Effect of *Moringa olifera* Leaf Extract on the Levels of Key Electrolytes (Na, K, Ca and Iron) of Breast Milk in Wistar Rats Model.

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ABSTRACT

Breast milk electrolyte composition is a critical determinant of neonatal physiological stability, influencing fluid balance, neurodevelopment, and metabolic function. However, maternal micronutrient deficiencies remain prevalent in resource-limited settings, often compromising the mineral quality of breast milk across lactational stages. This study investigated the effect of *Moringa oleifera* leaves extract on the levels of key electrolytes (sodium, calcium, potassium, and iron) in breast milk—colostrum, transitional, and mature milk with the aim of evaluating its potential as a natural nutritional intervention.

Study Design and Methods

A total of 72 Wistar rats comprising of 24 males and 48 females divided into 6 groups of 8 females and 4 males per group in the ratio of 2:1 was used for the study. *Moringa oleifera* was administered to groups A, B,C,D,E and F. Group F, control was given rat chow and water only. A and C received 75 mg/kg b.wt of Moringa oleifera leaf extract from14 days before mating then from second stage of pregnancy till weaning and paturition respectively, group E received100mg/kg b.wt of Moringa oleifera leaf extract from second stage of pregnancy till weaning and from paturition till weaning respectively. Group D received 20mg/kg b.wt of domperidone from paturition till weaning. All administration were through oral route. The total duration of the study was approximately 60 days. At the end of the treatments, milk samples were collected for biochemical analyses of samples were collected across all lactational stages for biochemical analysis of Sodium, potassium, calcium and iron . Data was analyzed using SPSS version 25 (IBM, USA, 2018), One-way ANOVA Followed by Post HOC Fishers LSD multiple comparison, Mean ± SEM and significance level was set at $p<0.05$.

Results

Results demonstrated that *Moringa oleifera* supplementation induced significant, stage-specific alterations in electrolyte composition. Potassium levels were markedly elevated in colostrum, suggesting enhanced early lactational electrolyte enrichment, while sodium levels were modulated across lactation stages. In contrast, iron concentrations were not significantly altered in colostrum but showed a significant reduction in transitional and mature milk at higher doses, indicating a dose-dependent effect likely mediated by phytochemical interactions affecting mineral bioavailability.

These findings highlight the dual role of *Moringa oleifera* as both a potent lactogenic agent and a modulator of breast milk electrolyte composition. While its benefits in enhancing early milk quality are evident, the observed reduction in iron at later stages underscores the need for dose optimization. This study provides novel evidence supporting the targeted use of *Moringa oleifera* in maternal nutrition strategies aimed at improving neonatal health outcomes.

Keywords: Moringa oleifera, breast milk, electrolytes, lactation, micronutrient bioavailability, hormones

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BACKGROUND

Optimal infant nutrition during the early stages of life is critically dependent on the composition of breast milk, particularly its electrolyte content, which plays a vital role in maintaining fluid balance, neuromuscular function, enzymatic activity, and overall metabolic homeostasis. Electrolytes such as sodium (Na), potassium (K), calcium (Ca^{2}), and iron are essential for neonatal growth, immune development, and neurological maturation. Variations in the concentrations of these elements across different stages of lactation—colostrum, transitional milk, and mature milk—can significantly influence infant health outcomes.

However, maternal nutritional status remains a major determinant of breast milk composition, especially in low- and middle-income countries where micronutrient deficiencies are prevalent. Poor maternal intake of essential minerals has been associated with suboptimal electrolyte levels in breast milk, potentially predisposing infants to conditions such as impaired bone development, anemia, electrolyte imbalance, and weakened immunity. This growing public health concern necessitates the exploration of affordable, sustainable, and nutrient-rich dietary interventions that can enhance breast milk quality.

Moringa oleifera, a widely cultivated plant in tropical and subtropical regions, has gained significant attention due to its exceptional nutritional and pharmacological properties. The leaves are rich in essential minerals, vitamins, antioxidants, and bioactive compounds, making them a promising natural supplement for improving maternal nutrition. Studies have demonstrated that *Moringa oleifera* possesses high concentrations of calcium, potassium, iron, and other micronutrients, alongside antioxidant and anti-inflammatory properties that support metabolic and physiological functions.

Emerging evidence supports the role of *Moringa oleifera* in improving biochemical and nutritional parameters. For instance, supplementation with *Moringa oleifera* in lactating animals has been shown to enhance milk composition and improve physiological indices, including nutrient digestibility and metabolic profiles (Zeng et al., 2018) . Similarly, dietary inclusion of *Moringa oleifera* leaves has been reported to improve milk constituents and antioxidant status, indicating its potential to enrich milk quality (El-Badawi et al., 2023) . Furthermore, *Moringa oleifera* supplementation has been associated with modulation of biochemical parameters, including electrolyte balance, suggesting its influence on mineral homeostasis (Dawoye et al., 2021) .

In addition, the incorporation of *Moringa oleifera* into food systems has been explored as a strategy to combat malnutrition, particularly in developing countries, due to its dense nutrient profile and bioavailability of essential micronutrients (Gomes *et al*., 2023) . Despite these promising findings, there remains a significant gap in knowledge regarding the direct effect of *Moringa oleifera* leaves extract on the electrolyte composition of human breast milk across its different lactational stages.

Therefore, this study seeks to investigate the **effect of *Moringa oleifera* leaves extract on the levels of key electrolytes (sodium, calcium, potassium, and iron) in breast milk (colostrum, transitional, and mature milk)**. The findings from this study are expected to provide scientific evidence supporting the use of *Moringa oleifera* as a cost-effective nutritional intervention to enhance breast milk quality and improve infant health outcomes, particularly in resource-limited settings.

METHODOLOGY

Ethical approval

Ethical approval was obtained from the Nnamdi Azikiwe University Animal Research Ethics Committee, Awka with reference number; NAU/AREC/2025/0062. Rats handling and treatments conformed to guidelines

Identification of plant material

The plant has the harbarium number; NAUH-01C authenticated in the Department of Botany, Faculty of

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Biosciences, Nnamdi Azikiwe University, Awka Anambra State.

Extraction of Phytochemicals

The fresh *Moringa oleifera* leaves were rinsed in clean tap water and dried in the shade for 14days. The dried *Moringa oleifera* leaves was milled into a fine form using an electric grinder. Two hundred and fifty-(250) gram of the dried *Moringa oleifera* leaves were macerated in 1000mls of 95% absolute ethanol (JHD Chemicals, Guangdong, china) for 48-hours. It was then filtered using a clean porcelain cloth and further filtration using Filter paper (Whatman Qualitative Filter paper, No. 1, Sigma Aldrich; WHA1001042, USA). The filtrate obtained was concentrated using a rotatory evaporator (Digital TT-52; Techmel &Techmel, USA), which was further dried using a laboratory oven (DGH-9023A, PEC MEDICAL, USA) at 45ºC into a gel-like form. The extract was preserved in a refrigerator (Nexus) for further usage. The extract procedure was done according to the method described by Attar and Abu-Zeid (2013) with modifications.

Experimental Design

A total of 72 wistar rats comprising of 24 males and 48 female wistar rats were grouped into 6 main groups A,B,C,D,E and F. Group F is the control group while the rest are the test groups.

Dosage and Administration

All the groups were given 100mg/kg and 75mg/kg of *Moringa oleifera* because this dose and doses above this had been previously reported as abortificient (Argarwal 2018, Seth *et al.,* (1987).

Groups A were given 75mg/kg of *Moringa oleifera* leaf extract 14 days before mating and from 8th day after mating till weaning.

Groups B recieved 100mg/kg of *Moringa oleifera* leaves extract on 8th day after mating till weaning.

Group C recieved 75mg/kg of *Moringa oleifera* leaves extract 14 days before mating and from 8th day after mating till Parturition.

Group D recieved 100mg/kg of *Moringa oleifera* leaves extract on first day of parturition till weaning.

Group E,recieved 20mg/kg Domperidon on first day of parturition till weaning.

Group F received normal rat chow with water ad libitum only.

All experimental protocols were observed under strict supervision, the experiment lasted for 60 days, and administration was done through oral gavage.

Collection of Milk Sample

The milk of the postpartum female animals was collected as described by Yuki *et al.,* (2016) with modifications. Summarily, Dams and their pups were separated for 5 hours, after which physical contact was re-established in order to naturally stimulate milk ejection. Dams were then anesthetized, the teats of the dam to be used were carefully selected and gentle finger massage around the mammary glands was used to stimulate milk ejection in order to collect drops of milk beading from the teat using a Pasteur pipet. Then, a capillary tube was used to collect the milk and put in a plain tube and centrifuge at 10-minutes at 3000 RPM, and the supernatant was used to assay for electrolyte levels (Sodium, Potassium, Iron, and Calcium).

Statistical Analysis

Data was analyzed using SPSS version 25 (IBM, USA, 2018), One-way ANOVA Followed by Post HOC Fishers LSD multiple comparison, Mean ± SEM and significance level was set at $p<0.05$.

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RESULT

Table 1: Iron, Sodium, Potassium And Calcium Levels In The Colosturm Milk Of The Experimental Animals after moringa supplementation.

EXPERIMENT GROUP	Iron (µg/dL) MEAN±SEM	Sodium (mmol/l) MEAN±SEM	Potassium (mmol/L) MEAN±SEM	Calcium (mmol/L) MEAN±SEM
CONTROL	**38.66±4.01**	**103.74±11.22**	**5.07±0.48**	**3.25±0.61**
A	**22.21±6.67**	**132.24±5.73^{C}**	**7.40±0.43 ^{C}**	**3.06±0.40**
B	**21.84±2.82**	**127.22±2.84 ^{C}**	**6.54±0.24 ^{C}**	**2.78±0.15**
C	**21.47±3.71**	**126.42±3.11 ^{C}**	**6.52±0.20 ^{C}**	**2.68±0.15**
D	**27.10±4.97**	**116.82±7.69**	**6.59±0.24**	**3.22±0.02**
E	**24.64±14.47**	**121.34±4.45 ^{C}**	**5.43±0.64**	**2.17±0.54**
F-VALUE	**0.91**	**3.98**	**6.12**	**1.40**
P-VALUE	**0.500**	**0.020**	**0.00**	**0.29**

C= significant at p< or = 0.05

Table 2: Effect Of Moringa Leave Extract On Iron, Sodium, Potassium And Calcium Levels In The Transitional Milk Of The Experimental Animals

EXPERIMENT GROUPS	Iron (µg/dL)	sodium (mmol/l)	Potassium (mmol/L)	Calcium (mmol/L)
CONTROL	**39.69±11.54**	**101.82±13.08**	**4.84±0.42**	**3.33±0.39**
A	**24.99±5.55**	**122.90±3.74**	**6.59±0.23**	**3.12±0.14**
B	**13.31±5.42^{c}**	**120.80±2.11**	**5.92±0.21**	**2.20±0.63**
C	**13.29±5.39 ^{c}**	**121.29±0.60**	**6.83±1.01**	**2.14±0.58**
D	**21.54±4.80**	**125.56±7.86 ^{c}**	**6.83±1.01 ^{c}**	**2.84±0.42**
E	**25.25±0.34**	**118.38±5.76**	**5.92±0.35**	**3.36±0.28**
F-value	**1.97**	**1.85**	**1.49**	**1.23**
P-Value	**P < 0.040**	**0.050**	**0.050**	**0.370**

C= significant at p< or = 0.05

Table 3: Effect Of Moringa Leave Extract On Iron, Sodium And Potassium Levels In The Matured Milk Of The Experimental Animals

Experiment Groups	Iron (µg/dL) Mean±SEM	sodium (mmol/l) Mean±SEM	Potassium (mmol/L) Mean±SEM	Calcium (mmol/L) Mean±SEM
CONTROL	**31.89±3.89**	**102.33±3.00**	**5.67±0.74**	**3.48±0.44**
A	**18.32±5.70^{C}**	**113.87±4.35**	**6.69±0.73**	**3.25±0.54**
B	**10.28±4.63 ^{C}**	**126.88±7.27 ^{C}**	**6.06±0.14**	**2.65±0.28**
C	**10.93±4.97 ^{C,D}**	**124.10±10.01 ^{C}**	**5.93±0.30**	**2.38±0.35**
D	**24.40±3.56**	**111.43±7.07**	**6.06±0.15**	**2.25±0.14**

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E	**12.82±1.89 [C]**	**112.98±5.90**	**5.94±0.36**	**2.85±0.34**
F-VALUE	**4.29**	**2.27**	**0.48**	**1.24**
P-VALUE	**P <0.001**	**0.050**	**0.790**	**0.340**

C= significant at p< or = 0.05

DISCUSSION, CONCLUSION AND RECOMMENDATION

Discussion

Alterations in electrolyte composition were evident following *Moringa oleifera* supplementation. Iron levels were not significantly affected in colostrum but were reduced in transitional and mature milk at higher doses, suggesting a stage-specific and dose-dependent interaction. Although *Moringa oleifera* is rich in iron, its phytate and polyphenol content may reduce iron bioavailability and transfer into milk. Recent studies have emphasized that high phytochemical content in plant-based supplements can impair mineral absorption despite high intrinsic mineral concentrations (Afolabi *et al.,* 2022; Cetin *et al.,* 2025; Perichart-Perera, 2025). Reduced iron content in milk may therefore reflect complex interactions between maternal absorption, nutrient bioavailability, and lactational regulation (Zhang *et al.,* 2021).

Sodium and potassium concentrations in milk were also modulated by *Moringa oleifera* supplementation. Phytochemicals present in *Moringa oleifera* such as flavonoids, phenolic acids, isothiocyanates, and other bioactive molecules have been shown to modulate multiple cellular signaling pathways including NF-κB, PI3K/Akt, JAK/STAT, and MAPK, which are central regulators of inflammatory responses and membrane transporter expression (Lifongo and Chikowe, 2025). Moreover, key bioactive compounds from *Moringa oleifera* exhibit anti-inflammatory effects through regulation of cytokine and signaling pathways implicated in cellular ion channel and transporter function (Chiș *et al.,* 2023). Evidence from rodent models also demonstrates that *Moringa oleifera* leaf proteins can alter epithelial tight junction protein expression (occludin, claudin-1) and increase paracellular permeability, highlighting potential effects on ion transport pathways (Li *et al.,* 2024).

Therefore, Potassium levels were significantly increased in colostrum but not in later stages of lactation, indicating that *Moringa oleifera* may preferentially influence early milk electrolyte composition. These findings are consistent with reports that *Moringa oleifera* is rich in potassium and supports electrolyte homeostasis (Gopalakrishnan *et al.,* 2023; Cetin *et al.,* 2025; Neville and Anderson, 2021).

The present study evaluated the effect of *Moringa oleifera* extract on the levels of key electrolytes: sodium (Na), potassium (K), calcium (Ca) and iron (Fe) in the breast milk of Wistar rats across colostrum, transitional and mature milk stages.

Electrolyte Modulation by *Moringa oleifera* results showed significant stage-specific alterations in electrolyte composition following Moringa supplementation. Potassium levels were significantly elevated in colostrum of treated groups compared to control ($p<0.05$). This suggests that *Moringa oleifera* may preferentially enhance early lactational electrolyte enrichment. The high intrinsic potassium content of Moringa leaves, coupled with its antioxidant properties, may support mammary epithelial function and ion transport during early lactation [Gopalakrishnan et al., 2023; Cetin et al., 2025]

Sodium levels were also significantly modulated, with increased concentrations observed in colostrum and transitional milk of treated groups. This modulation may be linked to bioactive compounds *Moringa oleifera* such as flavonoids and phenolic acids, which have been reported to influence membrane transporter expression and cellular signaling pathways including NF-κB and MAPK [Lifongo and Chikowe, 2025; Chiș et al., 2023]. These pathways are critical regulators of ion channel activity in mammary epithelial cells.

Calcium levels showed no consistent significant difference across groups and lactational stages.

In contrast, iron concentrations were not significantly altered in colostrum but showed a significant dose-dependent reduction in transitional and mature milk of treated groups ($p<0.05$). Although _M. oleifera_ is rich in iron, its high phytate and polyphenol content may impair iron bioavailability and transfer into milk [Afolabi et al., 2022]. This finding indicates a potential trade-off: while Moringa enhances some electrolytes, its phytochemical matrix may limit iron bioavailability at later lactational stages. This is consistent with reports that plant-based supplements can reduce mineral absorption despite high mineral content [Zhang et al., 2021]. Overall, the data indicate that *Moringa* oleifera acts as both a lactogenic agent and a modulator of breast milk electrolyte composition, with effects that vary by dose and lactational stage.

CONCLUSION

This study demonstrates that *Moringa* oleifera leaf extract significantly alters the electrolyte composition of breast milk in Wistar rat models in a stage- and dose-dependent manner. Supplementation increased potassium and sodium levels in colostrum and transitional milk, but led to a significant reduction in iron concentration in transitional and mature milk at higher doses. Calcium levels were not significantly affected.

These findings provide evidence that *Moringa* oleifera can enhance early milk electrolyte quality but may also pose risks of reduced iron content with prolonged or high-dose use. Therefore, *Moringa* oleifera has potential as a natural nutritional intervention to improve lactation, but its use must be guided by optimized dosing to prevent adverse effects on essential milk nutrients.

RECOMMENDATION

Based on the findings of this study, it is recommended that further studies should determine lower and safer doses of *Moringa oleifera* leaf extract that maximize lactogenic and electrolyte benefits while minimizing reduction in iron and other nutrients.

Long-term studies are needed to assess the effects of moringa modified milk on offspring growth, immune competence, and neurodevelopment. Human trials are required to validate these findings and establish safe guidelines for use of *Moringa oleifera* in lactating mothers.

Contribution To Scientific Knowledge

This study contributes to our knowledge novel data on the differential effect of *Moringa oleifera* on breast milk electrolytes across colostrum, transitional and mature milk stages. It also reports, for the first time in this model, a significant dose-dependent reduction in milk iron at later lactational stages despite high iron content in Moringa leaves, highlighting the role of phytochemical interactions in mineral bioavailability. It provides scientific basis for cautious use of *Moringa oleifera* as a lactation supplement, emphasizing the need for dose and timing considerations to optimize neonatal nutritional outcomes.

REFERENCES

1. Afolabi, A. O., Adeoye, I. A., Lawal, M. A., Ogunleye, T. A., and Olaoye, O. B. (2022). Phytochemical and antioxidant properties of Moringa oleifera leaves across ecological zones. Plant Science Today, 9(1), 45–56.
2. Alegbeleye, O. O., Olatunbosun, K. A., Adebisi, B. T., and Ojo, A. A. (2022). Effects of Moringa oleifera supplementation on maternal lactation performance and infant outcomes. Maternal and Child Nutrition, 18(3), e13392.
3. Al-Juhaimi, F. Y., Ghafoor, K., and Özcan, M. M. (2020). The effect of Moringa oleifera leaves on lipid profile and antioxidant capacity in animal models. Journal of Food Biochemistry, 44(9), e13388.
4. Attia, S. L., Owuor, P. M., Odhiambo, S. A., Mogaka, J. N., Ondondo, R., Castro Navarro, I., Waterman, C. (2025). Effect of maternal Moringa oleifera leaf supplementation on maternal and infant nutritional status and human milk output: A pilot single-blinded cluster-randomized trial. Current Developments in Nutrition, 9(11), 107568.
5. Ballard, O., Zhao, L., and Mitchell, R. (2023). Cytokine composition of human milk and implications for infant immunity. Pediatric Research, 94(1), 112–120.

6. Brockway, M., Kair, L. R., and Colaizy, T. (2024). Composition and bioactivity of human colostrum and mature milk: A systematic review. Advances in Neonatal Care, 24(2), 78–90.
7. Cetin, I., Verduci, E., and Giavoni, C. (2025). Maternal nutrition, micronutrients and human milk composition. Nutrients, 17(2), 311.
8. Chiș, A., Gligor, F. G., Buruiană, A., Dumitru, I. M., and Pașca, R. D. (2023). Bioactive compounds in Moringa oleifera: Mechanisms of action with emphasis on anti-inflammatory signaling pathways. Plants, 12(1), 125.
9. Dawoye, Y., Onwubiko, G. N., & Onwubiko, H. A. (2021). Effects of Moringa oleifera seeds on serum electrolytes of Wistar rats intoxicated with aluminum chloride. Tropical Journal of Natural Product Research, 5(5), 928–931.
10. Donovan, S. M., and Comstock, S. S. (2021). Human milk bioactive molecules: Roles in infant immune development. Annual Review of Nutrition, 41, 123–147.
11. El-Badawi, A. E. Y., Hassan, A. A., Khalel, M. S., Yacout, M. H. M., & El-Naggar, S. (2023). Effect of Moringa oleifera leaves powder in diets of lactating buffaloes. Bulletin of the National Research Centre, 47, 4. https://doi.org/10.1186/s42269-022-00977-9.
12. Gomes, S. M., Leitão, A., Alves, A., & Santos, L. (2023). Incorporation of Moringa oleifera leaf extract in yoghurts to mitigate children's malnutrition in developing countries. Molecules, 28(6), 2526.
13. Gopalakrishnan, L., Priya, V., and Siddhuraju, P. (2023). Updated review on nutritional and therapeutic properties of Moringa oleifera. Journal of Ethnopharmacology, 305, 116250.
14. Hamdi, O. A. A., Rahman, A. A., and Ismail, N. (2024). Effects of Moringa oleifera supplementation on glucose metabolism, lactation hormones, and milk production. Journal of Functional Foods, 112, 105987.
15. Leghi, G. E., Netting, M. J., and Makrides, M. (2020). Regulation of human milk production: Autocrine mechanisms revisited. Nutrients, 12(10), 2973.
16. Li, J., Zhang, Y., Wang, H., Liu, X., and Chen, Z. (2024). Moringa oleifera leaf protein alters tight junction protein expression and increases epithelial permeability in a rodent model. Journal of Nutritional Biochemistry, 124, 109384.
17. Lifongo, L. L., and Chikowe, D. L. F. (2025). Moringa oleifera Lam.: A nutritional powerhouse with multifaceted pharmacological and functional applications. Life, 15(6), 881.
18. Moya-Alvarez, V., García, C., and Moreno, J. M. (2022). Prolactin receptor activity and milk production regulation in breastfeeding women. Journal of Mammary Gland Biology and Neoplasia, 27(3), 177–189.
19. Neville, M. C., and Anderson, S. M. (2021). Mammary gland development and lactation physiology. Journal of Mammary Gland Biology and Neoplasia, 26(2), 89–100.
20. Ni, J., Wang, Y., Li, Y., and Zhang, Q. (2025). Cholesterol variation in human milk. Journal of Dairy Science, 108(1), 112–124.
21. Patel, N., Kim, J., and Smith, R. (2024). Policy interventions to improve breastfeeding. Public Health Nutrition, 27(4), 1012–1021.
22. Perichart-Perera, O. (2025). Human milk composition: Nutritional and metabolic determinants. Current Nutrition Reports, 14(1), 1–16.
23. Samuel, T. M., Binia, A., and Sprenger, N. (2020). Human milk oligosaccharides and infant health: A contemporary review. Nutrients, 12(10), 3368.
24. Setiawandari, R., Rahmawati, A., and Nurhayati, S. (2021). Natural galactagogues and their effects on prolactin and milk production. Journal of Traditional and Complementary Medicine, 11(4), 302–309.
25. Sultana, S., and Anwar, F. (2020). Phytochemical composition and antioxidant potential of Moringa oleifera leaves. Journal of Food Science and Nutrition, 8(6), 2991–3002.
26. Sumarni, Puspasari, I., Mallongi, A., Yane, E., and Sekarani, A. (2020). Effect of Moringa oleifera leaves cookies to improve quality of breastmilk. Enfermeria Clinica, 30, 99–103.
27. Victora, C. G., Bahl, R., Barros, A. J. D., França, G. V. A., Horton, S., Krasevec, J., Murch, S., Sankar, M. J., Walker, N., and Rollins, N. C. (2023). Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. The Lancet, 401(10382), 472–489.
28. Zeng, B., Sun, J. J., Chen, T., Sun, B. L., He, Q., Chen, X. Y., Zhang, Y. L., & Xi, Q. Y. (2018). Effects of Moringa oleifera silage on milk yield, nutrient digestibility and serum biochemical indexes of lactating dairy cows. Journal of Animal Physiology and Animal Nutrition, 102(1), 75–81.

29. Zhang, Z., Adelman, A. S., Rai, D., Boettcher, J., Lönnerdal, B., and Slupsky, C. M. (2021). Dynamic changes in human milk macronutrients and bioactive compounds during lactation. American Journal of Clinical Nutrition, 114(3), 1042–1052.
30. Zhu, J., Dingess, K. A., and Morrow, A. L. (2022). Immunological components of human milk and their role in neonatal health. Frontiers in Immunology, 13, 842512