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# Prevalence of inadequate intake of folate in the post-fortification era: data from the Brazilian National Dietary Surveys 2008–2009 and 2017–2018

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## Abstract

The objectives were to compare the evolution of dietary folate intake, to estimate the prevalence of folate inadequacy (POFI) and the contribution of food groups to folate intake (dietary folate plus folic acid from fortified foods) in two post-fortification periods in the Brazilian population, according to life stages, geographic regions and per capita income. Population-based study including representative data from the National Dietary Survey – Brazilian Household Budget Surveys (NDS-HBS) 2008–2009 and 2017–2018, with a total of 32 749 (2008–2009) and 44 744 (2017–2018) individuals aged ≥ 10 years old, excluding pregnant and lactating women. The National Cancer Institute method was used to estimate the distributions of usual dietary folate intake. POFI was estimated according to estimated average requirement cut-off point method. After 10 years of the first NDS-HBS, POFI has increased in all sex-age groups, except for 10–13 years. POFI among women of reproductive age was around 30 and 40 % in 2008–2009 and 2017–2018. Higher POFI was observed in the North region. The top five food groups contributors to folate intake in Brazil were beans, breads, pasta and pizza, cakes and cookies and non-alcoholic beverages groups in both periods, differing in the rank order of the last two groups. Although being a country that has adopted mandatory folic acid flour fortification for almost two decades, increased POFI was observed in 2017–2018. This study brings significant scientific information, which can help understand folate dietary data in different contexts and consequently guide the approach for public health fortification strategies.

**Key words:** **Folate: Folic acid: Mandatory food fortification**

Vitamin $B_9$, also called folate, is one of B-complex water-soluble vitamins, being naturally found in a wide range of foods, as dark green leafy vegetables, beans, citric fruits, nuts, eggs, liver, seafood and others[1–3]. Folate plays an important role in cell growth and replication, being involved in DNA synthesis and maintainance[2–4] as well as in epigenetic mechanisms, including DNA, RNA and proteins methylation[4]. Inadequate folate intake and consequently poor maternal folate status during pregnancy have been associated with relevant negative outcomes for the mother–child pair, as pre-eclampsia, spontaneus abortion, abruptio placentae, preterm deliveries, low birth weight and congenital anomalies affecting both brain and spine cords, as spina bífida, anencephaly and encephalocele, known as neural tube defects[3]. Global pregnancies affected by neural tube defects were estimated as 260 100 in the year 2015, with an overall prevalence of 186 (153–230) per 100 000 live births[5].

In this context, folate is a nutrient of great interest for public health, leading to policy implementation of staple food fortification with folic acid, the synthetic form of this vitamin, to improve folate status mainly in the target group, women of reproductive age[3,6]. Food fortification with folic acid can be either mandatory or voluntary, depending on public health goals and nationals scenarios. The introduction of mandatory folic acid fortification has been first established in the USA and Canada in 1998[6], and in Brazil in 2002 (wheat and maize flour)[7]. Nowadays, eighty-six countries have legistation for mandatory folic acid fortification with wheat flour alone, or combined with other grains as maize and rice, except for Papua New Guinea that fortifies only

**Abbreviations** DFE, dietary folate equivalent; NDS-HBS, National Dietary Survey – Brazilian Household Budget Surveys; POFI, prevalence of folate inadequacy.

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rice[8]. So, bakery products (as breads, cookies, cakes, pancakes), pastas, ready-to-eat cereals, rice and others are also food sources contributing to dietary folate intake in countries that voluntarily or mandatorily fortify with folic acid[2,6].

The main benefits of fortifying foods with folic acid are that this strategy may improve folate status and reduce the occurrence of neural tube defects[3,8]. Worldwide data from live births showed that pooled prevalence of spina bifida per 100 000 births was lower in geographical regions with mandatory folic acid fortification (33·86; 95 % CI 31·05, 36·92) compared to those with voluntary one (48·35; 95 % CI 41·07, 56·93)[9]. Globally, it has been estimated that 65 380 folic acid-preventable spina bifida and anencephaly cases were avoided through wheat and/or maize flour mandatory folic acid fortification in 2019[10], reinforcing the importance of this public health strategy.

Brazilian prevalences of neural tube defects were 22·8, 34 and 30·1 % lower considering live births, stillbirths and all births in the post-fortification period (2005–2014) compared with the pre-fortification one (2001–2004)[11]. Although there is no representative folate status biomarkers data for overall Brazilian population with emphasis in the women of reproductive age group, the prevalence of global folate deficiency for this group has been estimated above 20 % in low income and less than 5 % in higher income countries[12]. With regard to dietary intake, data from the first National Dietary Survey – Household Budget Surveys (NDS-HBS, in portuguese *Análise do Consumo Alimentar Pessoal no Brasil – Pesquisa de Orçamentos Familiares*) performed in 2008–2009 allowed an overview of folate intake across all over the country[13] and can be updated with a new edition of NDS-HBS been released recently[14].

Considering the importance of folate and its impact in public health programmes delineation, implementation and monitoring, this population-based study aimed to compare dietary folate intake and estimate the prevalence of folate inadequacy (POFI) in two distinct post-fortification periods (2008–2009 and 2017–2018) in the Brazilian population, according to life stages, geographic regions and per capita income.

## Methods

### Study population and design

Subsamples of the HBS of 2008–2009 and 2017–2018 were used for this analysis. The HBS surveys are conducted by the Brazilian Institute of Geography and Statistics, considering an interval of approximately one decade, in order to measure household consumption, expenditures and income, allowing to draw a profile of the living conditions of Brazilian population[13,14]. The two most recent HBS included food intake data. Both surveys had two-stage cluster sampling, in which census sectors and households were randomly selected with geographical and socio-economic stratifications of the primary sampling units based on the 2000 Demographic Census. Data were collected throughout 12 months: HBS 2008–2009 from May 2008 to May 2009 and HBS 2017–2018 from July 2017 to July 2018.

Of the total 55 970 households[13] included in the 2008–2009 HBS, 34 003 individuals 10 years or older, from a subsample of 13 569 randomly selected households, collected individual food consumption data. From the 2017–2018 HBS, of the 57 920 households[14], 46 164 individuals from a subsample of 20 112 households collected data on individual food consumption. Further detailed information about sampling and data collection can be found in previous publication by Brazilian Institute of Geography and Statistics [13,14].

In the present study, we have excluded pregnant and lactating women (*n* 1254 in 2008–2009 and *n* 1420 in 2017–2018) from the analysis, making a total of 32 749 and 44 744 individuals, respectively.

### Dietary intake assessment

In 2008–2009, dietary data were collected by two non-consecutive food records within a week, which consisted of a self-report of all foods and beverages consumed through the whole day, that is, over 24 h. To fill in the food records, individuals were instructed to register detailed information about time and eating occasions, portion sizes in household measures, ingredients, recipes and meal places (home or eating out). Moreover, the research agents reviewed the records along with the participants, adding missing or incomplete information when necessary during the household's interviews, with provided information being typed on a tablet using a specific data entry programme[13].

Regarding 2017–2018, dietary data were obtained through personal interviews of two non-consecutive 24-h dietary recall[14], conducted by trained research agents. These interviews followed a structured approach, based on the U.S. Department of Agriculture Automated Multiple-Pass Method[15], using a specifically software developed for this data collection, supported by a tablet. First, the research agents asked the participants to list all foods and beverages consumed in the previous day of each interview (over the past 24 h), creating the so-called quick list. Then, information about foods, beverages and recipes, portion sizes in household measures, preparation cooking techniques, items of addition, eating occasion and meal places was recorded[14].

In both surveys, the Table of Reference Measures for Food Consumed in Brazil[16] was used to convert food and beverages in grams and mililiters[13,14]. Subsequently, dietary folate intake, expressed as dietary folate equivalents (DFE), was calculated using the Brazilian Food Composition Table (TBCA-USP), version 7.0[17]. DFE were defined as follows: DFE = food folate (μg) + (1·7 × folic acid (μg))[1]. These data refer only to dietary folate intake, since supplement use was not evaluated.

### Statistical analysis

The National Cancer Institute method[18] was used to estimate the distributions of usual dietary folate intake. In this approach, a second food record or 24-h dietary recall is used to estimate day-to-day (within-person) variation in dietary intake. This parameter, along with other estimated by National Cancer Institute model (population mean, between-person variance, lambda value for the Box-Cox transformation, and the effect of sex age, region and income) is used as input in a Monte Carlo simulation to generate the usual folate intake distributions.

Sex-age groups were categorised as defined by the Institute of Medicine, for which there are reference intake values

established[1]: 10–13 years, 14–18 years, 19–30 years, 31–50 years and ≥ 51 years old. For women of reproductive age, which are of special interest since they are the main target population for the folic acid fortification, it was considered the age groups from 19 to 31 and 31 to 50, once the reference intakes are the same. Dietary folate intake, expressed as μg DFE, refers only to dietary intake and does not include any intake from dietary supplements, since supplement data were only collected in NDS-HBS 2017–2018, being unavailable in the 2008–2009 survey.

POFI was estimated using the estimated average requirement cut-point method[1,19]. Estimated average requirementis the daily amount of a nutrient estimated to meet the requirement of 50 % of healthy individuals regarding specific sex and life stage groups[1,19]. Mean intakes and prevalence of intake inadequacy were estimated for the population and stratified by age-sex groups, geographic regions (North, Northeast, Southeast, South and Center-West) and income level. Income level was expressed as household per capita income in minimum wages (< 0·5, 0·5–1, 1–2 and > 2) considering the value for the corresponding survey (US$ 174·4 in January 2009 and US$ 298·1 in January 2018).

The 95 % CI was calculated for means and POFI, based on the standard error values estimated using the balanced repeated replication technique, ran as a part of the National Cancer Institute method[18]. The results from the 95 % CI were used to compare the POFI across sex-age groups, regions and income between the surveys, by determining if the intervals overlapped. The SAS macros provided on National Cancer Institute website (mixtran and distrib) were used to estimate the usual intakes distribution. These statistical analyses were performed in SAS® software, version 9.4 of the SAS System for Windows.

Foods were categorised into groups according to their conceptual and nutritional similarities, as follows: alcoholic drinks, added sugars and sweeteners, beans, breads, cakes and cookies, cassava flour and farofas, coffee and teas, dairy products, eggs, fortified maize flour recipes, fruits and nuts/seeds, legumes, meats, non-alcoholic beverages, oils and fats, pasta and pizza, rice and& other cereals, soft drinks, soups and vegetables. We have analysed how much each food group have contributed for folate intake for the whole country and for all five geographic regions in both study periods. Food group contributors analysis was performed using STATA® Statistics/Data Analysis software, version 14.2. All analyses were weighted and took into account the complexity of the surveys.

## Results

Data presented in Table 1 show means and POFI among the overall population and sex-age groups. The overall POFI was higher in 2017–2018 (32·1 %; 95 % CI 30·9, 33·3) compared with 2008–2009 (25·2; 95 % CI 24·0, 26·3). Regarding sex-age groups, with the exception of 10–13 years old of both sexes, POFI values were higher in 2017–2018 than the previous edition. Moreover, it has also increased among women of reproductive age, with figures above 40 % in 2017–2018 while around 30 % in 2008–2009. The highest POFI was observed in women ≥ 51 years old in 2017–2018 (48·9 %; 95 % CI 48·0, 49·9) whereas the lowest one was described in 10–13 years old men group in 2008–2009 (10·1 %; 95 % CI 9·2, 11·0), as presented in Table 1.

With regard to men, the POFI among those in the fist quartile of family income *per capita* did not change overtime, but it was higher in 2017–2018 among those from 14 to 18 years old in the second quartile. In addition, men of all age groups from the third and fourth quartiles of income, besides 10–13 years old, have shown increased percentages of POFI in 2017–2018 (Table 2). For women, only the 10–13-year-old group did not differ among all quartiles of income comparing both survey periods. Considering the other age groups, with exception of 19–30 years old in the second quartile of income, all prevalences were around or above 40 % in 2017–2018 (Table 3).

North, the Brazilian geographic region that englobes Amazon rainforest, had the highest POFI in all age groups for both men (Table 4) and women (Table 5) in both survey periods when compared with the other regions in the country. It should also be pointed that the POFI in women of reproductive age of all regions has increased in 2017–2018 compared with 2008–2009, with the exception of 19–30-year-old group in the Northeast region. Furthermore, still considering this specific group, the prevalence of inadequacy was greater than 60 % in the North region and around or above 40 % in the other four regions in 2017–2018 (Table 5).

The top five food groups contributors to folate intake in the whole country were beans (all types of beans and peas, dishes prepared with beans and peas, vegetable proteins), breads (all types of bread), pasta and pizza (all types of pasta, pizzas, sandwiches, fried or baked cafeteria itens), cakes and cookies (all types of cakes, cookies and crackers) and non-alcoholic beverages (natural or pulp fruit juice, industrialised fruit juice, soya-based juice) groups in both periods, differing only in the rank order of the last two food groups. With regard to geographical regions, the top three food groups were all the same, following this order: beans, bread and pasta and pizza, cakes and cookies. The fourth and fifth places differed among the geographical regions, being meats (all types of animal protein including cattle, pork, chicken, fish, processed meat as salami, ham, mortadella, sausage and meat-based preparations), non-acoholic beverages or fortified maize flour recipes (regional dishes prepared with fortified maize flour) (Table 6).

Furthermore, beans, breads, pasta and pizza, cakes and cookies and non-alcoholic beverages were the most important contributors to folate intake among the age groups from 10 to 13 years, 14 to 18 years, 19 to 30 years and 31 to 50 years, while beans, breads, pasta and pizza, fruits and nuts/seeds, and cakes and cookies among those ≥ 51 years old, in both study periods.

## Discussion

This study has investigated the mean dietary intake of folate and the prevalence of inadequacy of this vitamin on large representative national data of two surveys in the post-fortification era. After 10 years of the first NDS-HBS survey, POFI has increased in all sex-age groups, excepted for 10–13-year-old males and females. POFI among women of reproductive age was around

**Table 1.** Dietary folate intake (μg DFE) and prevalence of folate inadequacy (POFI) according to sex and age group. Brazilian National Dietary Survey: 2008–2009 and 2017–2018 (Numbers; mean values and 95 % confidence intervals)

| | 2008–2009 | | | | | 2017–2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sex-age group | *n* | Mean | 95 % CI | POFI | 95 % CI | *n* | Mean | 95 % CI | POFI | 95 % CI |
| Men | | | | | | | | | | |
| 10–13 years | 1515 | 455·9 | 447·9, 463·9 | 10·1 | 9·2, 11·0 | 1730 | 433·4 | 412·1, 454·7 | 11·5 | 9·2, 13·7 |
| 14–18 years | 1905 | 524·5 | 506·1, 542·9 | 14·7 | 12·3, 17·2 | 2196 | 477·4 | 462·2, 492·7 | 20·2 | 18·0, 22·4 |
| 19–30 years | 3756 | 522·8 | 512·3, 533·3 | 13·1 | 11·8, 14·4 | 4173 | 481·4 | 471·0, 491·8 | 17·6 | 16·2, 19·0 |
| 31–50 years | 5064 | 502·5 | 497·4, 507·6 | 15·5 | 14·9, 16·2 | 6887 | 474·0 | 470·4, 477·6 | 18·6 | 17·9, 19·4 |
| ≥ 51 years | 3460 | 464·2 | 454·7, 473·7 | 21·3 | 19·3, 23·4 | 6474 | 435·3 | 428·9, 441·4 | 25·6 | 24·5, 26·7 |
| Women | | | | | | | | | | |
| 10–13 years | 1566 | 412·1 | 398·3, 425·9 | 15·7 | 13·6, 17·7 | 1519 | 393·5 | 378·2, 408·8 | 17·0 | 14·7, 19·3 |
| 14–18 years | 1811 | 427·8 | 417·0, 438·5 | 30·5 | 27·8, 33·1 | 2071 | 372·5 | 358·1, 386·9 | 43·0 | 39·3, 46·7 |
| 19–30 years | 3787 | 399·9 | 392·3, 407·6 | 34·1 | 32·0, 36·1 | 3958 | 368·8 | 362·1, 381·7 | 41·2 | 38·0, 44·4 |
| 31–50 years | 5804 | 392·5 | 388·4, 396·5 | 35·9 | 34·7, 37·0 | 7982 | 354·0 | 343·1, 364·8 | 45·3 | 42·6, 48·0 |
| ≥ 51 years | 4081 | 372·5 | 368·5, 376·5 | 41·0 | 39·9, 42·1 | 7754 | 341·5 | 339·0, 344·0 | 48·9 | 48·0, 49·9 |
| All | 32749 | 446·0 | 441·5, 450·5 | 25·2 | 24·0, 26·3 | 44744 | 408·5 | 401·4, 415·5 | 32·1 | 30·9, 33·3 |

**Table 2.** Dietary folate intake (μg DFE) and prevalence of folate inadequacy (POFI) among men according to age group and per capita family income. Brazilian National Dietary Survey: 2008–2009 and 2017–2018 (Numbers; mean values and 95 % confidence intervals)

| | 2008–2009 | | | | | 2017–2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Income and Age group | *n* | Mean | 95 % CI | POFI | 95 % CI | *n* | Mean | 95 % CI | POFI | 95 % CI |
| First quartile | | | | | | | | | | |
| 10–13 years | 622 | 432·0 | 419·6, 444·3 | 12·9 | 11·1, 14·7 | 600 | 416·6 | 404·3, 428·9 | 13·5 | 11·8, 15·1 |
| 14–18 years | 619 | 493·5 | 467·2, 519·7 | 18·8 | 14·2, 23·3 | 701 | 460·2 | 446·8, 473·6 | 23·3 | 20·5, 26·0 |
| 19–30 years | 849 | 494·8 | 474·2, 515·3 | 16·7 | 13·8, 19·5 | 943 | 462·7 | 450·3, 475·2 | 20·6 | 18·2, 23·1 |
| 31–50 years | 1089 | 472·7 | 461·6, 483·8 | 19·8 | 17·7, 22·0 | 1314 | 456·6 | 438·8, 474·4 | 21·3 | 17·5, 25·1 |
| ≥ 51 years | 407 | 433·0 | 413·6, 452·4 | 26·5 | 22·3, 30·8 | 616 | 418·0 | 404·4, 431·6 | 28·7 | 25·4, 31·9 |
| Second quartile | | | | | | | | | | |
| 10–13 years | 454 | 473·5 | 465·2, 481·9 | 8·3 | 7·4, 9·1 | 562 | 451·2 | 424·5, 477·9 | 9·4 | 6·8, 12·0 |
| 14–18 years | 591 | 538·7 | 524·9, 552·6 | 13·0 | 11·4, 14·6 | 723 | 495·8 | 473·6, 518·1 | 17·3 | 14·3, 20·3 |
| 19–30 years | 1020 | 537·7 | 526·6, 548·7 | 11·3 | 10·2, 12·5 | 1252 | 501·9 | 488·1, 515·8 | 14·6 | 12·6, 16·5 |
| 31–50 years | 1314 | 517·0 | 502·8, 531·3 | 13·7 | 12·0, 15·4 | 1884 | 493·5 | 485·7, 501·3 | 15·7 | 14·4, 16·9 |
| ≥ 51 years | 807 | 474·7 | 463·7, 485·8 | 19·3 | 17·3, 21·4 | 1421 | 455·7 | 446·9, 464·6 | 21·6 | 20·1, 23·1 |
| Third quartile | | | | | | | | | | |
| 10–13 years | 283 | 474·7 | 462·2, 487·1 | 8·4 | 7·3, 9·5 | 388 | 438·0 | 411·7, 464·3 | 10·7 | 8·5, 13·0 |
| 14–18 years | 432 | 540·5 | 524·8, 556·3 | 12·9 | 11·1, 14·7 | 536 | 483·4 | 462·6, 504·2 | 19·2 | 16·2, 22·1 |
| 19–30 years | 1019 | 539·2 | 526·3, 552·1 | 11·3 | 9·9, 12·6 | 1199 | 486·9 | 472·3, 501·5 | 16·7 | 15·2, 18·2 |
| 31–50 years | 1348 | 517·2 | 509·1, 525·4 | 13·6 | 12·6, 14·7 | 2097 | 479·5 | 470·5, 488·5 | 17·9 | 16·6, 19·2 |
| ≥ 51 years | 1178 | 477·1 | 464·4, 489·9 | 19·4 | 17·0, 21·8 | 2442 | 440·7 | 429·7, 451·7 | 24·5 | 22·5, 26·5 |
| Fourth quartile | | | | | | | | | | |
| 10–13 years | 156 | 452·0 | 437·7, 466·4 | 10·7 | 9·1, 12·3 | 180 | 420·7 | 399·2, 442·1 | 13·0 | 9·8, 16·1 |
| 14–18 years | 263 | 518·3 | 498·3, 538·3 | 15·7 | 12·4, 18·9 | 236 | 466·0 | 448·0, 484·0 | 21·9 | 19·5, 24·2 |
| 19–30 years | 868 | 514·0 | 503·2, 524·8 | 14·1 | 12·7, 15·4 | 779 | 469·1 | 454·2, 484·0 | 19·6 | 17·5, 21·6 |
| 31–50 years | 1313 | 495·6 | 487·7, 503·5 | 16·4 | 15·5, 17·3 | 1592 | 461·8 | 455·2, 468·3 | 20·5 | 19·5, 21·5 |
| ≥ 51 years | 1068 | 455·9 | 447·7, 464·1 | 22·5 | 20·7, 24·3 | 1995 | 424·2 | 418·6, 429·7 | 27·9 | 27·0, 28·8 |

DFE = dietary folate equivalents (μg) = food folate (μg) + (1·7 × folic acid (μg)).

30 % in 2008–2009 and has recently raised to around 40 % in 2017–2018. Higher POFI was observed among all age groups in the North Brazilian region.

Brazil is the fifth largest country in the world, with distinct national territory organisation divided into five geographical regions, characterised by a great diversity of natural, socio-economic, cultural and political aspects[20]. These range of factors have deeply contributed to the development of regional food eating habits and traditional dishes[13,14]. Recent data indicated that, according to a food security scale, the prevalence of food security was greater in the Southeast (68·8 %), South (79·3 %) and Central-West regions (64·8 %) than the figures observed in the North and Northeast regions' households (less than a half)[21]. The North region is the largest one considering territorial extension, including the Amazon rainforest, and its geographic condition is also a determinant for economic aspects and access to food[20], which may explain why this region had presented the highest POFI in the country, concomitant to low levels of food security[21].

In the present study, overall mean dietary folate intake was 446 (95 % CI 441·5, 450·5) μ DFE in 2008–2009 and 408·5 (95 % CI 401·4, 415·5) μ DFE in 2017–2018 in participants equal or above 10 years old. Recent data from the National Health and Nutrition Examination Survey 2017–2018 showed mean

**Table 3.** Dietary folate intake (μg DFE) and prevalence of folate inadequacy (POFI) among women according to age group and per capita family income. Brazilian National Dietary Survey: 2008–2009 and 2017–2018 (Numbers; mean values and 95 % confidence intervals)

| | 2008–2009 | | | | | 2017–2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Income and Age group | *n* | Mean | 95 % CI | POFI | 95 % CI | *n* | Mean | 95 % CI | POFI | 95 % CI |
| First quartile | | | | | | | | | | |
| 10–13 years | 601 | 391·3 | 379·9, 402·7 | 18·7 | 16·4, 21·1 | 597 | 378·7 | 361·4, 395·9 | 19·8 | 16·1, 23·5 |
| 14–18 years | 555 | 403·0 | 382·4, 423·6 | 36·0 | 31·1, 40·9 | 666 | 355·0 | 346·9, 363·1 | 47·9 | 45·6, 50·2 |
| 19–30 years | 902 | 373·8 | 358·8, 388·9 | 40·3 | 36·3, 44·3 | 960 | 353·7 | 344·1, 363·4 | 45·4 | 42·5, 48·2 |
| 31–50 years | 1243 | 367·1 | 354·4, 379·8 | 42·4 | 38·8, 46·0 | 1666 | 338·5 | 329·6, 347·3 | 49·8 | 47·1, 52·4 |
| ≥ 51 years | 393 | 348·6 | 331·7, 365·5 | 47·6 | 43·1, 52·2 | 648 | 328·2 | 311·6, 344·8 | 53·1 | 48·1, 58·2 |
| Second quartile | | | | | | | | | | |
| 10–13 years | 497 | 424·8 | 401·1, 448·5 | 14·0 | 10·4, 17·7 | 459 | 412·7 | 398·1, 427·3 | 14·1 | 12·3, 16·0 |
| 14–18 years | 562 | 440·1 | 429·0, 451·3 | 27·4 | 25·2, 29·7 | 674 | 388·2 | 368·3, 408·1 | 39·0 | 33·9, 44·1 |
| 19–30 years | 1064 | 411·8 | 405·2, 418·5 | 31·4 | 29·8, 33·1 | 1199 | 384·8 | 368·3, 401·4 | 36·9 | 32·9, 40·9 |
| 31–50 years | 1553 | 403·8 | 392·5, 415·1 | 33·1 | 30·8, 35·5 | 2269 | 369·5 | 355·2, 383·8 | 41·1 | 37·6, 44·6 |
| ≥ 51 years | 952 | 380·7 | 370·3, 391·2 | 39·0 | 36·6, 41·4 | 1768 | 357·3 | 352·5, 362·0 | 44·2 | 42·7, 45·6 |
| Third quartile | | | | | | | | | | |
| 10–13 years | 301 | 428·9 | 414·0, 443·8 | 13·3 | 10·9, 15·7 | 319 | 397·4 | 378·4, 416·5 | 16·3 | 13·7, 18·9 |
| 14–18 years | 414 | 443·4 | 428·6, 458·3 | 27·2 | 23·8, 30·5 | 493 | 376·2 | 356·1, 396·4 | 41·9 | 37·3, 46·5 |
| 19–30 years | 991 | 411·5 | 401·5, 421·6 | 31·4 | 29·1, 33·7 | 1118 | 373·3 | 356·4, 390·1 | 40·2 | 36·1, 44·3 |
| 31–50 years | 1553 | 406·0 | 400·5, 411·5 | 32·6 | 31·2, 34·1 | 2379 | 357·9 | 342·6, 373·2 | 44·1 | 40·1, 48·2 |
| ≥ 51 years | 1425 | 383·8 | 379·4, 388·3 | 38·0 | 36·7, 39·3 | 2910 | 346·2 | 339·7, 352·7 | 47·5 | 45·6, 49·4 |
| Fourth quartile | | | | | | | | | | |
| 10–13 years | 167 | 406·8 | 390·3, 423·3 | 16·2 | 14·3, 18·1 | 144 | 381·8 | 367·0, 396·7 | 18·8 | 16·5, 21·1 |
| 14–18 years | 280 | 419·8 | 412·2, 427·4 | 32·3 | 30·1, 34·5 | 238 | 361·4 | 339·0, 383·9 | 45·7 | 39·5, 51·9 |
| 19–30 years | 830 | 392·2 | 381·0, 403·5 | 35·9 | 32·9, 38·9 | 681 | 357·8 | 342·2, 373·3 | 44·3 | 40·5, 48·0 |
| 31–50 years | 1455 | 385·9 | 379·7, 392·2 | 37·3 | 35·9, 38·7 | 1668 | 343·7 | 330·4, 357·0 | 48·3 | 44·6, 52·1 |
| ≥ 51 years | 1311 | 364·7 | 357·6, 371·9 | 43·2 | 41·3, 45·0 | 2428 | 332·3 | 328·3, 336·3 | 51·6 | 50·4, 52·7 |

DFE = dietary folate equivalents (μg) = food folate (μg) + (1·7 × folic acid (μg)).

**Table 4.** Dietary folate intake (μg DFE) and prevalence of folate inadequacy (POFI) among men according to regions and age group. Brazilian National Dietary Survey: 2008–2009 and 2017–2018 (Numbers; mean values and 95 % confidence intervals)

| | 2008–2009 | | | | | 2017–2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Regions and Age group | *n* | Mean | 95 % CI | POFI | 95 % CI | *n* | Mean | 95 % CI | POFI | 95 % CI |
| North | | | | | | | | | | |
| 10–13 years | 278 | 386·6 | 375·3, 397·8 | 19·4 | 17·5, 21·4 | 345 | 360·7 | 342·2, 379·2 | 22·9 | 19·1, 26·8 |
| 14–18 years | 326 | 444·9 | 433·1, 456·7 | 26·9 | 24·3, 29·6 | 374 | 397·9 | 384·2, 411·6 | 36·4 | 33·3, 39·6 |
| 19–30 years | 696 | 446·3 | 438·6, 454·1 | 24·2 | 22·4, 26·0 | 746 | 400·4 | 385·6, 415·1 | 33·2 | 29·7, 36·6 |
| 31–50 years | 758 | 424·8 | 419·0, 430·6 | 28·5 | 27·4, 29·5 | 1063 | 393·4 | 379·6, 407·2 | 34·9 | 31·2, 38·6 |
| ≥ 51 years | 455 | 389·2 | 380·0, 398·3 | 36·6 | 34·2, 39·0 | 716 | 355·6 | 343·4, 367·8 | 44·9 | 41·3, 48·4 |
| Northeast | | | | | | | | | | |
| 10–13 years | 608 | 452·2 | 443·3, 461·2 | 10·3 | 9·2, 11·3 | 601 | 449·8 | 428·9, 470·6 | 9·3 | 7·3, 11·3 |
| 14–18 years | 788 | 514·7 | 498·3, 531·1 | 15·4 | 12·9, 17·9 | 801 | 494·8 | 481·3, 508·3 | 17·1 | 15·1, 19·1 |
| 19–30 years | 1449 | 515·8 | 503·5, 528·1 | 13·7 | 11·9, 15·4 | 1480 | 495·5 | 485·8, 505·1 | 15·2 | 13·7, 16·6 |
| 31–50 years | 1720 | 493·1 | 484·0, 502·1 | 16·5 | 15·3, 17·7 | 2354 | 488·0 | 480·9, 495·1 | 16·1 | 14·5, 17·7 |
| ≥ 51 years | 1183 | 452·2 | 439·2:465·1 | 23·0 | 20·3, 25·7 | 2049 | 445·6 | 440·9, 450·3 | 23·1 | 21·8, 24·4 |
| Southeast | | | | | | | | | | |
| 10–13 years | 277 | 484·6 | 474·1, 495·1 | 7·3 | 6·4, 8·2 | 370 | 446·4 | 420·2, 472·6 | 9·7 | 6·9, 12·4 |
| 14–18 years | 359 | 550·8 | 536·1, 565·5 | 11·8 | 10·3, 13·2 | 470 | 488·7 | 466·9, 510·4 | 17·7 | 14·9, 20·4 |
| 19–30 years | 730 | 549·6 | 537·5, 561·6 | 10·0 | 8·9, 11·2 | 948 | 490·1 | 472·5, 507·6 | 15·9 | 14·1, 17·8 |
| 31–50 years | 1153 | 526·3 | 520·9, 531·7 | 12·4 | 11·7, 13·1 | 1713 | 482·6 | 473·5, 491·6 | 17·1 | 15·8, 18·3 |
| ≥ 51 years | 832 | 485·6 | 475·4, 495·9 | 17·9 | 15·8, 19·9 | 1826 | 440·4 | 427·7, 453·2 | 24·4 | 22·3, 26·4 |
| South | | | | | | | | | | |
| 10–13 years | 159 | 458·5 | 448·7, 468·3 | 9·6 | 8·7, 10·5 | 173 | 443·0 | 425·0, 461·1 | 10·0 | 8·1, 12·0 |
| 14–18 years | 209 | 517·4 | 505·2, 529·6 | 15·6 | 13·4, 17·7 | 247 | 484·9 | 473·1, 496·6 | 18·7 | 17·0, 20·5 |
| 19–30 years | 393 | 519·9 | 512·2, 527·6 | 13·2 | 12·1, 14·4 | 499 | 489·0 | 479·0, 499·1 | 16·0 | 14·4, 17·6 |
| 31–50 years | 714 | 496·9 | 489·0, 504·9 | 16·0 | 15·1, 17·0 | 881 | 480·8 | 469·5, 492·1 | 17·3 | 15·2, 19·4 |
| ≥ 51 years | 483 | 456·0 | 447·9, 464·2 | 22·2 | 20·3, 24·1 | 1021 | 439·2 | 429·8, 448·5 | 24·6 | 22·8, 26·3 |
| Central-West | | | | | | | | | | |
| 10–13 years | 193 | 442·6 | 430·5, 454·6 | 11·1 | 9·6, 12·6 | 241 | 422·8 | 401·5, 444·1 | 12·0 | 9·6, 14·4 |
| 14–18 years | 223 | 507·8 | 495·5, 520·0 | 16·8 | 14·6, 19·0 | 304 | 466·9 | 451·4, 482·3 | 22·1 | 19·5, 24·8 |
| 19–30 years | 488 | 505·1 | 496·2, 514·1 | 15·2 | 13·7, 16·7 | 500 | 470·3 | 454·0, 486·7 | 19·2 | 15·7, 22·7 |
| 31–50 years | 719 | 485·9 | 476·5, 495·3 | 17·4 | 16·0, 18·7 | 876 | 462·3 | 446·5, 478·0 | 20·2 | 17·1, 23·3 |
| ≥ 51 years | 507 | 444·8 | 434·1, 455·5 | 24·6 | 22·2, 27·0 | 862 | 419·5 | 406·2, 432·7 | 28·5 | 25·4, 31·7 |

DFE = dietary folate equivalents (μg) = food folate (μg) + (1·7 × folic acid (μg)).

British Journal of Nutrition

**Table 5.** Dietary folate intake (μg DFE) and prevalence of folate inadequacy (POFI) among women according to regions and age group. Brazilian National Dietary Survey: 2008–2009 and 2017–2018 (Numbers; mean values and 95 % confidence intervals)

| | 2008–2009 | | | | | 2017–2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Regions and Age group | *n* | Mean | 95 % CI | POFI | 95 % CI | *n* | Mean | 95 % CI | POFI | 95 % CI |
| North | | | | | | | | | | |
| 10–13 years | 305 | 343·2 | 326·8, 359·6 | 28·3 | 24·6, 32·0 | 303 | 324·5 | 308·2, 340·9 | 31·7 | 27·3, 36·1 |
| 14–18 years | 301 | 358·6 | 350·7, 366·5 | 47·3 | 44·4, 50·2 | 390 | 303·6 | 291·5, 315·6 | 63·0 | 59·4, 66·7 |
| 19–30 years | 603 | 335·9 | 329·4, 342·5 | 50·9 | 48·9, 52·9 | 686 | 301·9 | 288·3, 315·5 | 61·0 | 56·7, 65·3 |
| 31–50 years | 814 | 327·5 | 321·6, 333·3 | 53·0 | 51·2, 54·7 | 1126 | 286·1 | 274·7, 297·4 | 65·7 | 62·0, 69·5 |
| ≥ 51 years | 462 | 304·9 | 299·6, 310·2 | 59·4 | 57·3, 61·4 | 793 | 275·8 | 264·2, 287·3 | 68·3 | 65·0, 71·7 |
| Northeast | | | | | | | | | | |
| 10–13 years | 600 | 405·3 | 385·8, 424·9 | 16·2 | 13·4, 18·9 | 568 | 408·3 | 395·6, 421·0 | 14·2 | 12·7, 15·7 |
| 14–18 years | 702 | 420·6 | 406·7, 434·5 | 31·8 | 28·4, 35·2 | 782 | 386·0 | 377·2, 394·7 | 39·5 | 37·6, 41·4 |
| 19–30 years | 1504 | 393·7 | 385·0, 402·3 | 35·5 | 33·1, 37·8 | 1423 | 382·5 | 369·4, 395·5 | 37·5 | 34·2, 40·7 |
| 31–50 years | 2079 | 384·3 | 377·1, 391·5 | 37·7 | 35·9, 39·6 | 2843 | 364·5 | 357·3, 371·8 | 42·2 | 40·4, 44·0 |
| ≥ 51 years | 1482 | 361·3 | 354·9, 367·6 | 43·8 | 42·1, 45·5 | 2665 | 350·8 | 344·0, 357·6 | 46·1 | 44·0, 48·3 |
| Southeast | | | | | | | | | | |
| 10–13 years | 295 | 436·8 | 421·3, 452·3 | 12·0 | 10·1, 13·9 | 319 | 404·5 | 381·6, 427·4 | 14·9 | 11·5, 18·2 |
| 14–18 years | 372 | 450·0 | 439·7, 460·3 | 25·7 | 23·3, 28·1 | 446 | 383·0 | 364·7, 401·2 | 39·9 | 35·4, 44·5 |
| 19–30 years | 699 | 421·0 | 414·6, 427·3 | 29·3 | 27·4, 31·1 | 925 | 376·8 | 359·3, 394·4 | 38·9 | 34·8, 43·1 |
| 31–50 years | 1332 | 412·3 | 408·1, 416·6 | 31·0 | 29·8, 32·1 | 1978 | 360·4 | 343·8, 377·0 | 43·4 | 39·4, 47·5 |
| ≥ 51 years | 1032 | 389·2 | 384·5, 393·8 | 36·8 | 35·4, 38·2 | 2190 | 345·9 | 340·6, 351·2 | 47·4 | 46·2, 48·6 |
| South | | | | | | | | | | |
| 10–13 years | 167 | 408·3 | 388·5, 428·2 | 16·0 | 13·2, 18·8 | 150 | 401·5 | 384·5, 418·6 | 15·7 | 13·3, 18·1 |
| 14–18 years | 206 | 424·9 | 416·7, 433·1 | 30·9 | 29·0, 32·8 | 210 | 380·8 | 366·0, 395·7 | 40·6 | 36·7, 44·6 |
| 19–30 years | 435 | 398·9 | 392·8, 404·9 | 34·0 | 32·4, 35·6 | 441 | 375·8 | 363·6, 388·0 | 39·4 | 36·3, 42·5 |
| 31–50 years | 741 | 388·9 | 383·7, 394·1 | 36·6 | 35·4, 37·7 | 1030 | 358·7 | 349·9, 367·6 | 43·8 | 41·7, 45·9 |
| ≥ 51 years | 561 | 366·6 | 362·5, 370·7 | 42·3 | 41·1, 43·6 | 1215 | 344·3 | 335·4, 353·2 | 48·0 | 45·3, 50·7 |
| Central-West | | | | | | | | | | |
| 10–13 years | 199 | 399·7 | 379·2, 420·3 | 17·3 | 14·1, 20·5 | 179 | 386·7 | 366·2, 407·3 | 18·3 | 14·0, 22·7 |
| 14–18 years | 230 | 411·1 | 400·5, 421·7 | 34·3 | 31·8, 36·9 | 243 | 363·9 | 351·9, 375·9 | 45·5 | 41·7, 49·3 |
| 19–30 years | 546 | 386·3 | 378·8, 393·9 | 36·8 | 34·9, 38·8 | 483 | 359·0 | 340·4, 377·6 | 43·8 | 38·4, 49·2 |
| 31–50 years | 838 | 375·3 | 367·4, 383·3 | 40·1 | 38·3, 42·0 | 1005 | 342·5 | 329·3, 355·8 | 48·4 | 44·3, 52·6 |
| ≥ 51 years | 544 | 355·3 | 348·9, 361·7 | 45·4 | 43·7, 47·0 | 891 | 329·2 | 316·9, 341·5 | 52·2 | 48·5, 55·9 |

DFE = dietary folate equivalents (μg) = food folate (μg) + (1·7 × folic acid (μg)).

amounts of 499 μ DFE for food folate and 658 μ for combined foods plus dietary supplements for the overall population from 2 to over years[22]. Considering the lack of representative national folate intake data in the pre-fortification era, data from a population-based study in Sao Paulo, the largest Brazilian city, demonstrated lower means of folate intake of 284·7 (95 % CI 267·8, 301·5) μ DFE for adult's males and 198·2 (95 % CI 184·6, 211·7) μ DFE for adult's females[23]. Moreover, prevalence of inadequate folate intake in the mentioned population was extremely high, with percentages varying from 72 to 83 % in males and from 88 to 96 % in females, after stratifying by age groups[23].

Although important decrease of the prevalence of inadequate folate intake was observed in both post-fortification surveys, increased prevalence of inadequacy (32·1 *v.* 25·2 %) was observed in 2017–2018 compared with 2008–2009, with all female age groups presenting higher prevalence of inadequacy than men in both survey periods. In the USA, the overall prevalence of total dietary intake inadequacy was 3·3 % in men and 10·1 % in women aged ≥ 19 years old from the National Health and Nutrition Examination Survey 2011–2012[24]. Among women of reproductive age, this prevalence was around 11 %, while in our study, three and four times this prevalence in 2008–2009 and 2017–2018, respectively. National Health and Nutrition Examination Survey figures are lower than those described in the present study; however, they have estimated total usual folate intake accounting for usual folate intake from foods and also from dietary supplements.

The use of supplements is very common in the USA, with evidence of mean values of 400 (95 % CI 379, 400) μg of folic acid/daily obtained from dietary supplement use in the individuals ≥ 1 year old, except from pregnant and lactating women[25]. In Brazil, recent data from NDS-HBS 2017–2018 showed that 19·2 % of the overall population reported the use of at least one dietary supplement within 30 d prior to the survey[14]. When considering only multivitamins, complex B vitamins and vitamin C, the overall prevalence dropped to 11·1 %[14].

Household income has been traditionally associated with food access and choices[26,27], with low income being related to poor dietary options[26]. However, in the present study, when comparing the first to the fourth quartile of family income per capita in 2008–2009 and 2017–2018, the POFI was almost the same, only increasing with age. A possible explanation is that important sources of folate, namely beans and bread, are commonly consumed by the Brazilian population[13,14], since the overall main five foods consumed in Brazil were, in this order: rice, coffee, beans, salt bread and red meat in 2008–2009[13], while coffee, rice, beans, salt bread, oils and fats in 2017–2018[14]. Interestingly, overall data from 2017 to 2018 showed higher average consumption per capita of beans and salt bread

**Table 6.** Relative and cumulative frequency (%) of food groups that most contributed to folate intake in Brazil and regions. Brazilian National Dietary Survey: 2008–2009 and 2017–2018

| | 2008–2009 | | | 2017–2018 | | |
|---|---|---|---|---|---|---|
| | Food group | % Relative | % Cumulative | Food group | % Relative | % Cumulative |
| Brazil | Beans | 38·7 | 38·7 | Beans | 37·7 | 37·7 |
| | Breads | 17·3 | 56·0 | Breads | 17·9 | 55·6 |
| | Pasta and pizza | 9·8 | 65·8 | Pasta and pizza | 11·3 | 66·9 |
| | Cakes and cookies | 6·4 | 72·2 | Cakes and cookies | 6·7 | 73·6 |
| | Non-alcoholic beverages | 5·4 | 77·6 | Non-alcoholic beverages | 6·1 | 79·7 |
| North | | | | | | |
| | Beans | 33·3 | 33·3 | Beans | 32·4 | 32·4 |
| | Breads | 16·5 | 49·8 | Breads | 22·5 | 54·9 |
| | Pasta and pizza | 9·2 | 59·0 | Pasta and pizza | 9·8 | 64·7 |
| | Meats | 8·3 | 67·3 | Meats | 7·6 | 72·3 |
| | Cakes and cookies | 6·6 | 73·9 | Non-alcoholic beverages | 6·3 | 78·6 |
| Northeast | | | | | | |
| | Beans | 36·2 | 36·2 | Beans | 36·4 | 36·4 |
| | Breads | 18·6 | 54·8 | Breads | 17·8 | 54·2 |
| | Pasta and pizza | 7·2 | 62·0 | Pasta and pizza | 10·5 | 64·7 |
| | Fortified wheat flour recipes | 7·0 | 69·0 | Cakes and cookies | 6·9 | 71·6 |
| | Cakes and cookies | 6·4 | 75·4 | Fortified wheat flour recipes | 5·8 | 77·4 |
| Southeast | | | | | | |
| | Beans | 42·8 | 42·8 | Beans | 41·1 | 41·1 |
| | Breads | 16·5 | 59·3 | Breads | 18·3 | 59·4 |
| | Pasta and pizza | 10·1 | 69·4 | Pasta and pizza | 10·9 | 70·3 |
| | Cakes and cookies | 6·2 | 75·6 | Cakes and cookies | 6·1 | 76·4 |
| | Non-alcoholic beverages | 5·6 | 81·2 | Non-alcoholic beverages | 5·9 | 82·3 |
| South | | | | | | |
| | Beans | 30·4 | 30·4 | Beans | 28·3 | 28·3 |
| | Breads | 19·6 | 50·0 | Breads | 17·3 | 45·6 |
| | Pasta and pizza | 14·5 | 64·5 | Pasta and pizza | 15·9 | 61·5 |
| | Cakes and cookies | 7·0 | 71·5 | Non-alcoholic beverages | 8·2 | 69·7 |
| | Non-alcoholic beverages | 6·3 | 77·8 | Cakes and cookies | 8·0 | 77·7 |
| Central-West | | | | | | |
| | Beans | 44·1 | 44·1 | Beans | 46·3 | 46·3 |
| | Breads | 14·1 | 58·2 | Breads | 13·2 | 59·5 |
| | Pasta and pizza | 8·7 | 66·9 | Pasta and pizza | 8·6 | 68·1 |
| | Non-alcoholic beverages | 6·4 | 73·3 | Cakes and cookies | 7·0 | 75·1 |
| | Cakes and cookies | 5·9 | 79·2 | Non-alcoholic beverages | 5·7 | 80·8 |

in the lowest income quartiles. On the other hand, higher average consumption per capita of fruits and other flour-based fortified foods as pizzas, sanduiches and cafeteria items was observed among those with higher income[14].

However, among the overall Brazilian population, the consumption of beans and bread items has decreased 12·8 and 12·1 % in 2017–2018 compared with 2008–2009[14]. Although there was slightly decrease of consumption in the general population, we have observed that these two food groups were those that most contributed to dietary folate intake in both studied periods. Remarkably, the beans group, a natural source of folate, contributed ~ 40 % to dietary folate intake, while the four food groups containing fortified folic acid flour products counted for 36 and 38 % in 2008–2009 and 2017–2018, respectively.

Undoubtedly, fortified food policies have led to both increased folate intake and biomarkers status in the target group and the overall population, with folate deficiency being almost non-existent in countries that have adopted it[28–30]. Despite these facts, it should be pointed out that some fortified products are classified as ultraprocessed food, as some types of cookies, maize chips, packaged cakes, some types of breads, frozen pasta and pizza[31]. In this sense, natural foods sources of folate should be constantly encouraged.

One of the strenghts of this study is that these are the two largest surveys about dietary intake in Brazil, which included adolescents and adults residents from urban and rural areas from the country as a whole and its all geographic regions. At the time of the first NDS-HBS in 2008–2009, dietary intakes were analysed with the aid of a North American food composition database derived from the Nutrition Data System for Research software (University of Minnesota, 2003), which demanded DFE values corrections to adjust differences in the folic acid fortification levels of wheat and maize flours between USA and Brazil[32]. The other strength of the present study is the use of a genuinely national food composition table to analyse data from the both 2008–2009[13] and 2017–2018[14] surveys, thus allowing more precise estimates and comparisons.

As limitations, it is worth noting that the methods for assessing dietary intake were not the same across the surveys, since food records were used in 2008–2009 while 24-h dietary recall in 2017–2018[14]. In a validation study conducted with a subsample of individuals from 2008 to 2009, energy intake was assessed by both instruments and compared with energy expenditure estimated by the doubly labelled water method. In conclusion, the frequency of energy intake underreporting was higher when estimated by food records (32 %) than by 24-h dietary recall (20 %)[33].

However, the possible difficulties in comparing both periods would be mainly regarding to added sugars and fats, which do not directly interfere with our analysis of dietary folate intake[14], since both methods are capable of providing information about types and amounts of foods and beverages consumed by the participants, also allowing to categorise food items into different types of food groups.

In conclusions, although being a country that has adopted mandatory folic acid flour fortification for almost two decades, this study demonstrated that POFI has increased from 2008–2009 to 2017–2018. For women of reproductive age, the target group of this policy, the POFI ranged from 30 to 40 %. The North region, which has elevated proportion of food-insecurity households, presented the highest rates of folate inadequacy in comparison with all other Brazilian regions. In both studied periods, folic acid from mandatory fortified foods accounted to approximately 40 % of total folate intake, while natural sources counted for 60 %, mainly represented by beans. As demonstrated by the present article, wheat and maize flours are staple foods regularly and widely consumed across the country. Even though the consumption of flour-based fortified foods has increased folate status, they should not be consumed in excess. As recommendations not only for the target group but for the population as a whole, the consumption of natural sources of folate, as beans, which are traditionally used in brazilian dishes, should be stimulated along with other sources as fruits and vegetables.

In this sense, this article brings significant scientific information, which can help understand folate dietary data in different contexts and consequently guide the approach for public health fortification strategies.

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