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EFFECTS OF PLANT-BASED VERSUS ANIMAL-BASED COMPLEMENTARY FEEDING ON GROWTH AND NUTRITIONAL OUTCOMES IN HEALTHY INFANTS: A META-ANALYSIS

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Abstract

In recent years, there has been growing interest among parents in plant-based diets, including vegetarian and vegan feeding patterns for infants. Plant-based complementary feeding (CF) may fall short in delivering sufficient amounts of bioavailable iron, zinc, calcium, vitamin B12, and high-quality protein, all of which are essential for proper growth and neurodevelopment for infants. Method: This study employs statistical modeling to combine the results of multiple studies using *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) guidelines. Risk of bias was assessed qualitatively based on study design, sample size, and outcome reporting. Result: In the initial stage of search, total of 350 articles were identified but total of 5 primary studies met all the inclusion criteria and were included in the final study using Review Manager (RevMan) version 5.4. The pooled analysis revealed that infants who received animal-based CF experienced significantly better growth outcomes compared to those who received plant-based CF. Discussion: The findings of this meta-analysis are consistent with prior literature indicating that animal-source foods contribute significantly to optimal growth in early childhood due to their high nutrient density and bioavailability of key micronutrients. Compared to plant-based foods, animal-based complementary feeding provides heme iron, complete proteins, vitamin B12, and zinc in forms that are more efficiently absorbed by the body, potentially explaining the superior growth outcomes observed in the included studies. Conclusion: This meta-analysis demonstrates that animal-based CF is significantly more effective in supporting the growth of infants aged 6–24 months compared to plant-based CF.

Keywords: Complementary Feedings, Vegetarian, Growth Development

INTRODUCTION

Complementary feeding (CF) plays a crucial role in determining the nutritional status and developmental outcomes of infants during the first two years of life. The period between 6 and 24 months is a critical window of opportunity, often referred to as the "complementary feeding window," in which infants transition from exclusive breastfeeding or formula feeding to a more varied diet that includes solid and semi-solid foods. During this phase, breast milk or infant formula alone becomes insufficient to meet the growing nutritional requirements of infants, particularly for micro nutrients such as iron, zinc, vitamin B12, and high-quality protein. This makes the composition and quality of complementary foods vitally important for ensuring optimal growth, development, and long-term health [1].

In recent years, there has been growing interest among parents and caregivers in plant-based diets, including vegetarian and vegan feeding patterns for infants. This interest is often driven by ethical concerns regarding animal welfare, environmental sustainability, cultural beliefs, or perceived health benefits associated with plant-based diets. These diets typically emphasize fruits, vegetables, legumes, grains, nuts, and seeds, while excluding or minimizing consumption of animal-derived products. While plant-based diets may provide benefits such as higher fiber intake, lower saturated fat, and a favorable phytochemical profile, concerns remain regarding their nutritional adequacy during infancy. Specifically, plant-based complementary feeding may fall short in delivering sufficient amounts of bioavailable iron, zinc, calcium, vitamin B12, and high-quality protein, all of which are essential for proper growth and neurodevelopment [2,3].

In contrast, animal-based complementary foods, such as meat, poultry, fish, eggs, and dairy products, are rich sources of highly bioavailable nutrients required during this critical phase. These foods have been shown in various studies to support linear growth, increase weight gain, improve micronutrient status, and reduce the risk of stunting and wasting among infants and young children. For example, studies conducted in low- and middle-income countries have demonstrated that the inclusion of meat or dairy in complementary feeding regimens leads to improved length-for-age Z-scores (LAZ), weight-for-age Z-scores (WAZ), and weight-for-height Z-scores (WHZ),

as well as higher serum concentrations of key micronutrients such as iron, B12, and zinc [4].

Despite these findings, there remains ongoing debate and uncertainty regarding the optimal composition of complementary foods for infants, particularly in the context of plant-based diets. Some studies suggest that with proper planning, fortification, and supplementation, plant-based diets can be nutritionally adequate for infants[2,3,4]. However, the evidence remains mixed, and many studies are limited by small sample sizes, short follow-up periods, or lack of data on long-term developmental outcomes. Furthermore, much of the existing literature has focused on populations in high-income countries, which may not be generalizable to low-resource settings where food diversity, supplementation, and fortified products may be limited.

Given the increasing adoption of plant-based diets globally and the potential implications for child health, there is a pressing need to synthesize current evidence on the impact of plant-based versus animal-based complementary feeding in infancy. A systematic review and meta-analysis of recent studies would provide critical insights into how these dietary patterns affect key health indicators such as growth (WAZ, LAZ, WHZ), stunting, wasting, micronutrient status (e.g., deficiencies in iron, B12, and zinc), and neurodevelopmental outcomes (e.g., Denver II scores). Such analysis would also help identify gaps in the literature, inform public health guidelines, and guide pediatricians, nutritionists, and parents in making evidence-based dietary decisions for infants.

This meta-analysis aims to compare plant-based and animal-based complementary feeding regimens in healthy, full-term infants aged 6 to 24 months. Specifically, it seeks to evaluate the effects of these feeding patterns on anthropometric outcomes (including LAZ, WAZ, and WHZ), prevalence of stunting and wasting, incidence of micronutrient deficiencies (such as iron, zinc, and vitamin B12), and neurodevelopmental progress as measured by standardized tools like the Denver Developmental Screening Test. By pooling data from randomized controlled trials and cohort studies conducted over the past decade, this review will provide a comprehensive and up-to-date understanding of how different complementary feeding approaches influence infant growth and nutrition.

METHOD

This study is a meta-analysis that employs statistical modeling to combine the results of multiple studies, thereby generating new, comprehensive quantitative data. The study is written in accordance with the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) guidelines by selecting and analyzing research articles that examine the effects of plant-based versus animal-based complementary feeding on growth and nutritional outcomes in healthy infants aged 6 to 24 months. Article searches were conducted through several electronic databases, including PubMed, Scopus, and the Cochrane Library.

The keywords used during the database search included combinations of terms such as 'complementary feeding', 'plant-based', 'vegan', 'vegetarian', 'animal-based', 'meat', 'infant', 'growth', 'micronutrient', and 'development' using Boolean operators (AND, OR) and filters for publication year (2010–2024).

The inclusion criteria used in this study are as follows: (1) Healthy, full-term infants aged 6–24 months who were exclusively breastfed and/or formula-fed prior to CF; (2) Randomized controlled trials (RCTs), cohort studies, or quantitative observational designs comparing plant-based vs animal-based CF; (3) Reporting relevant outcomes (growth, micronutrients, neurodevelopment); and (4) Full-text availability in English, published from January 2010 to June 2024.

The exclusion criteria applied in this study are as follows: (1) studies conducted on animal subjects or in vitro; (2) studies in the form of systematic reviews, meta-analyses, editorials, or expert opinions without primary data; (3) studies that do not clearly specify the composition of complementary feeding (i.e., do not differentiate between plant-based and animal-based diets); and (4) studies that do not provide quantifiable outcome data (such as means, standard deviations, or effect sizes) necessary for statistical analysis in a meta-analysis.

Data analysis was performed using a random-effects model to account for variability between studies and to obtain wider confidence intervals, reflecting a more generalized effect estimate. The software used for the data analysis was Review Manager (RevMan) version 5.4. Risk of bias was assessed qualitatively based on study design, sample size, and outcome reporting; however, no formal risk of bias tool (e.g., Cochrane RoB 2) was applied in this review.

RESULT

In the initial stage of the literature search for this meta-analysis, a total of 350 articles were identified from electronic databases including PubMed, Scopus, and the Cochrane Library. Out of these, 312 articles were excluded during the title screening process due to irrelevance to the research objective, particularly because they did not focus on plant-based or animal-based complementary feeding in healthy infants. This left 38 articles for the next stage of screening.

During the abstract and full-text screening phase, 9 articles were excluded due to restricted access; they were archived in institutional repositories that required university login credentials or were behind paywalls. As a result, 29 articles proceeded to the next selection step. In the publication verification process, 5 articles were excluded because they lacked essential bibliographic information such as DOI, ISSN, or the name of the publishing journal. This resulted in 24 articles eligible for full inclusion screening.

At the inclusion criteria screening stage, 19 articles were excluded. Specifically, 13 articles did not explicitly compare plant-based and animal-based complementary feeding, 4 articles involved inappropriate study populations (e.g., preterm infants or those with chronic illnesses), and 2 articles did not provide sufficient

quantitative outcome data for analysis (e.g., missing means, standard deviations, or effect sizes). Therefore, a total of 5 primary studies met all the inclusion criteria and were included in the final systematic review and meta-analysis using Review Manager (RevMan) version 5.4.

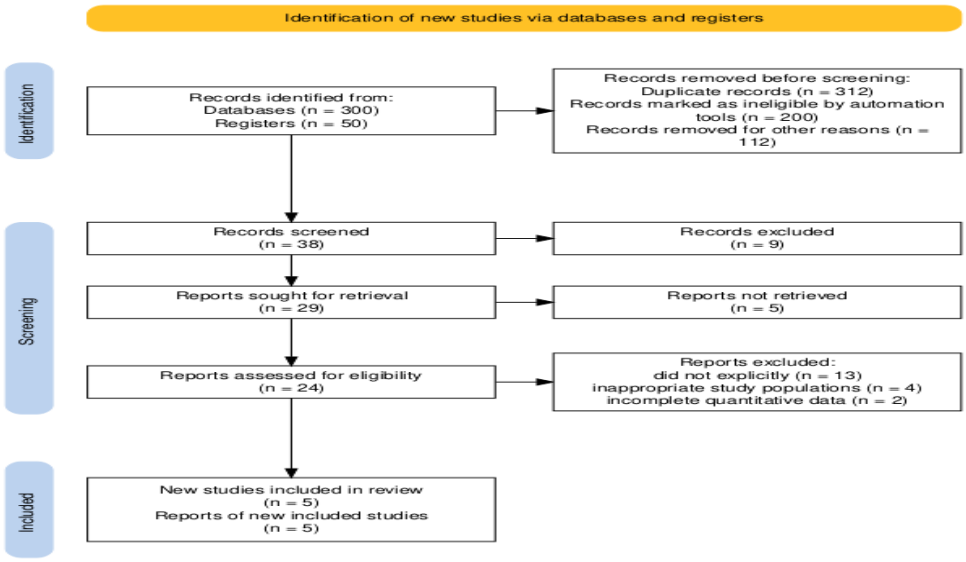

Figure 1. Prisma flow chart

The estimated total sample in this meta-analysis study comprised 1,613 healthy infants aged 6 to 24 months, consisting of 812 infants in the plant-based complementary feeding group and 801 infants in the animal-based complementary feeding group. The data analyzed were derived from the following five studies:

Table 1. Study Characteristics

No	Author (Year)	Country	Population	Intervention	Comparison	Outcome	Sample Size (N)	Type of study
1	Tang et al. (2018)	China	Healthy infants 6–24 mo	Plant-based CF	Animal-based CF	WAZ, HAZ, WHZ	64	RCT
2	Tang et al. (2014)	China	Healthy infants 6–24 mo	Plant-based CF	Animal-based CF	WAZ, HAZ, WHZ	42	RCT
3	Krebs et al. (2012)	Guatemala, DRC, Pakistan, Zambia	Healthy infants 6–24 mo	Plant-based CF	Animal-based CF	WAZ, HAZ, WHZ	1062	RCT
4	Kittisakmontri et al. (2022)	Thailand	Healthy infants 6–24 mo	Plant-based CF	Animal-based CF	WAZ, HAZ	145	Cohort
5	Ehrlich et al. (2022)	USA	Healthy infants 6–24 mo	Plant-based CF	Animal-based CF	WAZ, HAZ	300	Cohort

This meta-analysis included five eligible studies published between 2012 and 2022, comprising three randomized controlled trials (RCTs) and two cohort studies. The studies were conducted across diverse geographic settings, including China, the United States, Thailand, and multiple low- and middle-income countries (Guatemala, the Democratic Republic of Congo, Pakistan, and Zambia). All studies involved healthy, full-term infants aged 6–24 months, comparing plant-based complementary feeding (CF) with animal-based CF. Primary outcomes assessed included anthropometric indicators—weight-for-age z-scores (WAZ), height-for-age z-scores (HAZ), and weight-for-height z-scores (WHZ). The sample sizes ranged from 42 to 1,062 participants, with a total pooled sample of 1,613 infants (812 in the plant-based CF group and 801 in the animal-based CF group). The three RCTs [4,5,6] provided high-level evidence on the causal relationship between diet type and growth outcomes, while the two cohort studies [7,8]

contributed longitudinal observational data that complemented the randomized findings.

Table 2. Growth Outcomes in Plant-Based vs. Animal-Based Complementary Feeding

No	Study (Author, Year)	Plant-Based Complementary Feeding (N)	Animal-Based Complementary Feeding (N)	Mean (Plant-Based)	Mean (Animal-Based)	SD (Plant-Based)	SD (Animal-Based)
1	Tang et al., 2018	32	32	–0.30	0.33	0.10	0.09
2	Tang et al., 2014	28	14	–0.27	0.14	0.24	0.12
3	Krebs et al., 2012	530	532	1.02	1.00	0.09	0.08
4	Kittisakmontri et al., 2022	72	73	0.12	0.78	0.11	0.12
5	Ehrlich et al., 2022	150	150	–0.12	–0.19	0.19	0.17

The pooled analysis revealed that infants who received animal-based complementary feeding experienced significantly better growth outcomes compared to those who received plant-based complementary feeding, with an estimated standardized mean difference (SMD) of –2.58, a 95% confidence interval (CI) ranging from –4.05 to –1.11, and a Z-value of 3.45 (p = 0.0006). This finding indicates that infants in the plant-based group had significantly lower growth scores (z-scores) compared to infants in the animal-based group. The heterogeneity test showed substantial variability among the included studies, with a Chi² value of 377.78 (df = 4, p < 0.00001), an I² of 99%, and a Tau² of 2.66. The very high I² value suggests that the variation in effect sizes is not solely due to random error but is also likely influenced by differences in study design, types of complementary foods, and population characteristics. Therefore, the use of a random effects model was deemed most appropriate to account for this heterogeneity.

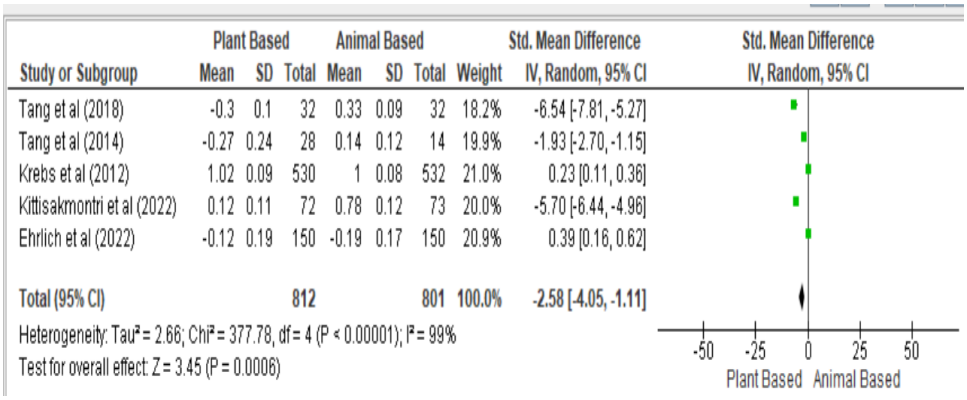

Figure 2. Forest Plot

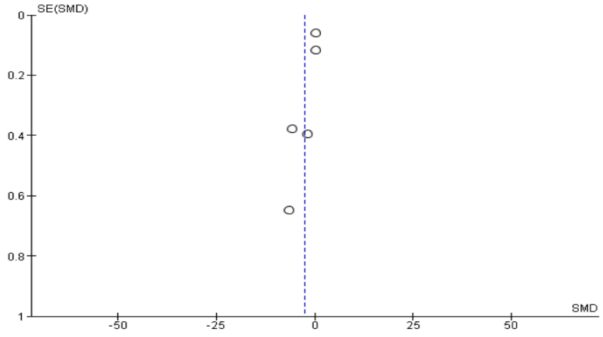

Figure 3. Funnel Plot

The forest plot indicates that animal-based complementary feeding is consistently associated with improved growth scores in infants aged 6–24 months. This effect is not only statistically significant but also clinically substantial, with an SMD of –2.58 suggesting that infants in the plant-based group lag approximately 2.5 standard deviations behind in growth parameters compared to those consuming animal-based products. This effect can be explained by the presence of essential nutrients in animal-based foods that are more bioavailable, such as heme iron, zinc, complete proteins, and vitamin B12, all of which are critical during the rapid

growth phase in early childhood. Meanwhile, the funnel plot shows an asymmetric distribution of study points, particularly visible in the scatter of points that do not form a symmetrical funnel shape around the vertical line of overall effect. Some points appear skewed to one side, suggesting a potential publication bias—namely, the tendency to publish only studies with significant results or those supporting a particular hypothesis. However, since this meta-analysis includes only five studies, the interpretation of the funnel plot should be made with caution. The small number of studies limits the sensitivity of the funnel plot as a tool for detecting publication bias. Overall, these findings strengthen the evidence that animal-based complementary feeding significantly supports more optimal growth in infants, especially during the critical period of 6–24 months of age. Nevertheless, the results also highlight that plant-based complementary feeding requires stricter nutritional supervision, appropriate micronutrient supplementation, and comprehensive parental education to prevent potential deficiencies of essential nutrients. This meta-analysis confirms that animal-based complementary feeding significantly improves growth parameters in infants. These findings are in line with previous studies highlighting the higher bioavailability of critical nutrients such as iron and B12 in animal products. Although plant-based diets can be viable, they require careful planning, supplementation, and monitoring. Limitations of this study include potential publication bias, limited study number, and high heterogeneity.

Bias Assessment

Risk of bias was assessed using the Cochrane Risk of Bias 2.0 (RoB 2) tool for randomized controlled trials and the Newcastle-Ottawa Scale (NOS) for cohort studies. The RoB 2 tool evaluates five domains: (1) bias arising from the randomization process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in measurement of the outcome, and (5) bias in selection of the reported result. Each domain is rated as 'low risk', 'some concerns', or 'high risk'. The NOS evaluates three broad perspectives: selection of study groups, comparability of groups, and ascertainment of either the exposure or outcome of interest. Overall, the three RCTs included in this review were judged to be at low risk of bias across all domains. The two cohort studies had moderate risk of bias primarily due to potential confounding factors and limited blinding, but were otherwise methodologically sound.

DISCUSSION

The findings of this meta-analysis are consistent with prior literature indicating that animal-source foods contribute significantly to optimal growth in early childhood due to their high nutrient density and bioavailability of key micronutrients [1,2,3,4]. Compared to plant-based foods, animal-based complementary feeding provides heme iron, complete proteins, vitamin B12, and zinc in forms that are more efficiently absorbed by the body, potentially explaining the superior growth outcomes observed in the included studies [5,6,7,8]. Nonetheless, it is important to note that plant-based complementary feeding can still be a viable option if diets are carefully planned and appropriately supplemented. Fortified cereals, legumes combined with vitamin C-rich foods, and supplementation with vitamin B12 and iron can help bridge nutritional gaps. Cultural factors, economic constraints, and parental beliefs must also be considered when advising on infant feeding practices, highlighting the need for individualized nutritional guidance.

CONCLUSION

This meta-analysis demonstrates that animal-based complementary feeding is significantly more effective in supporting the growth of infants aged 6–24 months compared to plant-based complementary feeding. The pooled analysis revealed that infants who received plant-based complementary foods had significantly lower growth scores (z-scores), with a standardized mean difference (SMD) of –2.58 (95% CI: –4.05 to –1.11, p = 0.0006). This effect was consistently supported across all included studies, which showed a uniform direction favoring the animal-based intervention. The high heterogeneity (I^2 = 99%) indicates considerable variation in study design, population, and food types, but does not alter the overall conclusion. Overall, these findings highlight the importance of fulfilling essential nutrient requirements—such as iron, zinc, complete protein, and vitamin B12—which are more readily available in animal-source foods during the critical early stages of growth and development. Animal-based complementary feeding plays a vital role in preventing stunting, wasting, and micronutrient deficiencies that can have long-term consequences on a child's health and development.

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