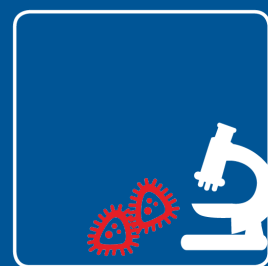


Mark Manary:

Beriget mælkepulver forbedrer skolebørns ernæring

Fortified milk powder improves nutrition of school children



Final report

for collaborative projects funded via the Danish Dairy Research Foundation (DDRF)

1. Title of the project

Danish: Beriget mælkpulver forbedrer skolebørns ernæring

English: Fortified milk powder improves nutrition of school children

2. Project manager

Mark Manary

Project Peanut Butter

7435 Flora Avenue, St. Louis, MO USA 63143

+1 3144542178

manarymj@wustl.edu

3. Other project staff

Matilda Steiner-Asiedu, University of Ghana, tillysteiner@gmail.com

Firibu K. Saalia, University of Ghana, fsaalia@gmail.com

Kevin Stephenson, Washington University in St. Louis, k.stephenson@wustl.edu

4. Sources of funding

Danish Dairy Research Foundation

5. Project period

Project period with DDRF funding: 01/2024 – 05/2026

Revised, if necessary: N/A

Total project period, if sub-project within a larger project: 01/2024 – 05/2026

Revised, if necessary: N/A

6. Project summary

Danish:

Underernæring i børn har langsigtede konsekvenser, herunder hæmmet vækst, manglende skolegang og reduceret livsindkomst, der strækker sig over hele skoleåret. I det nordlige Ghana, hvor omtrent hvert tredje barn under fem år er hæmmet, er skolemad en af de mest veldokumenterede og skalerbare interventioner, der har potentiale til at forbedre fremmødet, reducere frafald og bidrage til husholdningernes fødevarer sikkerhed. Ghanas nationale skolemadsprogram når ud til millioner af børn, men i den landlige nordlige region undermineres dets levering af utilstrækkelig og forsinket finansiering, så mange børn enten springer måltider helt over eller modtager mad, der er energirig, men fattig på mikronæringsstoffer. Vores tidligere arbejde i Ghana har vist, at tilsætning af mælk til skolemad forbedrer kognitionen hos skolebørn, og denne undersøgelse blev designet til at teste, om en centralt produceret, mælkeberiget skolemad også kan forbedre skolefremmødet.

Det primære formål med dette projekt var at bestemme, om det at give en færdiglavet skolemad baseret på jordnødder og mælk (PM-RUF) som et dagligt skolemåltid øger skolefremmødet sammenlignet med et lokalt tilberedt traditionelt måltid i den landlige nordlige region i Ghana. Sekundære mål var at vurdere effekterne på frafald, indskrivning, nye indskrevne elever og vækst, med særligt fokus på unge, en understuderet aldersgruppe i forskning i skolemad.

Denne undersøgelse var et klyngerandomiseret kontrolleret forsøg udført i Mion-distriktet, Northern Region, mellem maj 2024 og maj 2026. Tyve skoler blev randomiseret til PM-RUF (10 skoler) eller et lokalt tilberedt skolemåltid med tilsvarende energi (10 skoler), stratificeret efter skoletype (primær vs. ungdomsskole), skolestørrelse og afstand fra hovedvejen. PM-RUF blev produceret på Project Peanut Butters centraliserede fabrik i Kumasi og leveret til interventionskoler. Kontrolskoler tilberedte måltider lokalt af ris og andre ingredienser, hvor undersøgelsen leverede ris og midlerne til yderligere ingredienser direkte for at sikre ensartet madtilberedning. Dagligt fremmøde blev registreret på alle 20 skoler ved hjælp af biometriske fingeraftryksscannere, hvilket gav objektive data på individniveau uden afhængighed af lærerrapportering. Antropomi blev målt i 1. og 3. termin i hvert skoleår. I alt 5.726 elever blev inkluderet i den primære analyse. Det er værd at bemærke, at Ghanas skolemadningsprogram ikke når ud til alle skoler i landet, og de skoler, der blev udvalgt til dette forsøg, var ikke tilmeldt GSFP på tidspunktet for undersøgelsen.

Børn, der gik på PM-RUF-skoler, havde signifikant højere odds for daglig fremmøde end børn i kontrolskoler (justeret OR 2,04, 95% CI 1,01-4,15, $p=0,035$). Den justerede mediane daglige fremmødeprocent var 75,1% i interventionskoler versus 66,0% i kontrolskoler, en forskel på 9,0 procentpoint (95% CI +0,6 til +17,5). Effekten var ensartet på tværs af folkeskoler (+11,0 procentpoint forskel i median) og ungdomsuddannelser (+7,3 procentpoint), og PM-RUF-elever var betydeligt mere tilbøjelige til at opretholde en fremmødeprocent på over 80% (39% vs. 24%). Centraliseret PM-RUF-produktion og -distribution viste sig at være mulig og effektiv til at forbedre fremmødet i løbet af den toårige undersøgelsesperiode.

Afslutningsvis forbedrede et centralt produceret skolemåltid med mælkepulver skoledeltagelsen betydeligt i det nordlige Ghana landdistrikter sammenlignet med traditionelle lokalt tilberedte måltider. Centraliseret produktion af mælkebaserede færdiglavede skolemåltider tilbyder et muligt alternativ til hjemmedyrket skolemad i fødevarer usikre regioner og kan bidrage til at afhjælpe langvarige mangler i pålidelighed og kvalitet. Denne biometriske fremmødemetode giver også en skabelon til fremtidige evalueringer af skolemad.

English:

Childhood malnutrition has long-term consequences including stunted growth, missed schooling, and reduced lifetime earnings that extend across the school years. In northern Ghana, where roughly one in three children under five is stunted, school feeding is one of the most well-evidenced, scalable interventions that holds the potential to improve attendance, reduce dropouts, and contribute to household food security. Ghana's national school feeding program reaches millions of children, but in rural Northern Region its delivery is undermined by inadequate and delayed funding, so many children either miss meals entirely or receive food that is energy-sufficient but micronutrient poor. Our prior work in Ghana has shown that adding milk to school food improves cognition in school-aged children and this study was designed to test whether a centrally produced, milk-fortified school food can also improve school attendance.

The primary aim of this project was to determine whether providing a peanut and milk-based ready-to-use school food (PM-RUF) as a daily school meal increases school attendance compared with a locally prepared traditional meal in rural Northern Region, Ghana. Secondary aims were to assess effects on dropout, matriculation, new enrollment, and growth, with a particular focus on adolescents, an understudied age group in school feeding research.

This study was a cluster-randomized controlled trial conducted in Mion District, Northern Region, between May 2024 and May 2026. Twenty schools were randomized to PM-RUF (10 schools) or a locally prepared school meal of equivalent energy (10 schools), stratified by school type (primary vs. junior high), school size, and distance from the main road. PM-RUF was produced at Project Peanut Butter's centralized factory in Kumasi and delivered to intervention schools. Control schools prepared meals locally from rice and other ingredients, with the study providing the rice and funds for additional ingredients directly to ensure consistent meal preparation. Daily attendance was recorded at all 20 schools using biometric fingerprint scanners, providing objective individual-level data without reliance on teacher reporting. Anthropometry was measured in the 1st and 3rd terms of every school year. A total of 5,726 students were included in the primary analysis. Notably, the Ghana School Feeding Program does not reach every school in the country, and the study schools selected for this trial were not enrolled in GSFP at the time of the study.

Children attending PM-RUF schools had significantly higher odds of daily attendance than those in control schools (adjusted OR 2.04, 95% CI 1.01-4.15, $p=0.035$). Adjusted median daily attendance was 75.1% in intervention schools versus 66.0% in control schools, a difference of 9.0 percentage points (95% CI +0.6 to +17.5). The effect was consistent across primary schools (+11.0 pp difference in median) and junior high schools (+7.3 pp), and PM-RUF students were considerably more likely to maintain above 80% attendance (39% vs. 24%). Centralized PM-RUF production and distribution proved feasible and effective at improving attendance across the two-year study period.

In conclusion, a centrally produced school meal with milk powder significantly improved school participation in rural Northern Ghana compared with traditional locally prepared meals. Centralized production of milk-based ready-to-use school meals offers a feasible alternative to home-grown school feeding in food-insecure regions and may help to address long-standing reliability and quality gaps. This biometric attendance methodology also provides a template for future school feeding evaluations.

7. Project aim

Danish:

Formålet med dette projekt er at vurdere, om et nyt fødevariehjælpsprodukt — et klar-til-brug skolemåltid med mælk — kan øge skolegangen blandt elever i grundskolen og på mellemtrinnet i landdistrikterne i det nordlige Ghana. Sekundære effektmål omfatter matrikulering, fastholdelse og antropometrisk vækst.

English:

The objective of this project is to assess whether provision of a novel food aid product, a ready-to-use school meal with milk, can increase school attendance among primary and junior high students in rural northern Ghana. Secondary outcomes include matriculation, retention, and anthropometric growth.

8. Background for the project

School feeding has the potential to improve attendance, reduce dropout, and strengthen household food security, and our group's prior work has shown that adding milk to school food can promote physical growth and confer cognitive benefits in school-aged children. In a prior randomized controlled trial implemented by our group among primary school students in rural Northern Ghana, a peanut and milk based ready-to-use school food improved measures of cognition among 5-12-year-old children, with measurable gains in fluid cognition and processing speed compared with a fortified millet porridge. In another study by our group, higher milk protein intake (8.8 g/day) improved pattern

recognition memory and executive function after 4.5 months in a dose-response manner, and 9 months of milk protein supplementation increased lean body mass. These benefits are particularly relevant in rural northern Ghana, where milk and dairy are uncommon in children's diets, contributing to gaps in essential amino acids and key micronutrients.

Despite this evidence base, several crucial gaps remain in what we know about the effects of school feeding. First, most research has been conducted in primary school settings, with little focus on adolescence. The benefits of education accrue and compound as its duration increases and demonstrating that school feeding promotes retention into secondary school would substantially strengthen its value as low- and middle-income countries seek to reduce drop-outs. Adolescence is also a window of physical and cognitive growth. While many cultural, economic, and social factors contribute to reduced attendance and greater school attrition among girls, school feeding has shown potential to increase gender equity.

Second, most school feeding research has involved foods common in the school's locale rather than nutrient-rich, fortified options. In rural settings such as Northern Ghana, the typical school meal is rice with stew that may not always include animal-source protein or a full range of micronutrients. Food quality matters in child development, and the World Food Programme has identified nutrient quality as a significant research gap in school feeding.

Third, methods of food preparation and provision are of evolving interest in school feeding programs. In some policy circles there is an emphasis on Home Grown School Feeding (HGSF), and Ghana's national program reflects this approach. In remote and resource-limited settings, consistent delivery can be challenging, and reliability of meal provision is itself an important determinant of whether the benefits of school feeding are realized. An alternative model has been developed by Project Peanut Butter in northern Ghana, in which school foods are made at a centralized factory in Kumasi and distributed to schools. Ingredients are sourced locally whenever possible. The peanut and milk based ready-to-use food is shelf-stable, nutrient dense, fortified with micronutrients, and well accepted by children in this population.

What has not previously been tested is whether this centrally produced, milk-fortified ready-to-use food can improve school participation – attendance, retention, matriculation – when delivered as a daily meal at scale. This project was designed to test that hypothesis.

9. Sub-activities in the entire project period

The project's sub-activities were organized under five objectives, as set out in the Gantt chart submitted with the original application. Sub-activities under each objective are listed below.

Objective 1: Project Implementation and Start-Up. Sub-activities: initial planning, team mobilization, and protocol finalization.

Objective 2: Food Development and Production. Sub-activities: recipe finalization and PM-RUF production at Project Peanut Butter's centralized factory in Kumasi for distribution to intervention schools.

Objective 3: Baseline Attendance Tracking. Sub-activities: identification of and training on biometric attendance trackers; community meetings to explain the project to parents; enrollment of children and collection of baseline biometrics.

Objective 4: Determine if PM-RUF improves matriculation, increases enrollment, and reduces dropout rates among 5–17-year-olds in primary and secondary schools compared with control feeding. Sub-activities: initiation and continuation of food distribution to schools; attendance monitoring across school years; data analysis including individual-level tracking of class advancement.

Objective 5: Determine if PM-RUF reduces dropout rates among 10–17-year-old girls compared with control feeding.
Sub-activities: initiation and continuation of food distribution; attendance monitoring across school years; data analysis with focus on the adolescent girl subgroup.

10. Deviations

No scientific or financial deviations occurred. The trial was conducted as designed, with the primary outcome (school attendance) and secondary outcomes (dropout, matriculation, new enrollment, and anthropometric growth) all assessed as planned. The project period was extended from the originally proposed end date of 12/2025 to 05/2026 to allow for completion of attendance tracking through most of the 2025–26 school year and final data analysis.

11. Project results

Objective 1: Project Implementation and Start-Up

Sub-activity: Planning, ethics approvals, and team mobilization. The project team was assembled across Project Peanut Butter (Ghana), Washington University in St. Louis, and the University of Ghana. Approval was obtained from the relevant ethics committees prior to enrollment. Field staff were recruited and trained. Twenty schools in Mion District, Northern Region, were selected and randomized 1:1 to PM-RUF (intervention) or locally prepared meals (control), stratified by school type (primary vs. junior high), school size, and distance from the main road. Baseline anthropometry, household socioeconomic data, and food-insecurity measures were collected. The 20 schools selected for the trial were not enrolled in the Ghana School Feeding Program at the time of the study.



The two arms were well balanced at baseline with respect to age, sex, household characteristics, and anthropometry. Median age was 12 years (IQR 9–15) in the intervention arm and 13 years (8–15) in control, and 43–45% of participants were female across arms. Mean baseline weight was 36.0 ± 12.3 kg in intervention versus 35.8 ± 13.5 kg in control; mean height-for-age z-score was -1.0 in both arms; mean BMI z-score was -0.7 ± 0.9 in both arms. A total of 5,726 students were included in the primary analysis (3,065 intervention, 2,661 control).

Table 1. Baseline characteristics

Characteristic	Intervention N = 3,065	Control N = 2,661
Age, median (IQR), y	12 (9, 15)	13 (8, 15)
Female sex, no./total (%)	1,312/3,065 (43)	1,189/2,661 (45)
Mother alive, no./total (%)	2,943/2,964 (99)	2,565/2,578 (99)
Father alive, no./total (%)	2,901/2,961 (98)	2,544/2,581 (99)
Father lives in household, no./total (%)	2,842/2,887 (98)	2,495/2,533 (98)
Number of siblings, median (IQR)	6 (4, 6)	5 (3, 6)
Mother has paid work (non-farming), no./total (%)	353/2,925 (12)	533/2,522 (21)
Father has paid work (non-farming), no./total (%)	434/2,922 (15)	601/2,532 (24)
Household owns a computer, no./total (%)	203/2,944 (7)	189/2,549 (7)
Clean water source, no./total (%)	2,663/2,921 (91)	1,853/2,539 (73)
Severely food insecure household, no./total (%)	728/2,962 (25)	751/2,587 (29)
Anthropometry		
Weight, kg	36.0 ± 12.3	35.8 ± 13.5
MUAC, cm	20.2 ± 3.3	20.3 ± 3.6
Height-for-age z-score	-1.0 ± 1.2	-1.0 ± 1.1
BMI z-score	-0.7 ± 0.9	-0.7 ± 0.9
School characteristics (cluster level, N = 10 schools per arm)		
Primary school (vs Junior High), no./total (%)	5/10 (50)	5/10 (50)
Distance from main road, median (IQR), km	19.5 (13.0, 36.0)	18.5 (6.0, 44.0)

Student-level section (top): denominators reflect student counts. School-level section (bottom): K = 10 intervention / 10 control schools; denominators reflect school counts, not students. Continuous variables: median (IQR) for age, siblings, and distance; anthropometry as mean ± SD. Categorical variables: no./total (%). Clean water source = piped water (own or public) or borehole (own or public). Severely food insecure = HFIAS category 4. Number of siblings is top-coded at 6+ per the questionnaire.

Objective 2: Food Development and Production

Sub-activity: PM-RUF production and distribution. PM-RUF was produced at Project Peanut Butter's centralized factory in Kumasi and distributed to the 10 intervention schools. The food is a peanut-paste-based ready-to-use food containing 36% peanut, 27% fat-free milk powder, 13% palm oil, 11% sugar, 10% cowpea, and 1% micronutrient mix (14 micronutrients at 0.5–1 RDA each). Each daily ration provides approximately 400 kcal and 17.6 g protein, including 7.1 g essential amino acids, 341 mg calcium, and 1.6 mg vitamin B12. Control schools received rice from the study and locally sourced ingredients to prepare meals of approximately equivalent energy, most commonly jollof rice, rice and beans, or rice with groundnut soup. The control arm was designed to approximate the Ghana School Feeding Program's intended delivery by providing reliable, uninterrupted meal delivery without the funding delays that often constrain the national program in rural settings. First food deliveries began approximately 28 June 2024 and continued without supply interruption through May 2026.

Nutrient	PM-RUF	Local school meal*
Energy, kcal	402	~421
Protein, g	17.6	~6.8
Fat, g	24.7	~23.8
Essential amino acids, g	7.13	Not reported
Calcium, mg	341	~63
Vitamin B12, mg	1.6	~0
Zinc, mg	4.1	~1.3
Niacin, mg	10.0	~1.6
Folate, µg	201.7	Not reported
Vitamin C, mg	17.5	~25

* Control: approximate values based on typical GSFP meals (Agbozo et al., 2018). Control meals in this study vary by school cook.

Objective 3: Baseline Attendance Tracking

Sub-activity: Biometric scanner installation, community engagement, and enrollment. Biometric fingerprint scanners were installed at all 20 schools, and field staff were trained on daily scanning protocols. Community meetings were held with parents and local leaders at each site to explain the project. Children were enrolled and baseline biometrics were collected. Daily attendance scanning began at the start of the trial and continued throughout the project period.

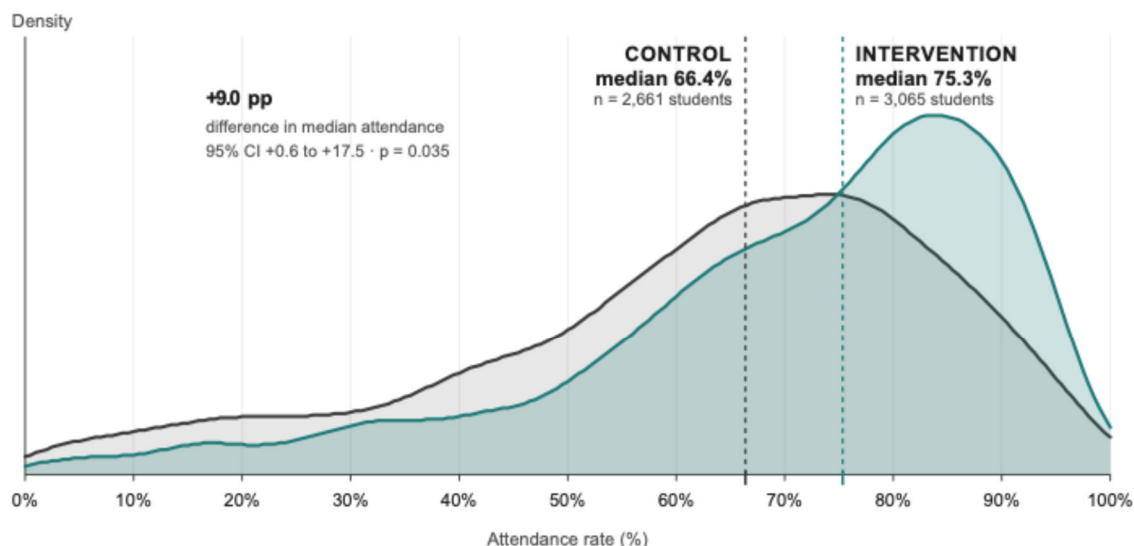
Objective 4: Determine if PM-RUF improves matriculation and reduces dropout among 5–17-year-olds compared with control feeding

Sub-activity: Daily attendance tracking and analysis. Daily attendance was recorded at all 20 schools using biometric fingerprint scanners from May 2024 through May 2026. Student-level attendance was computed as $100 \times (\text{present scans}) / (\text{present} + \text{absent scans})$. Attendance was compared across arms using ordinal logistic regression with school type, school size, and distance to main road as covariates, and cluster-bootstrap standard errors with school as the cluster ($B = 2,000$).

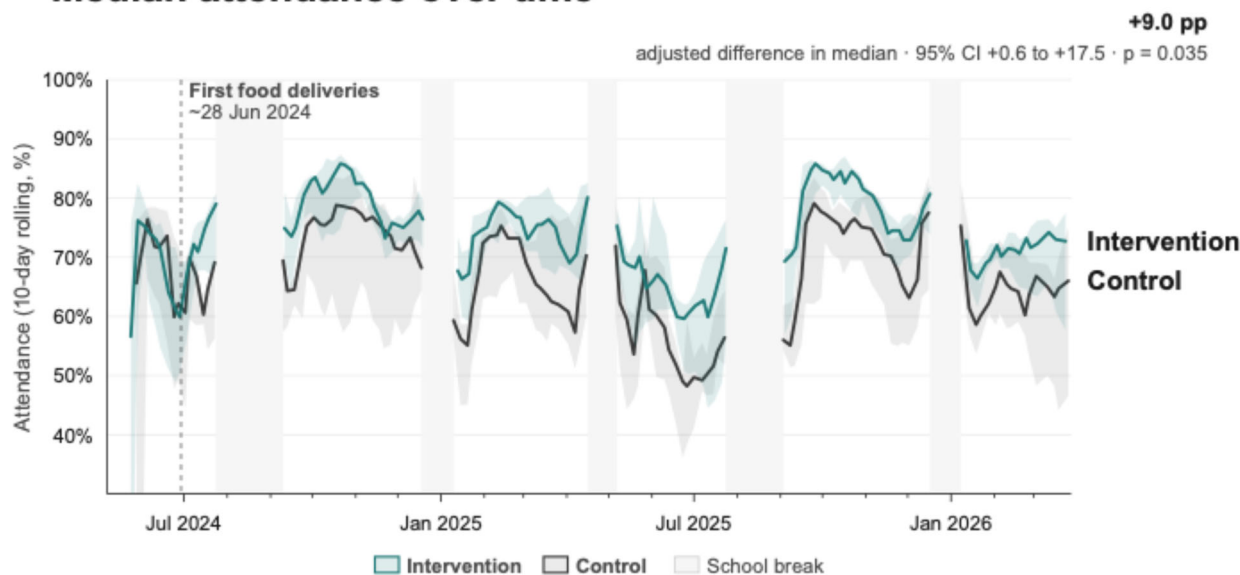
Across 5,726 students in 20 schools, students in PM-RUF schools had significantly higher odds of daily attendance than control students (adjusted OR 2.04, 95% CI 1.01–4.15, $p = 0.035$). Adjusted median daily attendance was 75.1% (95% CI 71.5–78.6) in intervention schools versus 66.0% (95% CI 59.0–73.1) in control schools, an adjusted difference of +9.0 percentage points (95% CI +0.6 to +17.5). The effect was consistent across primary schools (+11.0 pp difference in median attendance) and junior high schools (+7.3 pp). PM-RUF students were considerably more likely to maintain above 80% attendance (39%, 95% CI 31.5–45.6) than control students (24%, 95% CI 16.6–38.5).

Intervention shifts the student attendance distribution rightward

ALL SCHOOLS · PER-STUDENT ATTENDANCE RATE



Median attendance over time



Objective 5: Determine if PM-RUF reduces dropout rates among 10–17-year-old girls compared with control feeding

Sub-activity: Adolescent girl subgroup analysis. Subgroup analyses focused on adolescent girls are being completed and will be reported in the primary scientific publication, alongside longitudinal anthropometric outcomes (weight, height, MUAC) measured in terms 1 and 3 of each school year.

Conclusion

A centrally produced peanut-and-milk-based ready-to-use school food significantly improved the odds of daily attendance compared with a traditional locally prepared meal in rural northern Ghana. Centralized production proved feasible and reliable across two academic years and may help address gaps in supply chain reliability and food quality that constrain home-grown school feeding in food-insecure regions. Biometric attendance tracking provided a powerful objective measurement tool and offers a methodological framework for future school feeding evaluations.

12. The relevance of the results, including relevance for the dairy industry

This trial is among the first to evaluate a centrally produced milk-fortified ready-to-use school food against a traditional locally prepared meal in a low-income setting and is the first to our knowledge to deploy biometric fingerprint attendance tracking at scale in a school feeding trial in this context. The methodological framework — objective attendance measurement combined with cluster randomization stratified on school type, size, and remoteness — addresses long-standing concerns about teacher-reported attendance in school feeding research and provides a template for future evaluations. The inclusion of junior high school students also adds to a thin evidence base on school feeding for adolescents, a developmental window critical for catch-up growth, cognitive maturation, and educational attainment.

From a social perspective, a 9-percentage-point gain in median daily attendance represents a meaningful improvement in a population where school participation has been chronically constrained by food insecurity. Improved attendance has well-documented downstream consequences for educational attainment and lifetime earnings, and is particularly important for adolescent girls, who face elevated risks of leaving school early. The findings also support

concrete policy options for strengthening Ghana's national school feeding program in regions where home-grown delivery has been difficult to sustain.

For the dairy industry, this study provides direct trial-based evidence that fat-free milk powder, when incorporated into a shelf-stable, centrally produced school food, can be delivered reliably at scale in remote rural Africa and is associated with measurable improvements in school participation. The comparison was made against a control arm designed to approximate the Ghana School Feeding Program's intended delivery — locally prepared meals provided reliably and without the funding interruptions that constrain the national program — making the observed advantage of PM-RUF a conservative estimate of the gap between centralized milk-fortified feeding and HGSP as typically delivered. Together with prior work establishing milk's role in therapeutic foods for severely malnourished children — including the previous DDRF-funded Milk Matters study, which showed that both milk protein and lactose contribute to weight gain in malnutrition — this trial extends the evidence for milk powder beyond clinical malnutrition treatment and into population-level school nutrition. Several implications follow. First, it strengthens the case for milk powder as a high-value, shelf-stable animal-source protein in food-insecure settings. Second, it demonstrates school feeding as a viable channel for delivering dairy ingredients to populations with very limited access to fresh milk. Third, it supports the development of milk-fortified ready-to-use foods as a scalable category alongside more established therapeutic uses such as RUTF. Milk and dairy are uncommon in the diets of children in rural northern Ghana, making milk-based fortification of school feeding particularly relevant in this context.

Several new research areas emerge from these results. Future work could examine cost-effectiveness comparisons between centrally produced milk-fortified meals and locally prepared school meals, and testing of the model in different populations and settings to assess generalizability beyond rural northern Ghana.

13. Communication and knowledge sharing about the project

Papers in international journals:

Shani I, Agyemang F, Wegner D, Danquah AO, Manary MJ, Stephenson KB, Saalia FK, Steiner-Asiedu M. Ready-to-Use School Meals in Northern Ghana Are a Viable Alternative to Traditional School Meals. *Annals of the New York Academy of Sciences*. 2025 Sep 10;1552(1):29-35. doi: 10.1111/nyas.70072.

Additional papers are currently under preparation.

Easily read papers:

Igangsatte projekter under Mejeribrugets ForskningsFond. Mælkeritidende 2024, nr. 9.

Student theses:

None

Oral presentations at scientific conferences, symposiums etc.:

None

Oral presentations at meetings:

2026 "Final reporting: School Meals Fortified With Milk Powder Improves School Participation." Danish Dairy Research Foundation Health & Nutrition Coordination Group Meeting (funder meeting). Lyngby, Denmark.

Other:

None

14. Contribution to master and PhD education

The project contributes to training and education by sponsoring a PhD student from the University of Ghana, Issah Saani. He led the data collection, project operation and data analyses, thereby learning best practices and skills in clinical trial design and execution. Two other master's degree students in food science were engaged in the project, fulfilling a portion of their academic requirements.

15. New contacts/projects

The trial concluded in May 2026. The project has built a foundation for continued collaboration between Project Peanut Butter (Ghana), Washington University in St. Louis, and the Department of Nutrition and Food Science at the University of Ghana around centrally produced milk-fortified ready-to-use foods in institutional feeding programs. The biometric attendance methodology developed during this trial could be applied to further school feeding evaluations. The team anticipates that these results will inform follow-on research and partnership opportunities in the coming year.