INDONESIAN TRADITIONAL FERMENTED FOODS AND IRON STATUS IN ADOLESCENT GIRLS: A NARRATIVE REVIEW OF MECHANISMS AND AVAILABLE EVIDENCE

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Abstract

Anemia remains a major public health problem among Indonesian adolescent girls, with a national prevalence of 18% in the 2023 Indonesian Health Survey (SKI) and higher figures in the 2018 Basic Health Research (Riskesdas). Compliance with iron-folic acid supplementation remains difficult to sustain, keeping interest alive in food-based strategies that complement existing programs. Among the options available in Indonesia are traditional fermented foods, tempeh, dadih, tape, and oncom, whose fermentation processes are known to alter mineral bioavailability, though their specific contribution to adolescent iron status has received comparatively little attention. This narrative review brings together the scientific evidence and biological mechanisms linking Indonesian fermented foods to iron bioavailability and status, focusing on adolescent girls, drawing on PubMed, Google Scholar, and Scopus for openly accessible studies published between 2016 and 2026. Three mechanisms recur across the evidence: microbial phytase activity lowers phytate content, lactic acid bacteria reduce luminal pH and favor conversion of ferric to ferrous iron, and anti-inflammatory effects may lower hepcidin-mediated suppression of iron absorption. Tempeh carries the strongest support, with several small Indonesian studies linking tempeh-based products to higher hemoglobin levels in anemic adolescent girls. The case for dadih, tape, and oncom remains biologically plausible but rests mainly on mechanistic or preclinical data; dadih from Riau has yet to be tested against any iron-related outcome. Taken together, these fermented foods offer a culturally familiar, affordable complement to existing anemia-control efforts, though confirming their efficacy and establishing effective doses will require well-designed randomized controlled trials in Indonesian adolescent populations.

Keywords: Fermented Foods, Iron Bioavailability, Anemia, Adolescent Girls, Tempeh

1. INTRODUCTION

Anemia is one of the most chronic nutritional concerns among adolescents in Indonesia. The 2023 Indonesian Health Survey (SKI) revealed that 15.5% of individuals aged 15 to 24 were anemic, with adolescent females significantly impacted at 18% compared to 14.4% of boys [1]. Even though it is lower than the 32% reported for this age group in the 2018 Basic Health Research (Riskesdas), when girls reached 27.2% [1], [2], the current number exceeds the 10% threshold that the World Health Organization considers a public health problem [1] [2]. Rapid development, regular iron loss due to menstruation, and often imbalanced and low-bioavailable iron dietary patterns contribute to compounding risk factors for adolescent females [2] [3]. Anemia in this population is linked to a higher risk of complications for both the mother and the expectant child if it persists throughout pregnancy, as well as a diminished physical capacity and impaired cognitive function if left untreated [3].

The most common approach of the Indonesian government to prevent anemia in adolescent girls is the provision of weekly iron-folic acid tablets (TTD) through schools. However, side effects, taste aversion and irregular distribution often compromise compliance [3] [4]. This has maintained interest in complementary food-based strategies to improve dietary iron intake and absorption using locally available foods that are more affordable, culturally embedded and easier to sustain [3], [4].

Indonesia possesses a rich heritage of traditional fermented foods, including tempeh (fermented soybean using Rhizopus oligosporus) [5], dadih (fermented buffalo milk from West Sumatra and Riau) [6], tape (fermented cassava or glutinous rice) [7], and oncom (fermented soybean or tofu pulp) [8]. Fermentation is well established in the food-science literature as a process capable of altering the mineral bioavailability of plant-based staples: microbial phytase activity degrades phytate, the principal antinutrient that binds iron and zinc in legumes and cereals, while lactic acid bacteria (LAB) generate organic acids that further support mineral solubility [9], [10]. A related narrative review of these same Indonesian fermented foods examined their relationship to mental health via the gut-brain axis and found the clearest clinical evidence for tempeh, while evidence for dadih, tape, and oncom remained largely mechanistic. That review did not, however, examine iron-related outcomes, despite anemia being a substantially larger public health burden among Indonesian adolescent girls, and despite iron status and mental health sharing overlapping physiological pathways such as inflammation.

This narrative review aims to: (1) investigate the biological processes by which fermentation might affect iron bioavailability and status; (2) compile existing evidence regarding Indonesian traditional fermented foods (tempeh, dadih, tape, oncom) concerning iron-related outcomes, particularly focusing on adolescent girls; and (3) pinpoint research deficiencies to direct future investigations and enhance local anemia-control initiatives, especially in Riau, where dadih is indigenous.

2. METHODOLOGY

This narrative review used the electronic databases PubMed/MEDLINE, Google Scholar, and Scopus, including literature produced within the past decade (2016-2026) to guaranty the summary information is up-to-date. Search keywords included include "tempe," "tempeh," "dadih," "tape," "oncom," "Indonesian/traditional fermented meal," "phytate," "phytase," "iron bioavailability," "iron absorption," "anemia," "hemoglobin," "adolescent girls," "lactic acid bacteria," and "probiotics. Inclusion criteria consisted of: (1) publication dates from 2016 to 2026; (2) focus on fermented foods, especially traditional Indonesian items or their bioactive/microbial elements; (3) investigation of relationships with iron bioavailability, iron levels, hemoglobin, or anemia; and (4) availability in Indonesian or English. Mechanistic investigations concerning non-Indonesian fermented staples (such as fermented maize, sourdough bread, and lactic-fermented vegetables) were incorporated when they demonstrated a biologically credible mechanism relevant to Indonesian items. Titles, abstracts, and keywords were screened, followed by full- or partial-text review against the criteria above, and reference lists of relevant articles were hand-searched for additional sources.

3. RESULTS AND DISCUSSION

The studies that met the inclusion criteria were grouped into three categories: (1) mechanistic and food-science studies that examined the impact of fermentation on phytate content and mineral bioavailability; (2) a microbiological characterization study of Indonesian dadih, which included local Riau dadih; and (3) small-scale intervention and product development studies that tested the hemoglobin or iron content of adolescent girls using tempeh-based products. In an Indonesian adolescent population, no controlled trial was identified that directly tested dadih, tape, or oncom against iron-related outcomes. Table 1 provides a summary of the primary empirical studies; the following section provides a narrative discussion of broader mechanistic and review-type evidence

Table 1. *Summary of primary empirical studies included in the narrative review.*

No	Title	Study Design	Subject/Material	Results
1	Enhancing iron and zinc bioavailability in maize (*Zea mays)* thougt phytate reduction: the impact of fermentation alone and in combination with soaking and germination [10]	Experimental (fermentation/soaking/germination)	Maize flour	Combined processing reduced phytate by up to 85.6%, lowering phytate iron and phytate, zinc molar ratios toward recommended thresholds
2	Tempeh extract fortified with iron and synbiotic as a strategy against anemia[15]	Experimental (Wistar rats)	24 anemic model rats (3 groups)	Iron- and synbiotic-fortified tempeh extract showed potential to raise hemoglobin levels compared with an untreated control.
3	Effectiveness of Moringa Tempeh Burgers in Increasing Hemoglobin of Anemic Adolescent Girls [16]	Quasi-experimental	51 anemic girls, 13-15y (3 groups)	Hemoglobin rose by 0.46, 0.70, and 2.23 g/dL across control and two Moringa-tempeh burger doses after 30 days.
4	Pemberian Nugget Tempe terhadap Kadar Hemoglobin pada Remaja Putri [17]	Pre-experimental (pretest-posttest)	43 adolescent girls	Mean hemoglobin increase of 0.40 g/dL after one month of tempeh-nugget supplementation ($p < 0.001$).
5	Development of tempe flour-enriched snacks to prevent anemia in adolescent girls [18]	Product development (R&D) study	Adolescent girls (formulation/acceptability)	Best-accepted formula contained 1.46 mg iron per 100 g; proposed as a food-based approach, pending clinical trials.

6	Bacterial biodiversity and metagenomic study of dadih, traditional fermented buffalo milk from Kampar district, Riau, Indonesia [19]	Metagenomic/microbiological	Artisanal dadih from 3 villages	Identified a diverse native lactic acid bacteria community dominated by Lactococcus lactis; iron-related outcomes not yet tested.

3.1 Mechanisms linking fermentation to iron bioavailability

Three complementary mechanisms emerge from the literature. First, fermentation reduces phytate, the principal inhibitor of non-heme iron and zinc absorption in legume and cereal based diets. Phytases produced by Rhizopus oligosporus and associated Bacillus species during tempeh fermentation hydrolyze phytate, releasing bound minerals and improving their theoretical bioaccessibility [9]. This effect is not unique to soy based tempeh: studies on other fermented staples, such as maize, report phytate reductions of up to 85.6% when fermentation is combined with soaking and germination, correspondingly lowering Phytate:Iron and Phytate:Zinc molar ratios toward levels considered adequate for absorption (Table 1) [10]. Because Indonesian traditional fermented foods rely on comparable microbial phytase activity, similar improvements in mineral bioaccessibility are biologically plausible, although direct isotope-tracer or human-absorption data specific to tempeh, dadih, tape, or oncom remain scarce.

Second, lactic acid bacteria (LAB), abundant in dadih, tape, and to a lesser extent tempeh, generate organic acids that lower luminal pH and promote reduction of ferric (Fe^{3+}) to the more absorbable ferrous (Fe^{2+}) form of iron [11]. A recent systematic review of human intervention studies on the fermentation of bread reported an acute increase in non-heme iron bioavailability after meals, especially in low-phytate breads, although the long-term effect on iron status was inconsistent and not always translated into sustained improvement [12]. In contrast, studies on lactic-fermented vegetables report more clear increases in non-heme iron absorption, due to the formation of soluble ferric iron through acidification [13]. This mixed picture suggests that, while the underlying chemistry is plausible, the magnitude of clinical benefit likely depends on the food matrix, the degree of phytate reduction achieved, and the duration of exposure. Ascorbic acid and other organic acids act through a related pathway, forming soluble iron complexes that further enhance absorption when consumed alongside iron-containing foods [11].

Third, LAB and their metabolites may support iron status indirectly by reducing intestinal inflammation and, consequently, hepcidin, the master regulatory hormone that suppresses dietary iron absorption when elevated [11], [14]. By supporting mucosal integrity and dampening inflammatory signaling, regular fermented food consumption could theoretically lower hepcidin mediated iron sequestration, complementing the direct chemical effects of phytate reduction and pH modulation [11], [14].

3.2 Indonesian fermented foods and iron status: available evidence

Tempeh carries the most direct evidence base among Indonesian fermented foods. An iron- and synbiotic-fortified tempeh extract showed potential to raise hemoglobin in an anemic rat model compared with an untreated control (Table 1) [15], while several small human intervention studies have tested tempeh-based products specifically in anemic adolescent girls: tempeh nuggets produced a mean hemoglobin increase of 0.40 g/dL among junior-high students in Gorontalo (Table 1) [17], and a quasi-experimental trial of Moringa-enriched tempeh burgers reported dose-dependent hemoglobin increases over 30 days, from 0.46 g/dL in controls up to 2.23 g/dL in the highest-dose group (Table 1) [16]. A tempeh-flour snack containing 1.46 mg iron per 100 g has also been formulated and piloted specifically as an anemia-prevention product for adolescent girls, though the authors note that clinical

trials are still needed to confirm efficacy (Table 1) [18]. A second narrative literature review also found that the protein, iron, vitamin B12, and folate content of tempeh was adequate to provide it with potential to increase hemoglobin in anemic adolescents [20]. This compilation of evidence indicates that tempeh is a viable and feasible means of enhancing iron levels in adolescents, although the majority of primary studies are limited in size, duration, and geographic scope.

Dadih is a fermented buffalo-milk product from West Sumatra and Riau. It has a strong mechanistic potential but almost no direct evidence on iron outcomes. Metagenomic characterization of dadih produced in Kampar, Riau, confirms a diverse native LAB community dominated by Lactococcus lactis, with composition varying slightly by producer and village (Table 1) [19]. Given that LAB driven acidification and ferric to ferrous reduction are plausible iron-absorption mechanisms documented elsewhere [11]-[13], dadih is a biologically plausible but essentially untested candidate for local anemia-related research, particularly given its cultural relevance and production base within Riau itself.

Tape produced through mixed yeast-LAB fermentation of cassava or glutinous rice [7], offers a distinct potential pathway: cassava is itself a source of vitamin C and organic acids, both established enhancers of non-heme iron absorption when consumed alongside iron-containing foods [11]. However, no studies were identified that directly measured iron bioavailability or status outcomes from tape consumption, and this pathway remains inferential rather than tape-specific.

Oncom fermented from soybean or tofu pulp, is comparatively the least studied of the four in any nutritional context, let alone with regard to iron. Existing literature characterizes its antioxidant and polyphenol content but does not extend to mineral bioavailability or clinical iron outcomes [8].

3.3 Implications and research gaps

Taken together, the evidence positions Indonesian traditional fermented foods, and tempeh in particular, as a culturally accepted, affordable, food-based complement to existing TTD supplementation programs for adolescent girls. Adding products based on tempeh to school nutrition education or feeding programs is a relatively low-barrier intervention because tempeh is already a widely consumed and inexpensive source of iron relative to animal source iron foods. But there are significant gaps. There are almost no controlled trials testing dadih, tape, or oncom versus iron related outcomes in any population, and certainly not in Indonesian adolescents, making this a particularly notable gap for dadih given its established LAB profile and local production in Riau. Current tempeh trials are small, of short duration, and mostly quasi- or pre-experimental rather than randomized, thus limiting causal inference. Recent systematic evidence from non-Indonesian fermented foods also suggests that acute improvements in iron bioavailability do not necessarily translate into sustained gains in iron status . Similar claims for Indonesian fermented foods should be tested rather than assumed [12]. There has not been any systematic research on standardized dosing, processing methods and combination strategies such as combining fermented foods with local vitamin C rich fruits to further improve absorption. Finally, no identified study has directly measured iron absorption using isotope tracer methods in any Indonesian fermented food, meaning current conclusions rest on bioaccessibility proxies and hemoglobin outcomes rather than confirmed absorption data.

4. CONCLUSIONS

Indonesian traditional fermented foods act on iron bioavailability through three overlapping mechanisms: phytate reduction via microbial phytase activity, lactic acid driven acidification that favors absorbable ferrous iron, and potential hepcidin lowering effects via reduced inflammation, although recent human evidence indicates these acute benefits do not always persist over the longer term. Tempeh presents the most robust and unequivocal evidence among the four foods examined, as evidenced by numerous minor Indonesian studies that link tempeh products to improved hemoglobin levels in anemic adolescent females. Dadih, Riau dadih, tape, and oncom are biologically feasible; however, the supporting evidence is substantially mechanistic or composition-based, rather than derived from clinical trials. Consequently, conventional fermented foods represent a promising, locally rooted dietary approach that has the potential to improve the current anemia-management initiatives for Indonesian adolescent females. Nevertheless, definitive dietary guidelines must be established through comprehensive, sufficiently robust trials.

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REFERENCES

[1] Kementerian Kesehatan RI, Survei Kesehatan Indonesia (SKI) 2023. Jakarta: Badan Kebijakan Pembangunan Kesehatan, 2023.

[2] Kementerian Kesehatan RI, Laporan Riskesdas 2018. Jakarta: Lembaga Penerbit Badan Penelitian dan Pengembangan Kesehatan, 2018.

[3] Y. Deivita, S. Syafruddin, U. Andi Nilawati, A. Aminuddin, B. Burhanuddin, and Z. Zahir, "Overview of anemia: risk factors and solution offering," Gac. Sanit., vol. 35, suppl. 2, 2021.

[4] M. K. Nair, L. F. Augustine, and A. Konapur, "Food-Based Interventions to Modify Diet Quality and Diversity to Address Multiple Micronutrient Deficiency," Front. Public Health, vol. 3, pp. 1-14, Jan. 2016.

[5] S. Q. Teoh, N. L. Chin, C. W. Chong, A. M. Ripen, S. How, and J. J. L. Lim, "A review on health benefits and processing of tempeh with outlines on its functional microbes," Future Foods, vol. 9, p. 100330, Jun. 2024.

[6] Pramana, B. Yudhistira, M. Jayalaksamana, D. Kurnia, N. Husnayain, and R. Pramitasari, "Dadih, traditional fermented buffalo milk: a comprehensive review of the aspects of gastronomy, health benefits, and product development," J. Ethn. Food, vol. 12, no. 1, p. 1, Jan. 2025.

[7] U. Hasanah, H. Ratihwulan, and L. Nuraida, "Sensory Profiles and Lactic Acid Bacteria Density of Tape Ketan and Tape Singkong in Bogor," agriTECH, vol. 38, no. 3, pp. 265-272, Mar. 2019.

[8] C. H. Wijaya, L. Nuraida, D. R. Nuramalia, S. Hardanti, and K. Świąder, "Oncom: A Nutritive Functional Fermented Food Made from Food Process Solid Residue," Applied Sciences, vol. 14, no. 22, p. 10702, 2024.

[9] V. P. Yarlina, J. L. Tandra, R. Indiarto, R. Andoyo, P. W. Harlina, N. H. N. Ubaidillah, and M. N. Lani, "Unraveling Tempeh through omics: a scoping review of fermentation pathways and functional health benefits," npj Sci. Food, vol. 10, p. 122, Feb. 2026.

[10] S. Nsabimana, T. Ismail, and C. E. Lazarte, "Enhancing iron and zinc bioavailability in maize (Zea mays) through phytate reduction: the impact of fermentation alone and in combination with soaking and germination," Front. Nutr., vol. 11, p. 1478155, Dec. 2024.

[11] B. Webb, M. Farrell, C. Montelius, and G. Önning, "Probiotics and iron bioavailability: mechanisms, clinical evidence, and translational applications, a comprehensive review of the probiotic strain Lactiplantibacillus plantarum 299v (LP299V)," Front. Nutr., vol. 13, p. 1905459, Aug. 2026.

[12] Nikolaou, R. Assunção, B. Cvetković, A. Fardet, A. Gamero, M. Gandía, S. Mojsova, B. Yilmaz, M.-L. Kütt, D. Santa, C. Chassard, S. Praćer, G. Vergères, S. Karakaya, and M. Syrpas, "Effects of sourdough- or regular-bread fermentation, and phytate reduction on iron bioavailability, absorption, and iron status in humans: a systematic review of intervention studies," Front. Nutr., vol. 13, p. 1778997, May 2026.

[13] N. Scheers, L. Rossander-Hulthén, I. Torsdottir, and A.-S. Sandberg, "Increased iron bioavailability from lactic-fermented vegetables is likely an effect of promoting the formation of ferric iron (Fe3+)," Eur. J. Nutr., vol. 55, no. 1, pp. 373-382, Feb. 2016.

[14] B. Fikri, N. R. Ridha, S. H. Putri, S. B. Salekede, A. Juliaty, C. Tanjung, and N. Massi, "Effects of probiotics on immunity and iron homeostasis: A mini-review," Clin. Nutr. ESPEN, vol. 49, pp. 24-27, Jun. 2022.

[15] S. Helmyati, T. Sudargo, I. Kandarina, E. Yuliati, S. U. Wisnusanti, V. A. D. Puspitaningrum, and M. Juffrie, "Tempeh extract fortified with iron and synbiotic as a strategy against anemia," Int. Food Res. J., vol. 23, no. 5, pp. 2296-2299, 2016.

[16] T. M. N. Laksmi Wardhani, Y. L. Retno Dewi, and R. P. Febrinasari, "Effectiveness of Moringa Tempeh Burgers in Increasing Hemoglobin of Anemic Adolescent Girls," Media Gizi Indonesia, vol. 19, no. 2, pp. 158-163, 2024.

[17] Nurhidayah, "Pemberian Nugget Tempe terhadap Kadar Hemoglobin pada Remaja Putri," Journal Midwifery, vol. 6, no. 1, pp. 1-8, 2020.

[18] L. Hidayanti, M. Z. Rahfiludin, S. A. Nugraheni, and R. Murwani, "Development of tempe flour-enriched snacks to prevent anemia in adolescent girls," Progr. Nutr., vol. 25, no. 1, p. e2023003, 2023.

[19] E. Rossi, U. Pato, D. F. Ayu, S. Melia, A. Sukma, R. Rahmayuni, and A. N. Salman, "Bacterial biodiversity and metagenomic study of dadih, traditional fermented buffalo milk from Kampar district, Riau, Indonesia," J. Adv. Vet. Anim. Res., vol. 12, no. 3, pp. 717-727, 2025.

[20] L. Pinasti, Z. Nugraheni, and B. Wiboworini, "Potensi tempe sebagai pangan fungsional dalam meningkatkan kadar hemoglobin remaja penderita anemia," AcTion: Aceh Nutr. J., vol. 5, no. 1, pp. 19-26, 2020.