively [18]. Therefore, the WHO and FAO suggested level of zinc contained in a daily ration of complementary cereal should be 0.16–0.93 mg for infants and 0.12–0.69 mg for young children. However, according to results of this survey, only 14% of commercial complementary cereals in Germany provided at least 15% of the RDI for zinc. Manufacturers should ensure that commercial cereals are good sources of zinc.

During the first years of life, iodine is important for the development of the thyroid and central nervous system. To ensure sufficient iodine intake, consumption of iodine-fortified complementary foods is recommended [20]. According to the WHO and FAO guidance [18], infants from birth to three years of age, the daily iodine intake recommendation is 90 μg/day or 6–30 μg/kg/day. The suggested total quantity of iodine contained in a daily ration of complementary cereal should be at least 50% of 90 μg/day [17], or 45 μg of iodine. In our study, dry cereals containing iodine had a median level of 59 μg/100 g dry product (IQR 50–104) and only 28% of commercial complementary cereals surveyed provided at least 15% of the RDI for iodine.

The authors of a market survey on CCF in Germany, in 2008, reported a higher proportion of commercial cereals fortified with iodine as compared with this survey. In that survey, 80 (83.3%) of 98 milk porridges surveyed were fortified with iodine, and the median iodine level of fortified milk porridges was 21 μg/100 g (IQR 8, 29) for ready-to-eat products [20]. This is presumably because milk porridges contained infant formula which had been fortified with iodine. However, only 6 of 45 (13.3%) fruit-cereal porridges were fortified with iodine, with a median iodine concentration of 20 μg/100 g (IQR 6, 20) for ready-to-eat products. Researchers also modeled dietary intakes of an 8-month-old infant fed one of three daily diets consisting of either human milk (with and without maternal iodine supplementation), or fortified infant or follow-on formula. Complementary meals in the modeled diet consisted of either homemade or fortified commercial complementary food. The results showed that a breast-fed infant getting homemade porridges obtained less than 50% of the recommended iodine intake [20]. An infant diet modeled using infant formula and fortified commercial porridges, exceeded recommended intakes by 39%–100%, depending on the products chosen [20]. The authors concluded that fortification of commercial complementary cereals is necessary to ensure adequate iodine intakes, especially for breastfed infants [20]. Our survey demonstrates that very few commercial complementary cereals in Germany are fortified with iodine.

Manufacturers should ensure that commercial cereals are good sources of iodine to supply adequate iodine for all infants, especially breastfed infants.

3.9. *Sodium*

Sodium salts can only be added to processed cereal-based baby foods for technological purposes [13]. Diets high in salt have been associated with non-communicable diseases such as hypertension, cardiovascular diseases, stomach cancers, and chronic kidney disease. In Germany, the intake of salt in the population is estimated using data from the German Health Interview and Examination Survey for Adults (DEGS), from 2008 to 2011. For infant girls and boys aged six months to one year, the median daily salt intake is 1.1 g and 1.4 g, respectively [21]. Studies from the United States have shown some commercial complementary foods to be high in salt [22]. According to the European directive from 2006 [13], sodium content for cereals shall not exceed 100 mg/100 kcal for ready-to use products or dry cereals when reconstituted as instructed by the manufacturer. Results from this survey did not show commercial complementary cereals in Germany to exceed the maximum level given in the 2006 EU Commission Directive [13]. In 2019, the WHO Europe recommended to further reduce the total sodium in CCF to 50 mg/100 kcal for most products [12].

3.10. *Total Carbohydrates, Total Sugar, and Added Sugars*

Many commercial cereal products surveyed contained high levels of sugar and added sugars (sucrose, glucose, honey, and fruit juice concentrates). Approximately one-third of the commercial cereals contained fruit, mostly from ingredients containing banana. A study from the United Kingdom evaluated the types of fruits and vegetables used in 329 CCF which had the fruits and vegetables in the product name and reported that CCF contained predominantly fruits and relatively sweet vegetables [23]. This is of concern, since high sugar intakes can contribute to the risk of childhood overweight/obesity and dental caries [24]. Furthermore, exposure to sweet products during infancy can promote a preference for sweet foods [25] and poor eating habits in childhood [26].

The 2006 EU Commission Directive set maximum levels for added sugars such as sucrose, fructose, glucose, glucose syrups, and honey in dry commercial complementary cereals [13]. The amount of added carbohydrates from all of these sources should not exceed 7.5 g/100 kcal, and should not exceed 3.75 g/100 kcal for added fructose [13]. However, manufacturers are not required by current EU labeling laws to report the quantity or percent weight of added sugars. Therefore, currently consumers can only draw conclusions on the addition of sugar from the ingredients list, while it is not possible to quantify added sugar.

A European Union report based on data in the Mintel GNPD database, published in 2019, included 4196 infant foods and 502 different processed cereal-based foods [27]. This report showed that 1359 (31.9%) baby foods had added or free sugars and 1167 (27.4%) had one or more types of sugar among the top five ingredients [27]. Sugars were added predominantly (75% of products) to baby biscuits and rusks. The report included 483 products from Germany, of which only 53 products were dry commercial complementary cereals [27]. According to that report, the average energy of dry commercial complementary cereals from Germany was 386 kcal/100 g, with an average of 69.1 g of carbohydrates and 15.3 g total sugar [27]. These values are similar to the nutrient contents found in this study for dry cereals, with an energy content of 396 ± 32 kcal, 69.8 ± 6 g of carbohydrates and 17 ± 15 g sugar. German ready-to-eat commercial cereal products were not included in the EU report.

In 2019, the WHO Regional Office for Europe published a report on 7955 CCF and drink products in Vienna, Austria, Sofia, Bulgaria, Budapest, Hungary, and Haifa, Israel [1]. This report included information from both dry and ready-to-eat commercial cereals and showed that around one-third of dry cereals containing whey or milk powder contained a 30% mean percentage of energy from total sugar (ranging from 29% in Italy to 44% in Hungary) [12]. The results of this study showed similar values for milk porridges in Germany, with an average of 29.8% ± 7% of energy derived from sugar.

In 2019, WHO Europe called for complete prohibition of added sugars and sweeteners (including syrups, honey, fruit juice, fruit juice concentrates, and non-sugar sweeteners) in all commercial complementary foods [28]. In addition, WHO Europe is drafting a nutrient profile model to guide decisions about which foods are inappropriate for promotion for infants and young children six to 36 months of age [12]. The model has been validated against nutrient label information from 1328 products on the market in Denmark, Spain, and the United Kingdom and pilot tested on a further 1314 products from seven additional countries (Estonia, Hungary, Italy, Malta, Norway, Portugal, and Slovenia) [12].

Limitations

This survey consolidated nutrient information for commercial complementary cereals from food labels. Laboratory analysis of commercial complementary cereals would provide a more accurate assessment of actual nutrient contents. A laboratory analysis of 100 samples of CCF from the United States demonstrated that nutrient label data both under- and overestimated total sugars [29]. Approximately 25% of all foods evaluated had total sugar values with either less than 10% or more than 10% of total sugar contents listed on ingredients labels [29]. It seems possible that total sugar reported on food labels in Europe could also be different from actual sugar content.

Current EU food labeling hinders the evaluation of calories from added sugars in commercial complementary cereals. Lactose in milk porridges and fructose from fruit ingredients both contribute to total sugar content. Since sugars which naturally occur in milk and fruit are not currently differentiated from added sugars on CCF food labels, it was not possible to obtain information on the contribution of added sugars to total calories or total carbohydrates. In 2019, a policy brief from the WHO Regional Office for Europe proposed improvements of product labeling for sugar and total fruit content of CCF marketed in Europe [28].

A limitation of this cross-sectional study is that the available commercial food products, and potentially the nutritional composition of these products, are constantly changing. This has potential implications for reproducibility of this study. Multiple cross-sectional studies are needed to understand potential time-related trends in nutrient composition of commercial baby foods.

Sodium contents of prepared commercial cereals were based on food label sodium values and recipe simulation with a water and cow's milk mixture (*Halbmilchbrei*). Without detailed data on actual preparation practices, it is not possible to fully reflect real-world scenarios.

Recommendations

Commercial complementary cereals are commonly consumed and often recommended as first complementary foods amongst German infants. Most of the commercial complementary cereals evaluated in this study were poor sources of iron, zinc, and iodine. One-third of the products contained added sugars. Few products recommended human milk for reconstitution. Nutrient composition of commercial complementary cereals should be improved, and regulatory standards should provide stronger guidance for an adequate composition and reconstitution that serves to promote child health.

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