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Prevention of acute malnutrition in children aged 6 months to 2 years using red goat milk in Maradi Niger from 2023 to 2026

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ABSTRACT

Acute malnutrition remains a major public health challenge for children under five years of age in Niger. The Maradi region one of the areas with the highest malnutrition burden in the country faced a serious acute malnutrition situation between 2025 and 2026 with several departments classified in Integrated Food Security Phase Classification Phase Four which is the critical level. The Maradi Red Goat is a local high yielding dairy breed whose milk is rich in vitamin A and easily digestible and has long been used at community level to improve the nutrition of young children. This study aimed to evaluate the effect of using red goat milk to prevent acute malnutrition in children aged 6 to 24 months in Maradi over the period 2023 to 2026. The study used a prospective cohort design comparing children receiving red goat milk supplementation with children not receiving supplementation in Maradi region. Data collection included anthropometric indicators such as weight height and mid upper arm circumference as well as dietary intake information. The results showed that red goat milk supplementation was positively associated with child weight gain and mid upper arm circumference improvement but no significant effect on height growth was observed during the study period. Goat milk availability household allocation patterns and maternal education level were key factors influencing intervention effectiveness. This study provides empirical evidence for using local resources in malnutrition prevention.

Keywords: : red goat milk, acute malnutrition, Maradi, Niger, child nutrition, prevention

RESUME

La malnutrition aigue demeure un defi majeur de sante publique pour les enfants de moins de cinq ans au Niger. La region de Maradi l une des plus touchees par le fardeau de la malnutrition a connu une situation de malnutrition aigue preoccupante entre 2025 et 2026 avec plusieurs departements classes en Phase Quatre de l IPC Malnutrition Aigue qui est le niveau critique. La chevre rouge de Maradi est une race laitiere locale prolifique dont le lait est riche en vitamine A et facilement digestible et est traditionnellement utilise au niveau communautaire pour ameliorer la nutrition des jeunes enfants. Cette etude vise a evaluer l effet de la supplementation en lait de chevre rouge sur la prevention de la malnutrition aigue chez les enfants ages de 6 a 24 mois dans la region de Maradi sur la periode 2023 a 2026. Une cohorte prospective a ete constituee comparant les enfants recevant une supplementation en lait de chevre a ceux ne la recevant pas. Les donnees anthropometriques telles que le poids la taille et le perimetre brachial ainsi que les informations sur les apports alimentaires ont ete collectees. Les resultats indiquent une association positive entre la supplementation en lait de chevre et la prise de poids ainsi que l amelioration du perimetre brachial mais aucun effet significatif sur la croissance staturale n a ete observe durant la periode d etude. L accessibilite du lait de chevre les modalites de distribution au sein du menage et le niveau d education des meres sont des facteurs determinants de l efficacite de l intervention.

Mots-clés : lait de chevre rouge, malnutrition aigue, Maradi, Niger, nutrition infantile, prevention

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1. INTRODUCTION

Acute malnutrition remains a major public health problem for children under five years of age in Niger. According to the Integrated Food Security Phase Classification acute malnutrition analysis for the period from August 2025 to July 2026 approximately 1.6 million children aged 6 to 59 months in Niger are expected to suffer from acute malnutrition including more than 410000 children facing severe acute malnutrition. In addition, more than 306800 pregnant and lactating women are also expected to suffer from acute malnutrition during the same period.

The situation in Maradi region is particularly severe. According to the Integrated Food Security Phase Classification analysis the departments of Bermo and Tessoua in Maradi region were classified in Phase Four which is the critical level during the peak malnutrition period from August to November 2025 while twenty-two other departments and two urban areas were classified in Phase Three which is the serious level. Maradi region has long been one of the areas with the highest malnutrition burden in Niger. According to data from the Niger Living Conditions and Household Survey the stunting rate among children under five years in Maradi region is 65.5 percent which is one of the highest in the country. The same survey shows that the underweight prevalence among children in Maradi region is also 65.4 percent.

The high prevalence of malnutrition in Maradi region is associated with multiple factors. A study on environmental conditions and hygiene practices among children aged 6 to 24 months with severe acute malnutrition at the Maradi Regional Hospital Center showed that low birth weight father without education poor household hygiene conditions and inappropriate feeding practices including failure to ingest colostrum early cessation of exclusive breastfeeding and early introduction of complementary foods are all important risk factors for severe acute malnutrition. These findings indicate that malnutrition prevention requires multisectoral intervention strategies that simultaneously address feeding practices hygiene conditions and household socioeconomic factors.

In this context strategies that use local resources for malnutrition prevention have attracted increasing attention. The Maradi Red Goat is a local breed specific to the Maradi region of Niger and is called the poor man cow by local farmers. This breed is known for its high prolificacy with two to three kids per litter and sometimes up to four and its milk production capacity of approximately 0.6 liters per day with two lactation periods per year each lasting three to four months. Red goat milk is rich in vitamin A and is described as extremely easy to digest especially suitable for young children. The milk of this breed has a long history of traditional use in rural Maradi and many orphans who lost their mothers survived on goat milk.

Historically interventions using goat milk to improve child nutrition have been implemented in Niger. In 2005 the United Nations Children Fund implemented a women led goat project in approximately 150 villages in Maradi region providing female goats as loans to mothers of malnourished children with the condition that they pass on the first offspring to another woman in need. The evaluation of this project showed that goat milk and its products including cheese and meat provided nutritional supplementation for children while income from selling cheese and meat enabled families to purchase cereals and medicines. Community growth

monitoring groups trained by the United Nations Children Fund identified families most in need of goats and provided counseling to women on optimal nutrition practices including exclusive breastfeeding.

A project funded by the African Development Bank in Maradi and Tillabery regions used a similar strategy. The project established goat kits enabling women in four municipalities to expand goat milk production. More than 8070 liters of goat milk were sold with a large proportion used to improve household nutrition especially for children and infants.

The nutritional properties of red goat milk provide a biological basis for its use in child malnutrition prevention. Studies show that goat milk fat globules are smaller and more easily broken down by digestive enzymes with digestion time approximately 20 percent less than cow milk. Goat milk protein is more easily digestible and its amino acids are more easily absorbed. In addition, goat milk contains higher levels of taurine at approximately 6.62 milligrams per 100 milliliters with some Mediterranean breeds reaching 6.90 to 11.37 milligrams which is ten times the taurine content of cow milk. Goat milk also contains a higher proportion of medium chain fatty acids which have antibacterial and antiviral properties and are rapidly absorbed from the intestine. However, it should be noted that pediatricians do not recommend goat milk as a complete substitute for infants under one year of age because of its higher protein and mineral content and lower carbohydrate folate and vitamin C D E B6 and B12 content.

A systematic review and meta-analysis on the effects of goat milk formula on infant growth and safety parameters included four studies with 670 infants and showed that infants fed goat milk formula had similar growth and safety parameters to those fed cow milk formula indicating that goat milk formula is safe for use from birth.

This study aimed to evaluate the effect of using red goat milk to prevent acute malnutrition in children aged 6 to 24 months in Maradi region over the period 2023 to 2026. The study sought to answer the following questions. Can red goat milk supplementation effectively prevent acute malnutrition in children of this age group. What factors moderate or influence the effectiveness of the intervention. The results of this study will provide empirical evidence for strategies using local animal resources for child malnutrition prevention and will inform intervention design in similar settings.

2. LITERATURE REVIEW

2.1 Burden and Determinants of Child Malnutrition in Niger

Niger is one of the countries with the highest burden of child malnutrition globally. According to the 2025 Integrated Food Security Phase Classification acute malnutrition analysis approximately 1.6 million children aged 6 to 59 months will suffer from acute malnutrition between August 2025 and July 2026 with more than 410000 children facing severe acute malnutrition. During the same period more than 306800 pregnant and lactating women are expected to suffer from acute malnutrition.

The drivers of malnutrition are multiple. The Integrated Food Security Phase Classification analysis notes that low food consumption and poor child dietary diversity high anemia rates prevalence of childhood diseases low coverage of acute malnutrition management programs and health facilities difficult access to safe drinking water floods and civil insecurity are the main drivers. In Maradi region a case control study on severe acute malnutrition among children aged 6 to 24 months found that children aged 6 to 11 months had lower risk than older children with adjusted odds ratio of 0.34 and p value of 0.003 suggesting the protective effect of breastfeeding. Low birth weight with adjusted odds ratio of 8.12 and p value of 0.039 and father without education with adjusted odds ratio of 3.46 and p value of 0.01 were strong predictors. Poor household hygiene conditions with cleaning less than twice per day having adjusted odds ratio of 3.36 and inadequate latrine maintenance with only weekly cleaning having adjusted

odds ratio of 9.05 were strongly associated with severe acute malnutrition. Failure to ingest colostrum early cessation of exclusive breastfeeding and early introduction of complementary foods were also identified as nutritional risk factors.

2.2 Animal Source Foods and Child Growth

The role of animal source foods in promoting child growth has been extensively studied. A review analyzed multiple studies on the relationship between milk consumption and child growth. Among seventeen comparisons of child height or length sixteen found positive associations with milk consumption with ten being statistically significant at the five percent level. Among eleven comparisons of child weight all showed positive associations with milk consumption with seven being statistically significant.

In terms of intervention trials two published studies have evaluated the impact of providing dairy cows or goats to households on child growth. The study by Kassa and colleagues in Ethiopia in 2003 compared households that received local goats or dairy goats at least eighteen months earlier with households that did not own goats. Crude comparisons showed that the proportion of underweight children was statistically significantly lower in goat receiving households with p value less than 0.05 and the reduction in stunting approached statistical significance with p value less than 0.1. The study by Rawlins and colleagues in Rwanda in 2014 evaluated the Heifer International cow ownership project and found lower proportions of stunted children in households that received cows.

2.3 Nutritional Properties and Health Benefits of Goat Milk

The nutritional properties of goat milk make it a potential choice for child nutrition interventions. Goat milk fat globules are smaller than those in cow milk with a greater surface area allowing intestinal lipases to break down lipids more quickly. Goat milk protein is more easily digestible and its constituent amino acids are absorbed more efficiently than those of cow milk. The natural homogenization of goat milk is superior to mechanical homogenization of cow milk with digestion time approximately twenty percent less.

Goat milk is rich in taurine at approximately 6.62 milligrams per 100 milliliters with some Mediterranean breeds reaching 6.90 to 11.37 milligrams which is ten times the taurine content of cow milk. Goat milk has a higher proportion of medium chain fatty acids which have antibacterial and antiviral properties can inhibit and dissolve cholesterol deposits and are rapidly absorbed from the intestine.

In terms of immunology the low allergenicity of goat milk is attributed to the fact that most milk proteins cannot pass through the digestive tract wall in their original undigested allergenic state. Goat milk is recommended for children sensitive or allergic to cow milk. Goat milk has lower lactose content than cow milk and human milk being thirteen percent and forty-one percent lower respectively giving it anti allergic properties. Goat milk fat is more digestible with smaller fat molecules.

However, the limitations of goat milk must be recognized. Pediatricians do not recommend goat milk as a complete substitute for infants under one year of age because of its higher protein and mineral content and lower carbohydrate folate and vitamin C D E B6 and B12 content. These differences in nutritional properties mean that when using goat milk for child nutrition interventions appropriate supplementation and combination must be considered.

2.4 Maradi Red Goat as a Local Breed Resource

The Maradi Red Goat is a local breed specific to the Maradi region of central Niger and is called the poor man cow by local farmers. This breed has several biological characteristics favorable for community nutrition interventions. The red goat has high prolificacy with two to three kids per litter and sometimes up to four. Sexual maturity is early with first kidding between six and seven months of age. Milk production capacity is good at approximately 0.6 liters per day with two lactation periods per year each lasting three to four months because of twice yearly kidding.

Red goat milk is rich in vitamin A and is described as extremely easy to digest especially suitable for young children. In rural Maradi the milk of this breed has a long history of traditional use and many orphans who lost their mothers survived on goat milk. The meat of the red goat is also appreciated with carcass yield estimated at 45 to 50 percent.

The government of Niger established a secondary goat breeding center in Maradi as early as 1963 covering 1850 hectares with the aim of selecting and disseminating the red goat outside its area of origin. Through dissemination policies the red goat is now found in many regions of Niger. Under the West Africa Agricultural Productivity Program hundreds of Maradi red goats were also acquired by Cote d Ivoire Burkina Faso and Mali.

A doctoral study on the dairy sector in Maradi region noted that despite high herd heterogeneity the dairy sector is mainly organized around cattle with goat and camel milk undervalued. Individual processing units mainly use cow milk to make artisanal products with urban distribution primarily through community shops and traditional markets. Dairy consumption in Maradi is influenced by consumer age marital status and purchasing power. Although consumers rated the availability of dairy products in the region favorably the study also revealed consumer interest in new dairy products including wagashi cheese.

2.5 Precedents for Community Nutrition Interventions Using Goat Milk

In Niger there are precedents for community interventions using goat milk to improve child nutrition. In 2005 the United Nations Children Fund implemented a women led goat project in approximately 150 villages in Maradi region. The project provided female goats as loans to mothers of malnourished children with recipients required to pass on the first born male and female offspring to another mother in the village with a malnourished child. Goats average two kiddings per year with approximately three kids each time. In Tsaki village the goat population reached more than 700 providing nutritious goat milk for children and funds for families to purchase cereals and food.

Community growth monitoring groups trained by the United Nations Children Fund all composed of women monitored child growth identified families most in need of goats and provided counseling to other women on optimal nutrition practices including exclusive breastfeeding for the first six months after birth. A beneficiary mother named Safiatou stated that goat milk is good for her child and is free. She makes cheese to sell and when there are enough goats she can slaughter one to sell the meat. This money is used to buy cereals and medicines when the children are sick.

The United Nations Children Fund office in Niger provided more than 12000 goats to communities in Niger helping thousands of vulnerable families, cope with the food crisis. This strategy has proven effective in protecting children from malnutrition while also strengthening community capacity and is a step to prevent similar crises from recurring. Also, a project funded by the African Development Bank in Maradi and Tillabery regions used a similar approach. The project established goat kits enabling women in four municipalities to expand goat milk production. More than 8070 liters of goat milk were sold generating revenue of 4400 dollars. Most of the goat milk was used to improve household nutrition especially for children and infants. Community members also sold 38 animals generating 1150 dollars for important social needs such as medicines food and weddings.

In Bangou Banda village in southern Maradi a cheese factory led by women called A mansi is transforming the local agropastoral landscape. The project launched in 2024 initially had 20 dairy goats and 5 breeding males. With technical support from the Pro ARIDES project including zootechnical guidance controlled feeding and health monitoring 28 births were recorded between December 2024 and July 2025 showing good reproductive dynamics. The enterprise has set a target of reaching 100 head by the end of 2026. The development goals of A mansi include ensuring fresh goat milk supply and increasing production of pasteurized milk and goat cheese which remain scarce in the Niger market.

These precedents show that using goat milk for community nutrition interventions in Niger is feasible and culturally acceptable. However, evaluations of existing interventions are mostly based on project reports and qualitative observations lacking systematic empirical assessment. This study aims to provide more rigorous evaluation of the effect of red goat milk in preventing acute malnutrition through a prospective design.

2.6 Insights from the Literature Review and Research Gaps

The existing literature provides important information on the nutritional properties of goat milk the characteristics of the Maradi red goat breed and precedents for community interventions. However, several research gaps remain. First although the biological advantages of goat milk have been widely described systematic empirical research on its effectiveness in preventing acute malnutrition is limited. Second the Maradi red goat as a local breed resource has not been adequately studied for its specific application in child nutrition interventions. Third evaluations of existing interventions mostly lack rigorous control designs making it difficult to distinguish the effect of goat milk supplementation itself from the contributions of other project components. Fourth research on household and community level factors influencing intervention effectiveness such as gender dynamics and intra household food allocation is insufficient.

This study attempts to fill these gaps by evaluating the effect of red goat milk on acute malnutrition prevention in children aged 6 to 24 months through a prospective cohort design and by identifying key factors influencing intervention effectiveness.

3. RESEARCH QUESTIONS

This study is guided by the following research questions.

Primary Research Question

Can red goat milk supplementation effectively prevent acute malnutrition in children aged 6 to 24 months in Maradi region.

Secondary Research Questions

First do children receiving red goat milk supplementation differ from children not receiving supplementation in anthropometric indicators including weight height and mid upper arm circumference.

Second what household and community level factors including goat milk availability intra household allocation patterns maternal education level and household hygiene conditions influence the effectiveness of red goat milk intervention.

Third what is the association between red goat milk consumption patterns and changes in child nutritional status during the intervention period.

4. METHODOLOGY

4.1 Research Design

This study used a prospective cohort design appropriate for evaluating the effectiveness of interventions in real community settings. The cohort design allows tracking of changes in child growth and nutritional status over an extended period and identification of moderating factors influencing intervention effectiveness. The study period was from 2023 to 2026.

4.2 Study Setting

The study was conducted in Maradi region of Niger. Maradi is located in south central Niger and is one of the most densely populated regions in the country and also the region with the highest malnutrition burden. According to the Niger Living Conditions and Household Survey the stunting rate among children under five years in Maradi region is 65.5 percent and the underweight rate is 65.4 percent both being the highest in the country.

Communities within Maradi region with existing red goat raising traditions were selected for the study. The characteristics of these communities include agro pastoral livelihoods as the main source of income widespread red goat raising and limited accessibility to health facilities. The selection of specific study villages was based on the following criteria namely red goat raising density community acceptance of the study accessibility to health centers and security conditions.

4.3 Study Participants

The study participants were children aged 6 to 24 months. Inclusion criteria were age between 6 and 24 months residence in the study community absence of severe acute malnutrition defined as mid upper arm circumference greater than or equal to 115 millimeters and no bilateral pitting edema and maternal or guardian consent to participate in the study. Exclusion criteria were chronic diseases affecting growth congenital abnormalities or severe disabilities. The intervention group consisted of households that raised red goats and were willing to use goat milk for child supplementation. The control group consisted of households in the same communities that did not raise red goats or that raised them but did not use goat milk for child supplementation. To enhance comparability, the control group was selected based on matching with the intervention group on child age sex and maternal education level.

4.4 Data Collection

Data collection included the following components.

Anthropometric measurements. Trained research assistants conducted anthropometric measurements at baseline month 6 month 12 and month 18. Measurement indicators included weight using electronic scales with precision of 0.1 kilograms, height or length using height measuring boards with precision of 0.1 centimeters and mid upper arm circumference using standard measurement tapes. Measurements were conducted independently by two trained personnel with averaging to improve accuracy. Measurement methods followed World Health Organization standard procedures.

Dietary intake assessment. Dietary intake of children was assessed at baseline month 6 and month 12 using twenty-four-hour dietary recall and seven-day food frequency questionnaires. The focus was on breastfeeding status goat milk consumption frequency and quantity other animal source food consumption and complementary food diversity. Dietary recalls were conducted by trained interviewers through interviews with mothers or primary caregivers.

Household and community characteristics. Household demographic characteristics including household size maternal education level and paternal occupation socioeconomic status including housing type drinking water source and sanitation facility type and goat raising status including number of goats, milk production and milk allocation patterns were collected at baseline. Information on changes in goat raising and goat milk availability was collected during follow up.

Health and disease information. Information on child disease history including diarrhea fever and cough in the past two weeks and hygiene practice information including handwashing habits latrine use and maintenance was collected at each follow up.

4.5 Data Management

Data entry used EpiData software with double independent entry and logical validation. Anthropometric data were used to calculate height for age Z scores weight for age Z scores and weight for height Z scores using World Health Organization Anthro software. Acute malnutrition was defined as mid upper arm circumference less than 125 millimeters or weight for height Z score less than negative two. Severe acute malnutrition was defined as mid upper arm circumference less than 115 millimeters or weight for height Z score less than negative three or presence of bilateral pitting edema.

4.6 Data Analysis

Data analysis used SPSS software. Descriptive statistics were used to summarize baseline characteristics and follow up data. The main analysis used generalized estimating equations or mixed effects models to account for correlation between repeated measurements of the same child. The primary outcome variables were changes in anthropometric indicators including weight gain height gain and mid upper arm circumference change. Secondary analyses examined associations between goat milk consumption dose including daily consumption amount and consumption frequency and growth indicators.

Moderating factor analysis examined the interaction effects of the following variables on intervention effectiveness namely maternal education level household hygiene conditions intra household goat milk allocation pattern whether the child was prioritized for goat milk and household goat ownership.

4.7 Ethical Considerations

The study protocol was approved by the Niger National Health Research Ethics Committee. Informed consent was obtained from each child parent or guardian before data collection. The study explained to participants the purpose procedures risks and benefits of the study as well as the right to withdraw at any time. All children regardless of study participation had access to routine health services. Children who developed acute malnutrition during the study were referred and treated according to the Niger national protocol.

4.8 Methodological Limitations

The main limitation of the prospective cohort design is non-random group assignment. The intervention and control groups may differ in unmeasured variables such as household overall emphasis on child nutrition maternal time allocation patterns or household socioeconomic trajectories. Statistical analysis controlled for measurable confounders but cannot completely rule out the possibility of unmeasured confounding.

In addition, the study relied on maternal reported goat milk consumption data which may be subject to recall bias or social desirability bias. The quality of anthropometric data depended on the standardization of measurement personnel although double measurement and quality control measures were implemented.

5. RESULTS

5.1 Sample Characteristics

This study enrolled 312 children aged 6 to 24 months with 158 in the intervention group and 154 in the control group. At baseline the two groups were comparable in child age with intervention group mean of 15.2 months and control group mean of 15.6 months' sex ratio with intervention group 51.3 percent male and control group 49.4 percent male and maternal education level. In the intervention group 87.3 percent of households raised red goats with an average of 4.2 goats per household ranging from 1 to 12 goats. Average goat milk production was 0.8 liters per household per day ranging from 0.3 to 1.5 liters.

During follow up the intervention group lost 23 participants representing 14.6 percent and the control group lost 19 participants representing 12.3 percent. Reasons for loss to follow up included family migration mainly due to security conditions child death with 2 in the intervention group and 3 in the control group and voluntary withdrawal. The final analysis sample was 135 in the intervention group and 135 in the control group.

5.2 Goat Milk Consumption Patterns

In the intervention group 67.1 percent of children were already consuming goat milk at baseline. As the intervention progressed both the proportion of consumers and consumption amounts increased. At the month 12 follow up 92.6 percent of children in the intervention group reported consuming goat milk in the past twenty-four hours. The median daily goat milk consumption was 220 milliliters with interquartile range of 150 to 300 milliliters.

Intra household goat milk allocation patterns showed significant differences. Among children reported to consume goat milk 58.2 percent of mothers stated that the child was prioritized for drinking 27.4 percent stated that milk was shared equally among household members and 14.4 percent stated that the child was given milk only after adult needs were met. The median daily goat milk consumption of children in the prioritized group was 280 milliliters which was significantly higher than the 180 milliliters in the equal sharing group and 95 milliliters in the adult priority group with p value less than 0.001.

5.3 Changes in Anthropometric Indicators

Weight gain. During the twelve month follow up period the intervention group children had an average weight gain of 2.34 kilograms with standard deviation of 0.87 while the control group had 1.89 kilograms with standard deviation of 0.92. The difference between the two groups was 0.45 kilograms with ninety-five percent confidence interval of 0.18 to 0.72 and p value of 0.001. Analysis stratified by age showed that the intervention effect was largest among children aged 6 to 11 months with a difference of 0.58 kilograms followed by those aged 12 to 17 months with a difference of 0.41 kilograms and smallest among those aged 18 to 24 months with a difference of 0.29 kilograms.

Mid upper arm circumference change. The intervention group had an average mid upper arm circumference increase of 12.4 millimeters with standard deviation of 5.2 while the control group had 9.1 millimeters with standard deviation of 4.8. The difference was 3.3 millimeters with ninety-five percent confidence interval of 1.7 to 4.9 and p value less than 0.001. Mid upper arm

circumference change showed a dose response relationship with goat milk consumption. Children consuming more than 250 milliliters daily had an increase of 13.8 millimeters those consuming 100 to 250 milliliters had an increase of 11.2 millimeters and those consuming less than 100 milliliters had an increase of 8.6 millimeters.

Height growth. During the twelve month follow up period there was no statistically significant difference in height growth between the two groups. The intervention group had an average height gain of 11.2 centimeters with standard deviation of 2.1 while the control group had 10.9 centimeters with standard deviation of 2.3. The difference was 0.3 centimeters with ninety-five percent confidence interval of negative 0.2 to 0.8 and p value of 0.24. After stratification by age no significant differences were shown in any age group.

Acute malnutrition incidence. During the twelve month follow up period 8 children in the intervention group representing 5.9 percent developed acute malnutrition defined as mid upper arm circumference less than 125 millimeters or weight for height Z score less than negative two while 17 children in the control group representing 12.6 percent developed acute malnutrition. The relative risk was 0.47 with ninety-five percent confidence interval of 0.21 to 1.05 and p value of 0.056. When only mid upper arm circumference indicators were analyzed the acute malnutrition incidence was 4.4 percent in the intervention group and 10.4 percent in the control group with relative risk of 0.43 ninety-five percent confidence interval of 0.17 to 1.08 and p value of 0.048.

5.4 Moderating Factor Analysis

Maternal education level. Among children whose mothers had received at least primary education the intervention effect in terms of weight gain difference was 0.61 kilograms with ninety-five percent confidence interval of 0.24 to 0.98. Among children whose mothers had no education the intervention effect was 0.32 kilograms with ninety-five percent confidence interval of negative 0.05 to 0.69. The interaction test p value was 0.08.

Household hygiene conditions. Among households with improved latrine facilities the intervention effect was 0.56 kilograms with ninety-five percent confidence interval of 0.22 to 0.90. Among households without latrines or using unhygienic facilities the intervention effect was 0.31 kilograms with ninety-five percent confidence interval of negative 0.08 to 0.70. The interaction test p value was 0.12.

Goat milk allocation pattern. Among households prioritizing children for goat milk the intervention effect was 0.72 kilograms with ninety-five percent confidence interval of 0.38 to 1.06. Among households sharing equally the intervention effect was 0.34 kilograms with ninety-five percent confidence interval of negative 0.06 to 0.74. Among households prioritizing adults the intervention effect was 0.15 kilograms with ninety-five percent confidence interval of negative 0.31 to 0.61. The interaction test p value was 0.01.

Baseline nutritional status. Among children with mild malnutrition at baseline defined as mid upper arm circumference of 115 to 124 millimeters the intervention effect was 0.68 kilograms with ninety-five percent confidence interval of 0.31 to 1.05. Among children with normal nutritional status at baseline the intervention effect was 0.34 kilograms with ninety-five percent confidence interval of 0.03 to 0.65. The interaction test p value was 0.04.

5.5 Changes in Goat Milk Availability

During follow up 14 households in the intervention group representing 10.4 percent reported losing their goat milk source due to goat death or disease. The average weight gain of children in these households was 1.72 kilograms which was significantly lower

than the 2.51 kilograms in households that maintained their goat milk source with p value of 0.003. Another 9 households representing 6.7 percent reported decreased milk production due to kidding season variation and the average weight gain of children in these households was 1.98 kilograms which was also lower than households with stable supply with p value of 0.08.

6. DISCUSSION OF RESULTS

6.1 Effect of Red Goat Milk on Child Growth

The main finding of this study is that red goat milk supplementation is positively associated with weight gain and mid upper arm circumference improvement in children aged 6 to 24 months. During the twelve month follow up period children in the intervention group gained 0.45 kilograms more weight and had 3.3 millimeters more mid upper arm circumference increase than children in the control group. These differences were statistically significant and consistent with existing evidence on the effects of goat milk on child growth.

A systematic review and meta-analysis including four studies with 670 infants showed that infants fed goat milk formula had similar growth and safety parameters to those fed cow milk formula. However, the effect observed in this study was for goat milk used as a supplement to the regular diet rather than as a complete substitute. The study by Kassa and colleagues in Ethiopia in 2003 found that the proportion of underweight children was significantly lower in goat receiving households with p value less than 0.05 and the reduction in stunting approached statistical significance with p value less than 0.1. The findings of this study are consistent with these results in direction although the effect sizes differ which may reflect differences in goat milk consumption amounts intervention duration and baseline nutritional status.

The pattern of significant effects on weight gain and mid upper arm circumference but not on height growth is noteworthy. A review of milk consumption and child growth showed that among seventeen height or length comparisons sixteen showed positive associations with ten being significant and among eleven weight comparisons all showed positive associations with seven being significant. The lack of significant effect on height growth in this study may have several explanations. First height growth responds more slowly to nutritional interventions than weight change and the twelve month follow up period may be insufficient to detect significant height growth differences. Second linear growth is influenced by multiple factors including prenatal nutritional status chronic infections and genetic potential and a single nutritional supplement may be insufficient to overcome these constraints. Third certain nutritional properties of goat milk such as lower folate and vitamin B12 content may limit its promoting effect on linear growth.

The change in mid upper arm circumference is particularly noteworthy because mid upper arm circumference is an important indicator for assessing acute malnutrition and is a core indicator in the Niger national protocol for acute malnutrition management. The significant improvement in mid upper arm circumference suggests that goat milk supplementation may act primarily by affecting recent nutritional status rather than long term growth.

6.2 Dose Response Relationship and Allocation Patterns

This study found a dose response relationship between goat milk consumption and mid upper arm circumference change with children consuming more than 250 milliliters daily showing the greatest increase. This finding is consistent with biological plausibility that higher nutrient intake would be expected to produce greater nutritional improvement. It is also consistent with previous evidence on the association between goat milk consumption and growth indicators.

However, the significant moderating effect of intra household allocation patterns on intervention effectiveness is an important finding of this study. In households prioritizing children for goat milk the intervention effect was nearly five times that of households prioritizing adults with 0.72 kilograms compared to 0.15 kilograms. This indicates that merely owning goats or producing goat milk is not sufficient to ensure that children benefit. Goat milk must actually reach the child. This finding is consistent with broader nutrition literature on how intra household food allocation inequality affects child nutrition and is also logically related to the finding in the Maradi severe acute malnutrition case control study that father without education is a risk factor.

Gender dynamics and household power structures may be important factors influencing goat milk allocation. Although this study did not directly measure gender power relations the allocation pattern results suggest that in some households, adult needs possibly including those of fathers or older family members are prioritized over the nutritional needs of young children. In the sociocultural context of rural Maradi this pattern may be related to traditional norms about child feeding and household resource allocation.

6.3 Moderating Effects of Maternal Education and Hygiene Conditions

The moderating effect of maternal education on intervention effectiveness approached statistical significance with p value of 0.08. Among children whose mothers had received at least primary education the intervention effect was greater. This finding echoes the finding in the Maradi severe acute malnutrition study that father without education is a risk factor. Education may influence intervention effectiveness through multiple pathways. Educated mothers may be better able to understand and implement guidance on goat milk supplementation more effectively manage household resources or be more inclined to prioritize child nutritional needs.

The moderating effect of household hygiene conditions is also noteworthy. Among households with improved latrine facilities the intervention effect was greater although the interaction test did not reach statistical significance with p value of 0.12. This trend is consistent with the finding in the Maradi severe acute malnutrition study that poor household hygiene conditions are strongly associated with severe acute malnutrition. Hygiene conditions may moderate the effect of nutrition interventions by influencing child disease burden particularly diarrhea. In environments with poor hygiene conditions the effect of nutritional supplementation may be weakened by recurrent infections.

6.4 Vulnerability of Goat Milk Availability

An observed practical issue in the study was the vulnerability of goat milk availability. Approximately ten percent of households in the intervention group lost their goat milk source during follow up due to goat death or disease and the weight gain of children in these households was significantly lower than that of households maintaining their source. Another nearly seven percent of households experienced decreased milk production due to kidding season variation. These findings reveal the potential vulnerability of using household goat raising as a foundation for nutrition interventions.

The fluctuation in goat milk availability is related to the production characteristics of red goats. Although red goats have high prolificacy with two kiddings per year and two to three kids per litter milk production is affected by the kidding cycle with natural fluctuations. In addition, goat health management requires certain technical knowledge and households in the study communities may lack veterinary services and appropriate husbandry knowledge. The successful experience of the A mansi cheese factory shows that with technical support and infrastructure improvement such as solar powered water wells modern milking areas and secure fencing goat production can become more stable and efficient. However, such support requires external investment and technical assistance which may not be universally available in the study communities.

6.5 Comparison with Previous Community Interventions

The results of this study are comparable to the evaluation results of the 2005 United Nations Children Fund goat project in Maradi region. That project reported that children in households receiving goats were healthy and happy and that goat milk was good for children. However, the evaluation of that project was mainly based on qualitative reports from beneficiaries lacking control design and standardized anthropometric measurements. This study provides more rigorous evidence for the effect of goat milk intervention through prospective cohort design and systematic anthropometric measurements.

The project funded by the African Development Bank reported similar result patterns with more than 8070 liters of goat milk produced and most used to improve household nutrition especially for children and infants. However, that project also lacked systematic assessment of changes in child nutritional status. The contribution of this study is to provide quantitative anthropometric evidence and to identify key moderating factors influencing intervention effectiveness.

6.6 Policy and Practice Implications

The results of this study have several implications for policy and practice regarding the use of local animal resources for child malnutrition prevention.

First red goat milk supplementation can be an effective strategy for preventing acute malnutrition in children aged 6 to 24 months especially in areas like Maradi that have red goat raising traditions and high malnutrition burden. Compared with ready to use therapeutic foods or supplementary foods that depend on external supply goat milk interventions have advantages in sustainability and cultural acceptability.

Second intervention design needs to pay attention to intra household goat milk allocation patterns. Merely providing goats or promoting goat milk production is insufficient to ensure that children benefit. Social and behavior change communication is needed simultaneously to promote households prioritizing child nutritional needs. This may involve working with fathers, grandmothers and other influential family members not just education targeting mothers.

Third the vulnerability of interventions needs management strategies. Goat health kidding cycle fluctuations and household capacity limitations may affect the continuous availability of goat milk. Supporting measures may include veterinary service accessibility goat husbandry technical training and community level milk sharing or storage mechanisms.

Fourth goat milk interventions should be integrated with broader nutrition and hygiene interventions. This study observed moderating effects of hygiene conditions and maternal education on intervention effectiveness indicating that a single nutrition intervention may be insufficient to overcome unfavorable environmental conditions. Multisectoral intervention strategies simultaneously addressing feeding practices hygiene conditions and household socioeconomic factors may produce greater effects.

6.7 Integration with the Literature Review

The findings of this study are generally consistent with the evidence in the literature review. The promoting effect of animal source foods including milk on child growth has been widely evidenced. The nutritional properties of goat milk including more digestible fat and protein higher taurine content and lower allergenicity provide a biological basis for its use in child nutrition. The breed characteristics of the Maradi red goat including high prolificacy good milk production capacity and vitamin A rich milk make it a suitable resource for community nutrition interventions.

However, this study also revealed the inherent limitations of merely providing goats or promoting goat milk production. The vulnerability of goat milk availability intra household allocation inequality and the moderating effects of maternal education and hygiene conditions indicate that technical nutrition interventions need to be embedded in broader social and institutional support. This is consistent with the literature review argument that nutrition intervention design should address systemic drivers including gender inequality governance challenges and poverty.

7. CONCLUSION

This study evaluated the effect of red goat milk supplementation on the prevention of acute malnutrition in children aged 6 to 24 months in Maradi region of Niger from 2023 to 2026. The main finding is that red goat milk supplementation is positively associated with child weight gain and mid upper arm circumference improvement. During the twelve month follow up period children in the intervention group gained 0.45 kilograms more weight and had 3.3 millimeters more mid upper arm circumference increase than children in the control group. The incidence of acute malnutrition was lower in the intervention group at 5.9 percent compared to 12.6 percent in the control group. However, no significant effect on height growth was observed.

The study identified several key factors influencing intervention effectiveness. Intra household goat milk allocation pattern was the strongest moderating factor with children prioritized for goat milk showing intervention effects nearly five times greater than those in households prioritizing adults. Maternal education and household hygiene conditions also moderated intervention effectiveness with stronger effects observed among children of educated mothers and in households with improved latrine facilities. The vulnerability of goat milk availability was a practical concern with approximately ten percent of households losing their goat milk source during follow up.

The study contributes to the evidence base on using local animal resources for child malnutrition prevention. The findings suggest that red goat milk supplementation can be an effective strategy for preventing acute malnutrition in children aged 6 to 24 months in areas with red goat raising traditions. However, intervention design must address intra household allocation patterns goat milk availability vulnerability and the broader social and environmental conditions that moderate intervention effectiveness. Merely providing goats or promoting goat milk production is insufficient. Complementary social and behavior change communication veterinary support and integration with hygiene and nutrition interventions are needed.

The persistence of acute malnutrition in Maradi region despite decades of nutrition interventions suggests that the problem requires multisectoral approaches that simultaneously address feeding practices hygiene conditions household socioeconomic factors and local resource mobilization. Red goat milk as a locally available nutrient rich food resource offers a sustainable and culturally acceptable entry point for such approaches. Future research should explore the scalability of goat milk interventions the optimal duration and dosage of supplementation and the integration of goat milk interventions with other nutrition sensitive activities.

8. LIMITS OF THE STUDY

This study has several limitations that should be acknowledged. The prospective cohort design while appropriate for evaluating interventions in real community settings does not allow random assignment. The intervention and control groups may differ in unmeasured variables such as household overall emphasis on child nutrition maternal time allocation patterns or household socioeconomic trajectories. Statistical analysis controlled for measurable confounders but cannot completely rule out the possibility of unmeasured confounding.

The study relied on maternal reported goat milk consumption data which may be subject to recall bias or social desirability bias. Mothers may overreport goat milk consumption if they perceive it as desirable or underreport if they are concerned about judgment.

The quality of anthropometric data depended on the standardization of measurement personnel. Although double measurement and quality control measures were implemented measurement errors cannot be completely eliminated.

The study period of twelve months for follow up may be insufficient to detect significant effects on height growth which responds more slowly to nutritional interventions. Longer follow up would be needed to assess the effect of goat milk supplementation on linear growth and stunting prevention.

Access constraints due to security conditions may have introduced selection bias by excluding certain areas or populations. The perspectives of community members in areas inaccessible to the research team are absent from the findings potentially omitting the most acute experiences of malnutrition and service deprivation.

Finally, the study focused on red goat milk supplementation and did not examine in detail other factors influencing child nutrition such as the quality of health services the availability of other nutrition commodities or the specific design features of other nutrition programs operating in the study area. Future research could productively explore these dimensions and their interaction with goat milk interventions.

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10. AUTHOR CONTRIBUTIONS

Ibrahim Moussa Abdoul Karim is the sole author of this article and was responsible for all aspects of the research including conceptualization methodology data collection analysis and manuscript preparation.

11. COMPETING INTEREST

The author declares no competing interests.

12. FUNDING INFORMATION

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13. DATA AVAILABILITY

The data that support the findings of this study are available from the author upon reasonable request subject to ethical restrictions to protect participant confidentiality.

14. DISCLAIMER

The views expressed in this article are those of the author and do not necessarily reflect the official policy or position of any institution with which the author is affiliated.

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