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Research Article

Complementary feeding practices in children aged 0 to 24 months in Picos, Piauí

Prática da alimentação complementar em crianças de 0 a 24 meses em Picos, Piauí

Práctica de alimentación complementaria en niños de hasta 24 meses en Picos, Piauí

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Abstract

Introduction: Complementary feeding is the process of introducing foods in addition to breast milk or infant formula, when these are no longer sufficient to provide the child with nutritional support. It should be started at 6 months of age and continues until 24 months. The World Health Organization (WHO) indicates that this process should contain at least 5 of the 8 key groups: breast milk; meats; dairy products; eggs; legumes and nuts; fruits and vegetables rich in vitamin A; other fruits and vegetables; grains and roots. **Objective:** To investigate the social context and practice of complementary feeding for children up to 2 years of age in the municipality of Picos, Piauí, in the Northeast region of Brazil. **Methods:** This is a descriptive, cross-sectional, qualitative and quantitative study, carried out with mothers of children up to 2 years of age who use a Basic Health Unit in the city of Picos. A questionnaire was applied on socioeconomic aspects of the mothers and practical aspects and components of the child's complementary feeding, between November 2022 and July 2023. **Results:** A total of 38 mothers were interviewed, between 18 and 43 years old. The profile of the participants was of married/common-law women (63.3%), with secondary education (81.5%) and housewives (65.8%). Regarding the children, 17 were less than 6 months old and 21 were older. Of those under 6 months, 52.9% had already started some type of complementary feeding, with the most introduced foods being water, other milks and teas. Among those over 6 months old, the consumption of WHO-recommended foods ranged from 61.9 to 95.2%. In this age group, there was also a significant consumption of ultra-processed and sugar-added foods, with cookies (61.9%) being the most prevalent. **Conclusions:** A good overview of the practice of complementary feeding in Picos (PI) was obtained. On the positive side, there was a high rate of consumption of in natura foods and food groups necessary to meet the demand for important nutrients for proper child development. However, there was a low rate of exclusive breastfeeding, early introduction of food and a high consumption of sugar-added and ultra-processed foods. Thus, it is necessary to pay attention to possible risk factors that compromise the quality of complementary feeding.

Keywords: Infant nutritional physiological phenomena; Breast feeding; Primary health care.

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Resumo

Introdução: A alimentação complementar é o processo de introdução de alimentos em adição ao leite materno ou fórmulas infantis, quando estes não são mais suficientes para oferecer o suporte nutricional da criança. Ela deve ser iniciada aos seis meses de vida do bebê e continua até os seus 24 meses. A Organização Mundial da Saúde (OMS) afirma que esse processo deve conter ao menos cinco dos oito grupos-chave: leite materno; carnes; derivados de leite; ovos; leguminosas e nozes; frutas e vegetais ricos em vitamina A; outras frutas e vegetais; grãos e raízes. **Objetivo:** Investigar o contexto social e a prática da alimentação complementar de crianças com até dois anos de vida do município de Picos, Piauí, na Região Nordeste do Brasil. **Métodos:** Trata-se de um estudo descritivo, transversal, qualitativo e quantitativo, realizado com mães de crianças de até dois anos de idade usuárias de uma Unidade Básica de Saúde da cidade de Picos. Foi aplicado um questionário sobre aspectos socioeconômicos das mães e aspectos práticos e componentes da alimentação complementar da criança, entre novembro de 2022 e julho de 2023. **Resultados:** Foram entrevistadas 38 mães com idade entre 18 e 43 anos. O perfil das participantes foi de mulheres casadas/união estável (63,3%), com escolaridade de nível médio (81,5%) e donas de casa (65,8%). Quanto às crianças, 17 tinham menos de seis meses de vida e 21, mais. Das menores de seis meses, 52,9% já haviam iniciado algum tipo de alimentação complementar, sendo os alimentos mais introduzidos água, outros leites e chás. Dos maiores de seis meses, o consumo dos alimentos recomendados pela OMS variou de 61,9 a 95,2%. Ainda nessa faixa etária, observou-se consumo importante de ultraprocessados e adicionados de açúcar, sendo biscoito (61,9%) o mais prevalente. **Conclusões:** Conseguiu-se um bom panorama acerca da prática da alimentação complementar em Picos (PI). Como pontos positivos, observou-se alta taxa de consumo de alimentos *in natura* e dos grupos alimentares necessários para suprir a demanda de nutrientes importantes para o adequado desenvolvimento infantil. Entretanto, observou-se baixa taxa de aleitamento materno exclusivo, introdução alimentar precoce e alto consumo de alimentos adicionados de açúcar e ultraprocessados. Assim, faz-se necessário atentar para possíveis fatores de risco que comprometam a qualidade da alimentação complementar.

Palavras-chave: Fenômenos fisiológicos da nutrição do lactente; Aleitamento materno; Atenção primária à saúde.

Resumen

Introducción: La alimentación complementaria es la introducción de alimentos sólidos o semisólidos cuando la leche materna o las fórmulas infantiles ya no son suficientes para ofrecer el soporte adecuado al niño. Debe iniciarse a los 6 meses de vida del bebé y continúa hasta los 24 meses. La Organización Mundial de la Salud (OMS) indica que este proceso debe tener al menos 5 de los 8 grupos de alimentos: leche materna; carnes; derivados lácteos; huevos; leguminosas y frutos secos; frutas y hortalizas ricas en vitamina A; otras frutas y hortalizas; cereales y raíces. **Objetivo:** Investigar el contexto social y la práctica de la alimentación complementaria en niños de hasta 2 años de edad, en el municipio de Picos, Piauí, en la región Nordeste de Brasil. **Métodos:** Se trata de un estudio descriptivo, transversal, cualitativo y cuantitativo, realizado con madres de niños de hasta 2 años de edad, usuarias de una Unidad Básica de Salud del municipio de Picos. Se aplicó un cuestionario sobre aspectos socioeconómicos de las familias entrevistadas, así como componentes de la alimentación del niño en estas edades, entre noviembre de 2022 y julio de 2023. **Resultados:** Se interrogaron a 38 madres, con edades entre 18 y 43 años. La mayoría de ellas eran mujeres casadas/en unión estable (63,3%), con escolaridad de nivel medio (81,5%) y amas de casa (65,8%). Con relación a los menores, 17 tenían menos de 6 meses de vida y 21 por encima de esta edad. De los menores de 6 meses, el 52,9% ya habían iniciado algún tipo de alimentación complementaria, siendo en su mayoría el agua, otras leches y té. Entre los mayores de 6 meses, el consumo de alimentos recomendados por la OMS varió entre el 61,9% y el 95,2%. En este grupo de edad, también se observó un consumo importante de alimentos ultra procesados y con adición de azúcar, siendo las galletitas (61,9%) las más prevalentes. **Conclusiones:** Con este estudio pudimos observar cómo es introducida la alimentación, en una población bien delimitada, del municipio de Picos (PI). Como puntos positivos, se observó un alto índice de consumo de alimentos in natura y de grupos de alimentos necesarios para el adecuado desarrollo infantil. Sin embargo, se observó poca adhesión a la lactancia exclusiva, introducción precoz de alimentos y un alto consumo de alimentos con adición de azúcar y ultra procesados. Por lo tanto, es necesario prestar atención a los posibles factores de riesgo que comprometen la calidad de la alimentación complementaria.

Palabras clave: Fenómenos fisiológicos nutricionales del lactante; Lactancia materna; Atención primaria de salud.

INTRODUCTION

Complementary feeding is defined as the process of introducing foods other than breast milk when breast milk or infant formula alone is no longer sufficient to meet the nutritional needs of children. In general, this process is recommended to begin at six months of age and to continue until 24 months, a period considered critical both because of the increased risk of nutritional deficiencies and growth impairments and because it is when long-term eating behaviors are established[1].

The introduction of complementary feeding should begin at six months of age, as earlier introduction may be associated with increased gastrointestinal morbidity and mortality and lower nutritional quality,

whereas delayed introduction increases the risk of developing food allergies. The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) define eight key food groups for this introduction:

1. Breast milk;
2. Meat;
3. Dairy products;
4. Eggs;
5. Legumes and nuts;
6. Vitamin A–rich fruits and vegetables;
7. Other fruits and vegetables;
8. Grains, roots, and tubers. Ideally, at least five of these eight groups should be present in the complementary feeding of children from six months of age onward[1,2].

From a global perspective, UNICEF estimates based on data from several countries collected between 2006 and 2018 indicate a concerning situation regarding child nutrition worldwide[2]. These findings are also reflected at the national level. A Brazilian survey reported that 7.4% of children under five years of age were overweight, 1.6% were underweight, and 6.8% had short stature. Anemia was observed in 20.9% of children, and vitamin A deficiency in 17.4%. In the Northeast Region of Brazil, children were found to have a lower frequency of intake of both recommended and non-recommended foods; however, they consumed fruits, chicken, cookies, and snacks more frequently compared with children from other regions of the country[3].

Research indicates that the introduction of complementary foods in Brazil is frequently suboptimal, adversely affecting children's health by increasing the risk of overweight and type 2 diabetes mellitus and impairing brain development, particularly in language, hearing, vision, and cognitive functions[1]. In some instances, complementary feeding is both premature and of low nutritional quality. Several studies report low rates of exclusive breastfeeding (EBF) among children aged four months or older, alongside the consumption of water, teas, coffee, and other types of milk[4,5]. Simultaneously, foods such as fruits, vegetables, beans, meats, and other sources of iron and vitamin A are introduced late or at frequencies below the recommended minimum of once per day[4,6,7]. This situation is further highlighted by a high prevalence of ultra-processed foods and sweetened beverages in the diets of Brazilian children[8].

In Brazil, the Unified Health System (*Sistema Único de Saúde* – SUS) plays a crucial role in promoting child health, as emphasized in the National Policy for Comprehensive Child Health Care (*Política Nacional de Atenção Integral à Saúde da Criança* – PNAISC). Within this framework, food and nutrition are fundamental for promoting and protecting child health, as well as for supporting the full potential of human growth and development, quality of life, and citizenship. Consequently, actions related to food and nutrition are addressed within public health, primarily through Primary Health Care (PHC) and the Family Health Strategy[9,10]. In alignment with these principles and recognizing the benefits of adequate nutrition for children, the Ministry of Health (*Ministério da Saúde* – MS) has implemented programs such as the Breastfeeding and Feeding Brazil Strategy (*Estratégia Amamenta e Alimenta Brasil* – EAAB), which trains tutors to support teams at Basic Health Units (*Unidades Básicas de Saúde* – UBS) in carrying out actions aimed at promoting breastfeeding and appropriate complementary feeding[11,12].

Given this context, the present study aimed to investigate the social determinants and practices of complementary feeding among children up to two years of age in the municipality of Picos (Piauí – PI), in the Northeast Region of Brazil.

METHODS

This is a descriptive, cross-sectional study with both qualitative and quantitative approaches, conducted with mothers of children up to two years of age who attend a UBS in the city of Picos (PI). The municipality is located in the southeastern region of the state, 315 km from the capital, Teresina. According to the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE), Picos has a population of 83,090 inhabitants, a Municipal Human Development Index (MHDI) of 0.698, and 41.8% of its population has a monthly per capita income of up to 0.5 minimum wage[13]. The municipality also has 34 UBS, all covered by the Family Health Strategy[14].

The research was based on the application of a semi-structured questionnaire divided into two stages: one addressing the socioeconomic and demographic characteristics of the mothers and the other focusing on practical aspects and components of the child's complementary feeding. The instrument was adapted from a previously validated questionnaire[15] and was administered in person to the mothers at the UBS between November 2022 and July 2023.

The sociodemographic variables investigated were the mother's age, educational level, occupation, and marital status, as well as the child's age. With regard to the child's diet, the following items were assessed: consumption of breast milk, water, tea, other types of milk, natural fruit juice, processed juice, coconut water, soda, coffee, pureed foods, porridges, fruits, sweets (candies, lollipops, chewing gum), cookies, snacks, rice, beans or other legumes, meat, eggs, potatoes or other tubers, pasta, pumpkin, carrots, broccoli, kale, leafy greens, processed meats (sausages, salami, chicken nuggets), and instant noodles.

The study included women aged 18 years old or older who were mothers of children up to 24 months of age, registered in the territory of the UBS, and who attended the unit during the data collection period. All participants voluntarily agreed to take part in the study and signed an Informed Consent. Women under 18 years of age and those who did not agree to participate were excluded.

For data tabulation and graph construction, Microsoft Office Excel 2019 and GraphPad Prism 10 were used, respectively. The study was submitted to and approved by the Research Ethics Committee of Universidade Federal do Piauí (CEP-UFPI) under protocol number 3.579.477.

RESULTS

Thirty-eight mothers of children up to two years of age were interviewed. Maternal age ranged from 18 to 43 years, with a mean of 27.6 years, and child age ranged from 1.5 to 24 months, with 17 children under six months of age and 21 aged six months old or older. The sociodemographic profile of the mothers showed a predominance of secondary education (n=31; 81.5%), of which 52.6% had completed and 28.9% had not completed this level. The most frequent occupation was homemaker, reported by 65.8% (n=25) of the participants. Regarding marital status, 63.2% (n=24) reported being married or in a stable union, whereas 34.2% (n=13) and 3.3% (n=1) reported being single and widowed, respectively, at the time of data collection (Table 1).

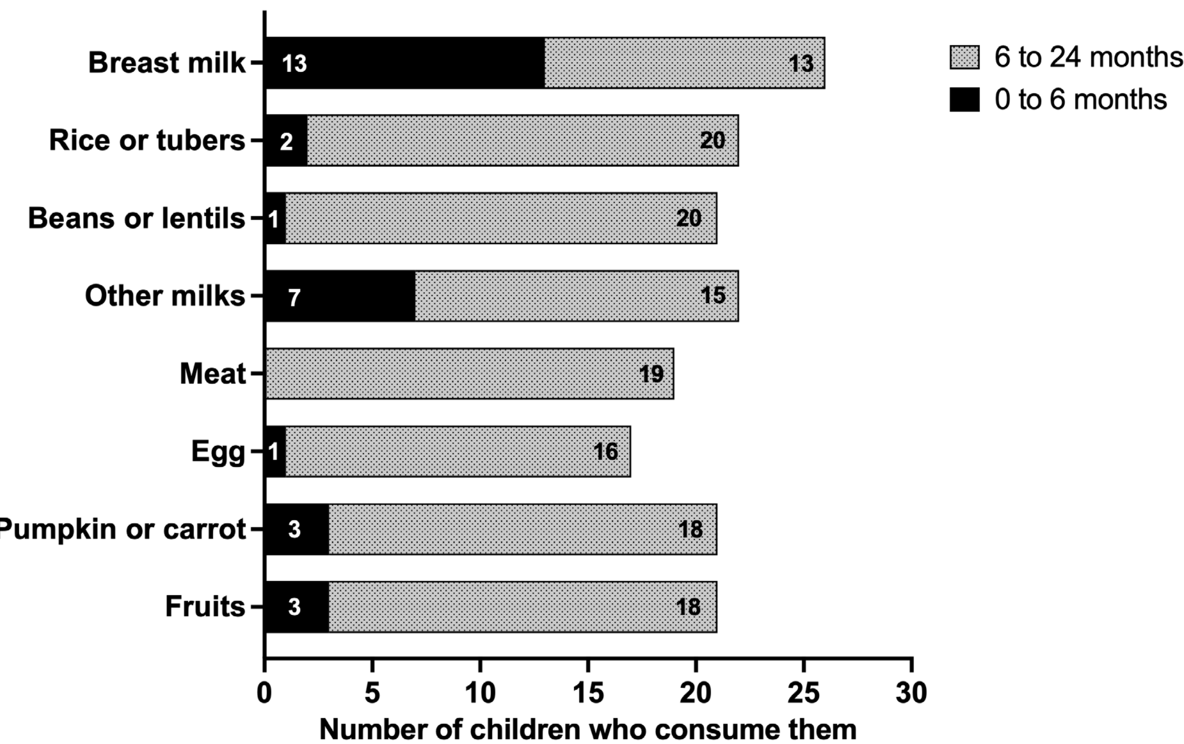
Among the eight food groups recommended by the WHO, rice, tubers, beans, and legumes were the most frequently consumed by children aged six months old or older (95.2% [n=20]), followed by meat (90.5% [n=19]) and fruits, pumpkin, and carrots (85.7% [n=18]). Among infants under six months of age, in addition to breast milk and other types of milk, the main foods consumed were fruits, pumpkin, and carrots, reported by 17.6% (n=3), followed by rice and tubers, reported by 11.8% (n=2) of the participants. The consumption of eggs and beans or lentils in this age group was reported by only one mother (Graphic 1).

Table 1. Sociodemographic characteristics of the participants (n=38).

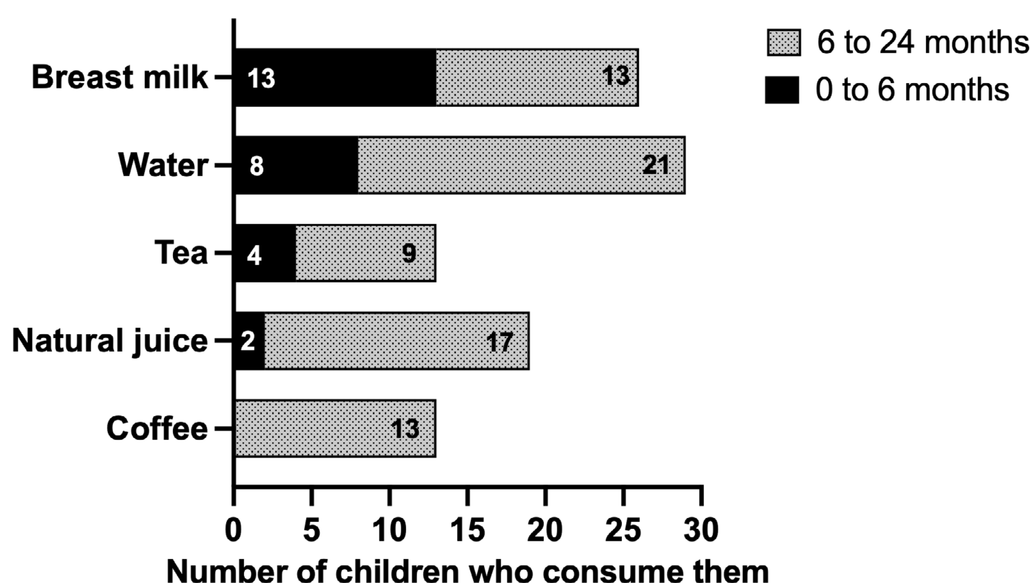
Age	**Years**	
Minimum	18	
Maximum	43	
Mean	27,3	
Marital status	**n**	**%**
Single	13	33.3
Married/Stable unión	24	63.3
Widowed	01	3.3
Educational level	**n**	**%**
Complete higher education	0	0
Incomplete higher education	01	02.6
Complete secondary education	20	52.6
Incomplete secondary education	11	28.9
Complete primary education	03	07.9
Incomplete primary education	03	07.9
Occupation	**n**	**%**
Housewife	25	65.8
Attendant	03	7.9
Self-employed	02	5.3
Hairdresser	02	5.3
Farm worker	02	5.3
Cook	01	2.6
Student	02	5.3
Saleswoman	01	2.6
Child's age (months)	**n**	**%**
<6	17	44.7
≥6 to 24	21	55.3

With regard to other liquid foods, natural fruit juice showed a high prevalence, being consumed by 80.1% (n=17) of children aged six months old or older and by 11.8% (n=2) of those younger than six months. Tea and coffee were also frequently reported among children aged six months old or older, with prevalences of 42.9% (n=9) and 61.9% (n=13), respectively. Among children younger than six months, only 47.1% (n=8) were still exclusively breastfed, and 23.5% (n=4) had been completely weaned. The main foods consumed in this age group were water (47.1% [n=8]) and other types of milk (41.2% [n=7]), followed by tea (23.5% [n=4]). Coffee consumption was not reported in this age group (Graphic 2).

This study also identified the consumption of ultra-processed foods and foods with added sugar, predominantly among children aged six months old or older. Among those younger than six months, only 5.9% (n=1) were reported to consume these foods, specifically cookies, which also showed the highest prevalence among children aged six months or older (61.9% [n=13]). Sweets (candies, chewing gum, lollipops), sweetened foods (with added sugar, honey, molasses, or sweeteners), and processed meats (sausages, hot dogs) were reported at similar frequencies, with 52.4% (n=11) of children consuming each of these items. Instant noodles, soft drinks, and processed juices were the least frequently reported, with prevalences of 33.3% (n=7), 28.6% (n=6), and 23.8% (n=5), respectively (Graphic 3).



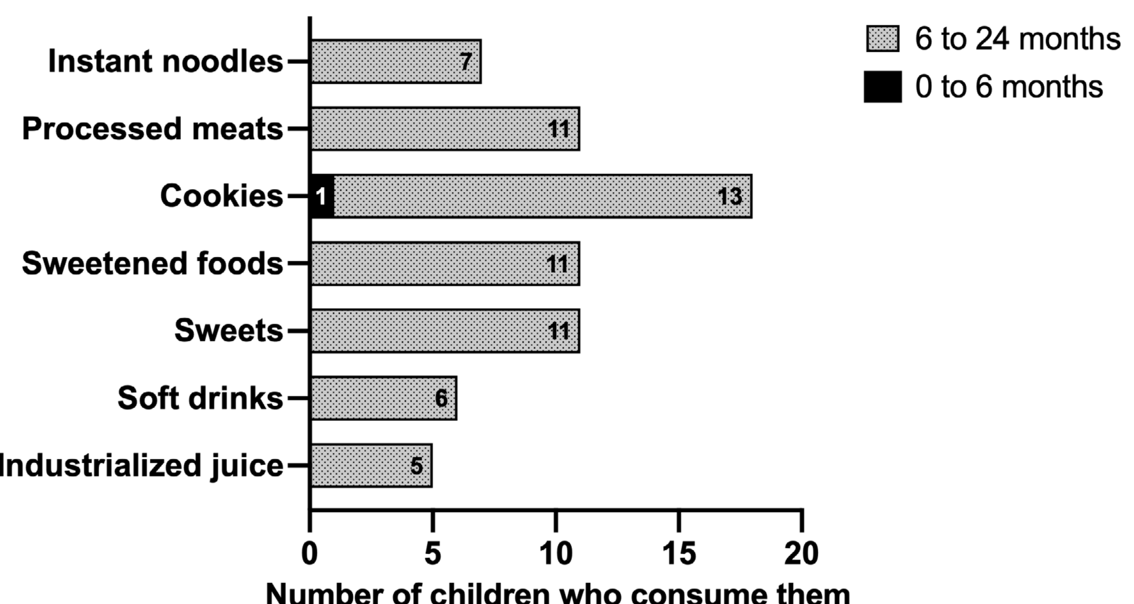
Graphic 1. Consumption of foods recommended by the World Health Organization among children up to 24 months of age in Picos (PI).



Graphic 2. Consumption of liquid foods among children up to 24 months of age in Picos (PI).

DISCUSSION

Exclusive breastfeeding should be maintained until six months of age; however, in this study, only 47.1% (n=8) of children under six months were exclusively breastfed. Similar results were reported in a 2015 study that analyzed data from the Food and Nutrition Surveillance System (*Sistema de*



Graphic 3. Consumption of ultra-processed foods and foods with added sugar among children up to 24 months of age in Picos (PI).

Vigilância Alimentar e Nutricional – Sisvan), which found that only 56.1% of Brazilian children under six months were exclusively breastfed[16]. Additionally, a study conducted in primary health care units in the city of Rio de Janeiro reported EBF rates of only 50.1%[17]. In comparison, the most recent population-based survey, the National Study of Infant Feeding and Nutrition (*Estudo Nacional de Alimentação e Nutrição Infantil* – ENANI-2019), showed that in Brazil, 45.8% of children under six months are exclusively breastfed, and in the Northeast Region this proportion decreases to 40.3%[18], corroborating the findings of the present study.

Several factors appear to be involved in this issue. Some studies have reported a higher prevalence of EBF among wealthier population groups, among children of parents with higher levels of education, among children of couples with marital stability, and among those whose mothers attended more than six prenatal visits[19-21]. Maternal occupation has also been associated with breastfeeding practices; however, findings are inconsistent across studies, as some research has shown that mothers who are unemployed or whose sole occupation is homemaker more frequently practice mixed breastfeeding[22,23]. The mothers who participated in this study live in a socially vulnerable neighborhood, and the predominant occupation was homemaker; therefore, they fit the profile most often associated with mixed breastfeeding and early weaning.

In addition, other reasons cited by mothers to justify early weaning include low milk production, the perception of "weak milk" or insufficient milk to satisfy the child's hunger, infant refusal, and having a nipple considered unfavorable for breastfeeding[22,24,25]. It has also been observed that such beliefs are often reinforced by family members, especially the children's grandmothers, who may exert greater influence on first-time mothers, possibly due to their inexperience[21]. Thus, behavior is shaped not only by intellectual knowledge but also by beliefs and cultural factors present in the maternal context, indicating that access to information alone does not necessarily guarantee adequate breastfeeding practices[23].

This study found that water was the most frequently introduced liquid in the diets of children under six months of age, reported by 88.9% of mothers who had already initiated some form of complementary

feeding. This finding has also been reported in other studies[23], likely because mothers believe that breast milk is insufficient to quench the child's thirst. Complementary feeding often begins with liquid foods, as observed in a study conducted in Rio Grande do Sul, in which 36% of mothers introduced complementary feeding with juices or soups[26]. This practice is contraindicated by the WHO and the MS, as these foods have a high sugar content and may promote early satiety, thereby reducing the intake of other nutritionally adequate foods[1,27].

The introduction of other types of milk, characterized as mixed feeding and observed among the mothers interviewed, is also common in Brazil[22]. According to ENANI-2019, a national prevalence of 19.8% for this practice was observed among children under six months of age, increasing to 26.8% in the Northeast Region[18]. Despite this considerable prevalence, the introduction of other milks, as well as any other foods before six months of age, is considered harmful to infant health and is associated with a higher risk of cardiovascular diseases, obesity, atopy, exposure to contamination from foods and feeding devices (such as nipples and bottles), anemia, and infectious diseases[21,28,29]. Furthermore, it may lead to a reduction or interruption of breastfeeding and decreased milk production[30].

For children between six and 24 months of age, a key factor in ensuring adequate nutrient intake for development is minimum dietary diversity, defined as the daily consumption of at least five of the eight appropriate food groups[1]. According to ENANI-2019, 57.1% of children met this criterion; however, in the Northeast Region, this proportion decreased to 48.5%[31]. In a study conducted in the state of Bahia with 12-month-old children, only 38.8% met the adequacy criterion[32]. In the present study, 90.47% of mothers reported that their children consumed the estimated amount of food within the diversity range, a proportion similar to the 81.2% observed in Paraná[33]. However, mothers were not asked whether the consumption of these foods occurred on a daily basis, which may partially explain the discrepancy between the findings.

With regard to solid, semi-solid, or pasty foods, their introduction should be encouraged from the beginning of complementary feeding, as their consistency stimulates chewing and the acceptance of new foods, in addition to increasing the energy and nutrient density of the diet[16]. Among these foods, cereals and tubers were the most frequently consumed by the population in this study, in agreement with Brazilian data[33]. Meat also showed a high prevalence, consistent with findings from other national studies, which is a positive indicator, as it is the main source of iron, with high bioavailability, as well as other micronutrients[33,34].

Vitamin A also deserves attention, as it is a nutrient found primarily in orange-colored vegetables, such as pumpkin and carrots, and its deficiency is associated with an increased risk of infections and visual impairment, which may progress to blindness[27]. Studies have reported low consumption of foods that are sources of vitamin A, with prevalences of 26.8% in a study conducted in Bahia[33], 37.9% in the Northeast Region, and 38.6% in Brazil, according to a national survey[31]. In contrast, in the present study, 85.7% (n=13) of mothers reported that their children consumed foods rich in this vitamin. This discrepancy may be related to methodological differences, as the present study assessed whether children consumed these foods in general, whereas the comparative studies recorded dietary intake on a specific day, which may indicate that consumption occurs, but not necessarily at the recommended frequency.

The problem of early exposure to added sugars and ultra-processed foods is evident in this study, as 85.7% of children aged 6 to 24 months had consumed at least one type of these products. Similar findings have been reported in other studies, in which 70 to 100% of children had tried such foods[35,36] before the

minimum age of two years recommended by the WHO and the MS[1,27]. In Brazil, 68.4 and 80.5% of children in this age group had consumed foods with added sugars and ultra-processed foods, respectively, with comparable proportions observed in the Northeast Region (66.3 and 82%)[31]. Cookies, soft drinks, sweets, and snacks were the most frequently consumed items in this category[24,37], consistent with the findings of the present study.

Several factors may be associated with the availability and consumption of ultra-processed foods, including guidance provided to mothers regarding appropriate nutrition, EBF up to six months of age, and maternal educational level. Mothers with higher levels of education tend to offer fewer ultra-processed foods to their children and are also more likely to practice breastfeeding, and breastfed children generally present a more adequate dietary profile[38-40]. Additionally, higher consumption of ultra-processed foods has been observed in households with fewer residents and in those in which the mother was not the primary caregiver, highlighting the importance of the family support network[36].

It is important that complementary feeding be addressed and promoted early within the context of PHC, as delaying the child's first consultation at the UBS may be associated with the early introduction of ultra-processed foods[38]. This emphasis is justified by the fact that early and prolonged consumption of these foods can lead to several health problems, impairing appetite regulation and satiety due to their high sugar and fat content; therefore, the later they are introduced into the child's diet, the better[41,42]. In addition, their consumption is associated with an increasingly early onset of chronic diseases, as it contributes to inadequate complementary feeding, which is a risk factor for childhood obesity[38,40]. This occurs because these foods are characterized by high energy density, high contents of sugars, saturated fats, sodium, and preservatives, and low levels of fiber and micronutrients[43].

Finally, it is emphasized that the present study was conducted within the context of mothers attending a specific UBS located in a socially vulnerable area of the municipality. Therefore, the need for studies with a broader population scope within the municipality is highlighted, encompassing different maternal profiles, in order to obtain more comprehensive information and enable a more representative assessment of the local context.

CONCLUSION

This study made it possible to characterize the complementary feeding practices of children up to 24 months of age whose mothers attend the UBS investigated in the city of Picos (PI). Relevant positive aspects were identified, such as the high frequency of consumption of unprocessed foods and of food groups considered essential to meet the nutritional requirements for adequate child development.

However, some concerning indicators were also identified, such as low rates of exclusive breastfeeding and, consequently, early introduction of solid foods, in addition to high consumption of foods with added sugars and ultra-processed foods, which should be avoided at all ages and should not be introduced before two years of age.

With this in mind, attention should be directed to factors potentially associated with adequate complementary feeding, such as professional guidance on infant nutrition, prenatal care, promotion of breastfeeding, maternal educational level, maternal availability, and family income. This approach may contribute to the development of targeted intervention strategies at governmental and social levels, aimed at reinforcing positive practices and addressing identified shortcomings, in order to promote, as effectively as possible, food dignity for Brazilian children.

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CONFLICT OF INTERESTS

Nothing to declare.

AUTHORS' CONTRIBUTIONS

DSV: Conceptualization, Writing – original draft, Writing – review & editing, Investigation, Methodology, Visualization. FKCM: Conceptualization, Investigation, Methodology, Visualization. LCS: Investigation, Methodology. RSC: Investigation, Methodology. PFG: Conceptualization, Data curation, Writing – review & editing, Methodology, Supervision, Visualization. AFMS: Conceptualization, Data curation, Writing – review & editing, Methodology, Supervision, Visualization.

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