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RESEARCH ARTICLE

Association between productivity, market access, and financing on consumption of dairy products and diet quality among dairy farming households in Tanzania

[version 1]

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Abstract

Background

The Tanzania Inclusive Processor-Producer Partnerships in Dairy project (TI3P) is a dairy development project, offering loans across the entire dairy value chain, including loans for dairy cow ownership to smallholder farmers. This study explores how dairy production, market access, and financing impacts diet quality of men and women in dairy producing households.

Methods

Our mixed-methods, cross-sectional design included household survey among members of Farmer producer organization (FPOs) in Tanzania. Households were sampled to be representative of the populations of TI3P/TADB loan holders and non-loan holders and

included men and women from the same households. We also conducted a market access assessment, focus group discussions and key informant interviews.

Results

Farmers reported a Global Diet Quality Score (GDQS) of 17.3 and Dietary Diversity Score (DDS) of 3.8 out of 10 food groups. Diet quality was similar among men and women, but men consumed significantly more dairy (0.2 vs. 0.1 liters per day). Increased dairy production was significantly associated with increased consumption at lower values of milk production for both men and women. Dairy production was weakly associated with increased GDQS among men and increased DDS among both men and women; however, these differences were small in magnitude. On average farmers lived 9.8 kilometers from the nearest high-quality market. The relationship between dairy production and diet was not impacted by market access and we found no evidence that better market access is associated with improved dietary quality. Similarly, access to financing was not associated with improved diet quality. Qualitative data revealed that income from milk sales was used for essential household expenses and re-investing in dairy farming, but expanding dietary quality or diversity was not a priority.

Conclusions

Increased dairy production and access to financing alone does not appear to be an adequate strategy to achieve high dietary quality.

Keywords
Tanzania, Dairy, Nutrition, Market Access, Smallholder farmers, Agricultural Financing

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Introduction

Animal source foods (ASFs) have significant amount of minerals, high-quality protein, as well as vitamins and have been shown to help reducing stunting and increase macro- and micro-nutrient adequacy (Adesogan et al., 2020). However in Tanzania, the proportion of total energy consumption that is derived from ASFs such as milk, eggs, chicken, fish, and beef; has remained at approximately 5 percent for over a decade (Ignowski et al., 2023). This low level of consumption translates to an average of less than one serving per person per day (Miller et al., 2022). In the Tanzanian context, where 30% of children under 5 are stunted and over 40% of women are anemic (Ministry of Heath [Tanzania Mainland] et al., 2022), increased consumption of ASF is a promising strategy to improve population health.

Despite milk and dairy products being important ASF products with substantial nutritional benefits, in sub-Saharan Africa, both milk production and milk consumption lag behind the rest of the world (Muehlhoff et al., 2013). In Tanzania, there is some evidence that livestock ownership and increased dairy production have been associated with improved diets, household food security, household food consumption scores, and dietary diversity for women and children (Bellows et al., 2020; Hadley et al., 2007; Häsler et al., 2018, 2019). Elsewhere in East Africa, uptake of improved cattle breeds, membership in dairy markets, and membership in dairy producing groups are also associated with improved diets at both the household and individual level (Jebessa et al., 2023; Lenjiso et al., 2016; Walton et al., 2014). Lenjiso et al., (2016) suggested two primary mechanisms by which increased household milk consumption might enhance dietary quality. First, household members could directly consume the additional milk that they produce, leading to a more nutrient-rich diet. Second, they might sell the surplus milk and use the income to purchase other nutritious or diverse foods, thereby indirectly improving their dietary intake.

Despite the potential for increased milk production to improve diets, Tanzania's dairy industry faces substantial challenges for expansion. At the smallholder producer level, farmers describe a lack of knowledge around best practices, lack of access to high-quality breeds, limited availability of capital, and challenges accessing inputs such as pasture, water, and feed (Häsler et al., 2018). These challenges can be compounded by gender dynamics. For example, women in Tanzania, who often play a substantial role in dairy production, rarely own the cattle (Tanager, 2023). Furthermore, although access to capital can be a challenge for dairy farmers of all genders, in Tanzania only 2.9% of female-headed households have been able to use a land-owning certificate as collateral to secure a loan compared to 6.6% of male-headed households (National Bureau of Statistics (NBS) [Tanzania], 2022).

Tanzania Agricultural Development Bank (TADB) has been implementing the Tanzania Inclusive Processor-Producer Partnerships in Dairy project (TI3P), a three-year dairy development project, running from 2022 to 2025, funded by the Bill & Melinda Gates Foundation (BMGF) and implemented in partnership with the Ministry of Livestock and Fisheries (MLF), Tanzania Dairy Board (TDB), Land O'Lakes Venture37 (Venture37), and Heifer International (HI). The goal of TI3P is to catalyze the inclusive transformation of the Tanzania dairy industry by promoting public-private investments to increase incomes of smallholder dairy farmers through increased formal milk aggregation, sustainable scale-up of on-farm production and productivity, growth of dairy processing, and increased demand generation. Through the project, TADB offers loans across the entire dairy value chain focusing on processors, small, medium, and large-scale farmers, and input suppliers.

This cross-sectional study sought to explore the links between dairy production and dietary quality among men and women in dairy-producing households. Our study explores two hypothesized pathways. First, a direct pathway, where farmers improve their diet by consuming the additional milk that they produce. Second, an indirect pathway, through which farmers sell their surplus milk and use the income to purchase other nutritious or diverse foods. We additionally sought to explore whether contextual factors, including access to and quality of local food market and access to financing by TADB/TI3P impacted these dietary outcomes. Finally, we sought to contextualize our findings using insights from qualitative focus group discussion (FGD) and key informant interviews (KIIs).

Methods

Study design

The study employed a cross-sectional, mixed-methods design with four major activities: a) a quantitative household survey; b) a market access assessment; and c) FGDs; and d) KIIs.

Study setting

This study focuses on smallholder dairy producers in four regions of Tanzania namely Arusha, Kilimanjaro, Mbeya, and Tanga. These regions are considered to have established dairy markets with pre-existing infrastructure for a commercial dairy market, including established Farmer Producer Organizations (FPOs) that produce and aggregate milk. At the time of our study there were a total of 81 dairy FPOs in these regions, ten of which had members who had begun to received TADB/TI3P loans. Data collection occurred between 17 October and 9 December, 2023.

Household survey

We sampled households from three different groups for the household survey: Group 1 households that had received a TADB/TI3P loan at least 6 months prior to the survey. Group 2 households belonged to one of the 10 FPOs where members had begun to receive TADB/TI3P loans *but* had not received loan themselves. Group 3 households belonging to one of the remaining 71 FPOs that has not yet distributed TADB/TI3P loans. Ensuring adequate representation from each of these three groups was important to the overall goal of our study because we were interested in understanding the relationship between dairy production and diet quality in the overall population of dairy farmers as well as the relationship between dairy financing and dairy production and diet quality. Within each of these three groups, we used a distinct sampling scheme which was designed to maximize the sample size of each group while minimizing the impact of clustering on our study's power and respecting budgetary constraints. For Group 1, we sought to conduct a full census of the 429 households that had received a loan. For Group 2, we randomly sampled up to 30 non-loan holders from each of the 10 FPOs with members eligible to receive TADB/TI3P loan. If a group had fewer than 30 non-loan holders, all non-loan holders were eligible to participate. For Group 3, we conducted two-stage sampling. First, we selected 50 out of the 71 of FPOs who had not participated in the TADB/TI3P loan using proportional-to-size sampling. Second, we randomly sampled up to 10 households within the selected FPOs. This sampling scheme was expected to result in a total of over 1,200 households, with up to 429 in Group 1, 300 in Group 2, and 500 in Group 3. Simulated sample size calculations showed that this sample would ensure over 80% power to detect a 2.4-point difference in the Global Diet Quality Score (GDQS), which ranges from 0 to 49. These simulations test for significance using a mixed-effects linear regression model with a random intercept for FPO and assuming an alpha level of 0.05, a mean GDQS of 22.4, that FPO-random intercepts are normally distributed with a mean of zero and standard deviation of 2.4, and that residuals are normally distributed with a mean of zero and standard deviation of 3.7. These parameters, which were taken from the literature, approximately correspond to a standard deviation of 4.4 and intra-cluster correlation (ICC) of 0.30 (Bromage et al., 2021).

Within each household, we identified up to two types of respondents. The primary respondent, who could be a man or woman, the individual who was most involved in dairy farming. In loan-holding households, this was assumed to be the loan holder. In households with at least one adult man and one adult woman, we additionally interviewed one opposite-sex household member. Our first choice would be the spouse of the index subject. If the index subject had multiple spouses, the spouse who is most involved in dairy-related activities was invited to participate. Our second choice was the opposite-sex household member who is most involved in dairy-related activities, as identified by the index subject.

Dairy production

During the household survey, we asked the primary respondent to report on the total volume of milk produced from all cows in the previous week. This value was winsorized at the 98th percentile to mitigate the effects of influential outliers.

Global Diet Quality Score (GDQS)

We assessed individual dietary quality using the Global Diet Quality Score (GDQS). The GDQS is a food-based metric that uses a 24-hour recall to assess consumption of 25 food groups: 16 healthy food groups, 7 unhealthy food groups, and 2 food groups that are unhealthy when consumed in excessive amounts (Bromage, Batis, et al., 2021a). The GDQS uses standardized cubes to enable respondents to estimate the volume of each food group that was consumed, and the consumption of each of these food groups is classified as low, medium, or high based on standard scoring procedures. The GDQS metric has a possible range of 0-49, with a higher score corresponding to better diet quality. It incorporates dimensions of both nutrient adequacy and dietary risk factors associated with non-communicable disease risk in its design and scoring method. It has been previously validated among men and women in Tanzania (Bromage, Zhang, et al., 2021b).

Dairy consumption

Volume of dairy consumed was also assessed using data from the 24-hour recall. As part of the GDQS data collection, respondents reported dairy consumption using the standardized GDQS cubes and this data was used to estimate the volume of dairy that was consumed and convert that data into grams based on standard density estimates for each food group. For the purpose of this analysis, we aggregated the volume of dairy or dairy products consumed and presented the value in liters. While this method has not been specifically validated for measuring the volume of dairy consumed, previous research has found that use of visual tools and three-dimensional models improve the accuracy of 24-hour recall data (Kirkpatrick et al., 2016; Nightingale et al., 2016).

Dietary Diversity Score (DDS)

We also used the 24-hour recall data to capture an individual dietary diversity score (DDS). This DDS was based on the consumption of ten food groups, which were selected to align with food groups used for the calculation of the Minimum Dietary Diversity for Women (MDD-W) indicator. Unlike the MDD-W indicator, which is a binary outcome indicating

whether or not women have consumed at least 5 food groups in the past 24 hours, our DDS was calculated to be a continuous variable ranging from 0 to 10 for both men and women.

Market access assessment

During the household survey, we collected data on which food markets were used by household respondents. We then conducted a list of food markets all 153 food markets used by dairy-producing households that are members of the ten FPOs (Groups 1 and 2). "Markets" were broadly defined to include a diverse range of places that sell food, including open-air markets, informal shops, and formal establishments but excluding formal and informal restaurants. We sent data collectors to collect geospatial data on the exact location of these markets and calculated distance to the nearest market for each household using this geospatial data.

For each market, we calculated a food basket score based on the availability of foods that are common in Tanzania and correspond to food groups on the GDQS. Similar approaches have been used previously in Tanzania (Cochrane & D'Souza, n.d.; Madzorera et al., 2021). The food basket was designed to include examples of foods from all 16 "healthy" food groups, two "unhealthy in excessive amounts", food groups, and two "unhealthy" food groups (Table 1). The specific examples of foods within each of these food groups were taken from the list of foods included in the Tanzanian version of the Diet Quality Questionnaire to ensure we selected locally relevant foods. The quantity included in the food basket and corresponding number of points were defined to align with GDQS scoring. The two unhealthy food groups, a) refined grains and baked goods and b) white roots and tubers were included in recognition of the fact that foods falling into these categories, including white rice, cassava root, and cooking bananas, are staples in the Tanzanian diet but are included in the score at a medium (rather than high) level of consumption. While this list does not reflect an exhaustive list of all nutritious foods that could be purchased in local markets, providing data collectors with a pre-determined list of

Table 1. Foods and quantities included in the food basket.

Food group	Items	Quantity for food basket	Points
Citrus fruits	Orange, lemon	70 grams	2
Deep orange fruits	Mango, papaya	130 grams	2
Other fruits	Sweet banana, pineapple	120 grams	2
Dark green leafy vegetables	Spinach, amaranth	40 grams	4
Cruciferous vegetables	Broccoli, cauliflower, cabbage, sukuma (collard greens)	30 grams	+0.25
Deep orange vegetables	Pumpkin, carrot	40 grams	+0.25
Other vegetables	Tomato, avocado	120 grams	+0.5
Legumes	Beans, green peas, cow peas	50 grams	+4
Nuts and seeds	Groundnuts, groundnut paste, cashew nuts	20 grams	+4
Whole grains	Whole-grain maize ugali, sorghum ugali, millet porridge	20 grams	+2
Liquid oils	Sunflower oil, palm oil or similar	10 grams	+2
Fish and shellfish	Fish	40 grams	+1
Poultry and game meat	Chicken, duck	40 grams	+1
Eggs	Eggs	1 egg	+2
Low-fat dairy	≤2% fat milk	140 grams	+2
High-fat dairy	Whole milk (cow, goat)	240 grams	+2
Red meat	Beef, goat	40 grams	+1
Refined grains and baked goods	White rice, bread, chapati	30 grams	+1
White roots and tubers	Irish potatoes, cassava root, white sweet potatoes, cooking bananas/plantain	100 grams	+1

common foods reduced the misclassification of foods into their appropriate food groups and enabled us to calculate the cost of a standardized market basket in addition to the DDS.

Using this data, we calculated a "food basket score" and a "food basket price" for each market. The food basket score was calculated by summing the points associated with each food group that was available at the market and can be interpreted as a metric of the quality of food available at that market. Markets with a food basket score of at least 23 (which corresponds to the GDQS's "low risk" category) were considered high-quality markets. For high-quality markets, we also calculated the "food basket price," which reflected the lowest price for which you could amass a 23-point food at that market. We used GIS data to assess the distance between each farmer's home and the nearest market with a food basket score of at least 5 as well as nearest to the nearest high-quality market. These variables were used to explore the association between the characteristics of the nearest food markets and the dietary quality of individuals in households.

Statistical analysis

Due to our complex sampling structure, we develop sampling weights to create an analytic sample that was representative of the broader population of dairy farmers belonging to an FPO in Arusha, Mbeya, Kilimanjaro, or Tanga and adjusted for clustering at the FPO level in our standard errors. These sampling weights were calculated using details from the original sampling frame to estimate the probability of an individual household being selected for participation based on their group, FPO, and FPO size. We used descriptive statistics that accounted for the survey design to describe households and to compare demographic variables and dietary outcomes among men and women respondents. We visualized the associations between dairy production and dietary outcomes using Lowess curves and tested for statistical significance using linear regression models that considered both a linear and quadratic association between production and consumption. These models also accounted for the survey design and were run in the overall sample as well as stratified by gender.

We used mixed-effects linear regression model to assess associations between market access variables, including quality of the nearest market, distance to the nearest high-quality market, and food basket price at the nearest high-quality market, and dietary quality. These models used random effects to account clustering at the group, FPO and household level. We assessed the associations in the overall population as well as in stratified models for men and women. In order to understand whether access to markets modified the relationship between dairy production and diet quality, we ran a second set of models that also included interaction terms between market access and dairy production.

We also used mixed-effects linear regression model to assess associations between TADB/TI3P loan status and dietary outcomes, with random effects for group, FPO and household. Our models included interaction terms between household loan status and sex of the respondent to capture gender-specific effects. In recognition that access to loans could be determined by pre-loan socioeconomic status, we adjusted for markers of socio-economic status, which we hypothesized could confound the association between access to loan and diet quality, including household's region, female-headed household status, distance to the nearest market measured in minutes, the total number cows cared for by the household excluding the cows purchased through the TADB/TI3P loan, and the EquityTool score, which is a measure of household wealth (Metrics for Management et al., 2024).

Due to relatively small amounts of missing data, we used a complete-case analysis for all analyses.

Qualitative data collection and analysis

We used purposive sampling to identify qualitative respondents that reflected regional diversity as well as diversity by role, gender and loan-holder status. We conducted FGDs among male and female dairy producers from one of the FPOs where TADB has already provided smallholder loans and KIIs with local TADB staff tasked with distributing loans (Business Development Officers, one per region), leaders of the dairy FPOs, and government livestock extension officials. Interviews were conducted in Kiswahili, transcribed, and translated into English. Each member of the qualitative analysis team conducted independent, inductive coding prior to a joint harmonization meeting where we developed a final codebook for deductive coding. Although the transcripts revealed a wide range of themes, this paper only presents findings related to diet and market access.

Results

Respondents to the household survey

Overall, we collected household survey data on 1,957 respondents across 1,143 households. Of these participants, 1,007 were women and 950 were men. This sample size was 93% of our initial target sample size. We were able to enroll 293/429 of target households in Group 1; 359/300 target households in Group 2, and 483/500 households in Group 3. The discrepancies between our target and actual sample sizes in each group reflected a combination of factors, particularly,

a) one FPO identified as having TADB/TI3P loan holders did not have any loan holders, resulting in some respondents being reclassified to a different group than anticipated; b) unavailability of respondents; c) rainy season preventing us from reaching respondents that were identified in villages experiencing heavy rainfall/flooding; and d) outdated membership lists from FPOs. After dropping observations that were missing data on the primary outcomes of GDQS, MMD-W, or dairy consumption as well as observations that were missing data on the primary exposure of dairy production in the last week, we were left with a final analytic sample of 1,939 respondents across 1,135 households, of whom 946 were men and 993 were women.

Almost half (48.0%) of households were from Tanga region with the remainder coming from Kilimanjaro (23.9%), Mbeya (19.4%), and Arusha (8.7%, Table 2). This geographic distribution reflects the fact that Tanga tends to have much larger FPOs than other regions and represented a large proportion of all farmers in our sampling frame. A quarter (25.8%) of households had received a TADB/TI3P loan for dairy farming. The average household had 5 members, including 3 adults and 2 children, and 17.6% were female-headed. Household were relatively wealthy, with most households belonging to the upper 40% of Tanzania's wealth distribution. However, about two thirds relied exclusively on

Table 2. Household characteristics (N=1,135).

	n (%)
Region	
Arusha	98 (8.7%)
Kilimanjaro	271 (23.9%)
Mbeya	221 (19.4%)
Tanga	546 (48.0%)
TADB loan holder	
No	843 (74.2%)
Yes	293 (25.8%)
Female-headed household[1]	
No	933 (82.4%)
Yes	199 (17.6%)
Equity Tool	
Equity tool - Low to Medium	165 (14.5%)
Equity tool - Higher	452 (39.8%)
Equity tool - Highest	518 (45.6%)
Livelihood Activities	
Agriculture only	740 (65.1%)
Agriculture and own business	238 (21.0%)
Agriculture plus formal work	101 (8.9%)
Agriculture plus informal work	57 (5.0%)
Household members (including resp)	5.0 (0.1)
Adults in the household	3.0 (0.1)
Children in the household	2.0 (0.1)
Median Monthly Income (USD)[2]	134.7 (8.1)
Median Annual Income (USD)[3]	1310.1 (98.7)
Minutes to the nearest market (self-reported)	12.7 (0.8)
Lactating cows	1.9 (0.2)
Liters of milk produced by the household in the last week[4]	10.0 (0.8)

[1]Missing data for 4 households;
[2]Missing data for 1 household;
[3]Missing for 3 households;
[4]Windosorized at the 98th percentile.

Table 3. Respondent demographics and dietary outcomes by gender (N = 1,939).

	Men N = 946 n (%)	Women N = 993 n (%)	
DEMOGRAPHICS			
Education			p = 0.059
No education	24 (2.5%)	35 (3.6%)	
Primary or less	669 (69.7%)	747 (75.5%)	
Above primary	267 (27.8%)	207 (20.9%)	
Marital Status			p < 0.001
Never married	102 (10.7%)	58 (5.9%)	
Widowed	12 (1.2%)	118 (11.9%)	
Divorced	3 (0.3%)	5 (0.5%)	
Separated	8 (0.9%)	17 (1.7%)	
Currently married	803 (83.7%)	747 (75.5%)	
Come we stay/cohabiting	31 (3.3%)	45 (4.5%)	
Age (years)	51.5 (0.7)	49.9 (0.6)	p = 0.069
DIETARY OUTCOMES			
Volume of dairy consumed (L)	0.2 (0.0)	0.1 (0.0)	p < 0.001
GDQS score	17.3 (0.1)	17.3 (0.2)	p = 0.804
GDQS risk category			p = 0.523
High risk (<15)	222 (23.2%)	210 (21.2%)	
Moderate risk (15-22)	675 (70.3%)	729 (73.7%)	
Low risk (≥23)	63 (6.5%)	50 (5.1%)	
Dietary Diversity Score	3.8 (0.0)	3.8 (0.1)	p = 0.447

agriculture for their income. Median incomes were estimated at 135 USD per month or 1310 USD per year. On average, households had 1.9 lactating cows and produced 10.0 liters of milk the past week. The majority of respondents had not completed primary education and the average age of respondents was 51.5 for men and 49.9 for women (Table 3). Marital status differed significantly between men and women with men being more likely to be currently married and women being more likely to be widowed.

Food consumption patterns and dietary outcomes among men and women

When comparing food consumption among men and women, we observed that men consume significantly more dairy and dairy products on average compared to women (Table 2). Men consume an average of 0.2 liters of dairy or dairy products in a day while women consume 0.1 liters of dairy or dairy products in a day ($p<0.001$). The average GDQS score for both men and women was 17.3, indicating a moderate risk of poor dietary quality. Twenty-three percent of men and 21% of women fell in the "high-risk" GDQS category. On average, both men and women consumed 3.8 out of the ten food groups included in the DDS.

Although the overall GDQS for men and women is the same, there are substantial differences in the consumption of individual food groups by sex (Figure 1). In GDQS, significantly more women (15.2%) consume low-fat dairy compared to men (9.7%) but significantly more men consume high-fat dairy (48.8%) than women (33%). However, because largest average amount of dairy products consumed among both men and women are high-fat dairy products (e.g., whole milk), overall, these findings are still consistent with greater dairy consumption among men. Among the 16 healthy GDQS food groups, five were significantly more likely to be consumed by women than by men (cruciferous vegetables, dark-green leafy vegetables, deep orange fruits, deep orange tubers, low-fat dairy, and other vegetables) while three were more likely to be consumed by men than by women (citrus fruits, nuts and seeds, and other fruits). Among the seven unhealthy food groups, men consume significantly more from three food groups (purchased fried food, refined grains and baked goods, and sugar-sweetened beverages) while women consume significantly more from one food group (sweets and ice cream). On the ten DDS food groups, men consumed more than women in three food groups (grains, white roots, and tubers; meat, poultry, and fish; and milk and milk products) while women consumed significantly more vitamin-A-rich fruits and vegetables and other vegetables than men (Figure 2).

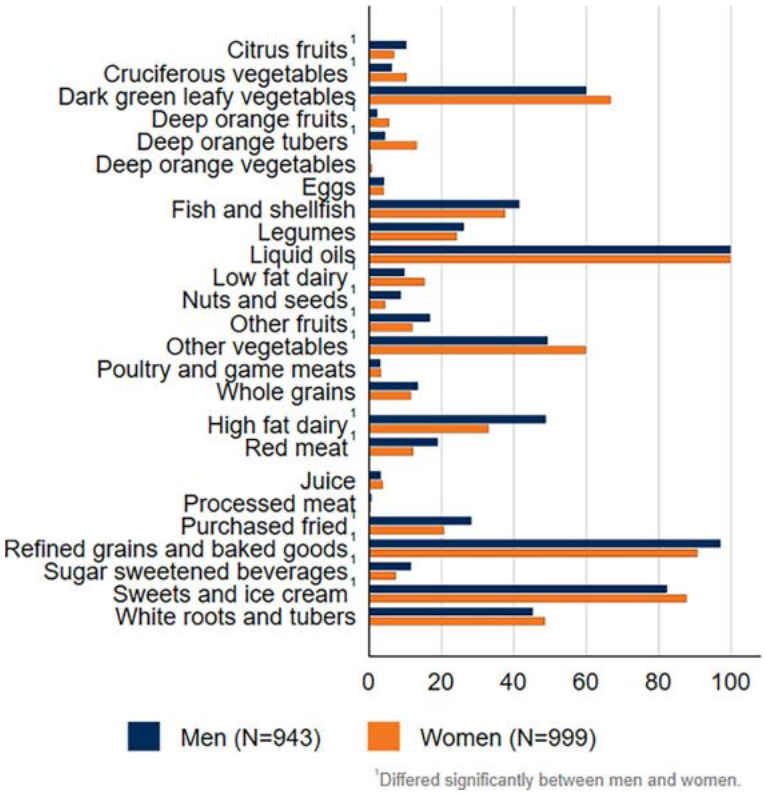

Figure 1. **GDQS food group consumption by gender.**

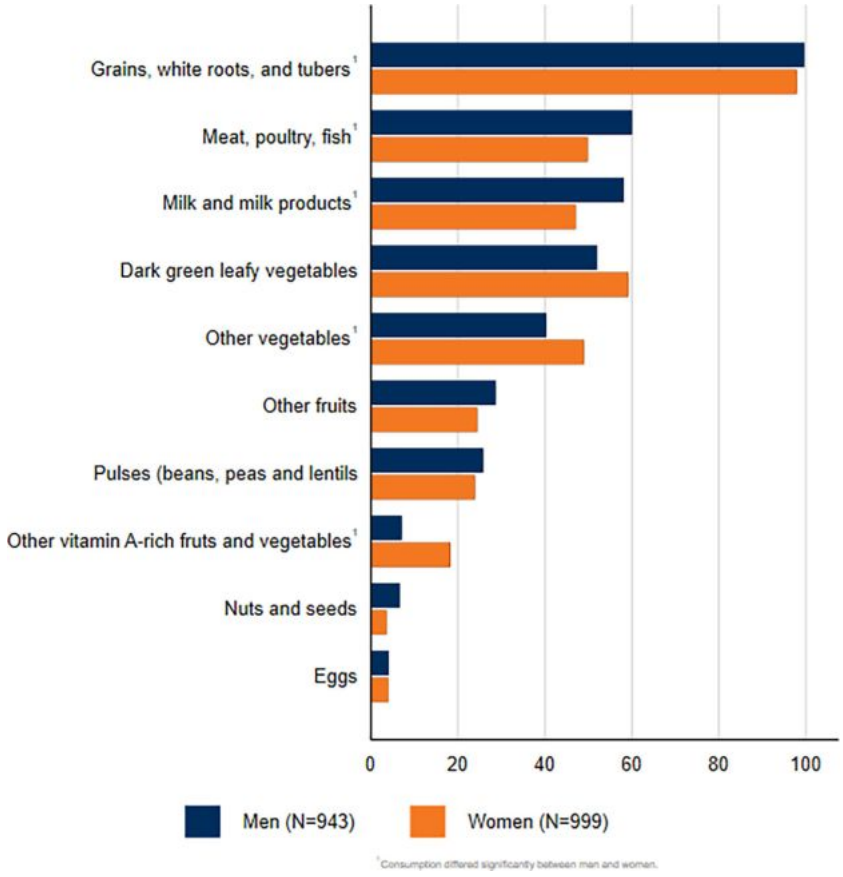

Figure 2. **Dietary Diversity Score food group consumption by gender.**

Dairy production, dairy consumption, and associations with diet quality

We observed a non-linear relationship between dairy production and dairy consumption among men and women (Figure 3). At the lower values of milk production (below 20 liters per household), more production is associated with increasing likelihood of individual milk consumption for both men and women. Assessing the relationship using non-linear regression models, we find that our model using a quadratic term to describe the relationship between dairy production and dairy consumption is significant for both men and women (Table 4). For the relationship between milk production and GDQS, we observed a weak positive, linear association among men where each additional liter of milk

Figure 3. Association between milk production and dairy consumption. Panels show the relationship between milk production and dairy consumption (top), GDQS (middle), and DDS (bottom).

Table 4. **Model-based estimates for the association between dairy production and diet. Cells give point estimates and (95% confidence intervals) for beta co-effiecints (N = 1,939).**

	All N = 1,939	Men N = 946		Women N = 993	
Dairy Volume					
Weekly dairy production (L)[1]	0.002	0.002	0.009	0.002	0.01
	(0.0005, 0.003)	(-0.0002, 0.004)	(0.002, 0.02)	(0.0003, 0.004)	(0.005, 0.02)
Quadratic term for dairy production (L)[1]			-0.0002		-0.0002
			(-0.0004, -0.00002)		(-0.0003, -0.0001)
p-value[2]	0.008	0.087	0.021	0.025	<0.001
Global Diet Quality score					
Weekly dairy production (L)[1]	0.02	0.03	0.07	0.01	0.03
	(-0.002, 0.04)	(0.003, 0.05)	(-0.03, 0.2)	(-0.02, 0.04)	(-0.03, 0.09)
Quadratic term for dairy production (L)[1]			-0.001		-0.0005
			(-0.003, 0.001)		(-0.002, 0.001)
p-value[2]	0.081	0.028	0.080	0.477	0.619
Dietary Diversity Score					
Weekly dairy production (L)[1]	0.009	0.011	0.031	0.007	0.028
	(0.004, 0.02)	(0.004, 0.02)	(0.007, 0.05)	(-0.0003, 0.01)	(0.01, 0.04)
Quadratic term for dairy production (L)[1]			-0.001		-0.001
			(-0.001, 0.00006)		(-0.0010, -0.0002)
p-value[2]	0.002	0.003	0.005	0.058	0.004

[1]Weekly dairy production was Winsorized at the 98th percentile.
[2]p-value is for the overall significance of milk production in the model.

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produced per week was significantly associated with a 0.03-point increase in GDQS, but no association with household milk production among women (Figure 3, Table 4). The DDS exhibited a significant non-linear association with milk production among both men and women, but the magnitude was small (Figure 3, Table 3).

Market access

Our market analysis was restricted to the ten FPOs where TADB/TI3P is being implemented (869 respondents, 428 men and 441 women). On average, farmer's closest market is 5.2 km away and has a food basket score of 20.6. Their nearest high-quality market was on average roughly twice as far (9.7 km). High quality markets have an average food basket score of 26.5 and the average minimum cost for a food basket at these markets was 1,212 TZS (USD 0.46). Market access was similar for men and women (Table 5).

Our research provides no evidence that residing closer to the nearest market is associated with better diet quality. Although we observed that, among men, a 1 kilometer *increase* in distance to the nearest market was significantly associated with a 0.06 point increase in the GDQS score (95% CI: (0.02, .12) and 0.02 point increase in the DDS (95% CI: 0.002, 0.03), the small magnitude of this association suggests that the find is not practically meaningful. Similarly, we found no evidence that the quality of the nearest market modifies the association between milk production and dietary quality.

Access to financing, dairy consumption, and diet quality

We found no association between dietary quality and household loan status, regardless of gender of the respondent. Similarly, we did not observe any association between household loan status and the volume of dairy consumed among men or women. However, consistent with our previous findings, we did observe that men consume more dairy products than women irrespective of their loan status (Table 6).

Table 5. Market access by sex. Table give means and (standard errors) (N = 869).

	Overall N = 869	Men N = 428	Women N = 441	p-value comparing
Distance to the nearest market	5.2 (1.9)	5.1 (1.9)	5.4 (2.0)	0.129
Food basket score at the nearest market	20.6 (1.8)	20.6 (1.7)	20.6 (1.8)	0.873
Distance to the nearest high-quality market	9.7 (2.6)	9.9 (2.7)	9.6 (2.5)	0.547
Food basket score at the nearest high-quality market	26.5 (0.7)	26.60 (0.6)	26.4 (0.7)	0.078
Food basket price at the nearest high-quality market (TZS)	1212 (131.5)	1201.8 (133.9)	1222.2 (129.3)	0.097

Table 6. Relationship between access to financing and dietary quality outcomes (N = 1935[1]).

	Dairy Consumption (L)	GDQS	DDS
Model-based means			
Male non-loan holders	0.2	17.3	3.9
Female non-loan holders	0.1	17.4	3.7
Male loan holders	0.2	17.6	3.9
Female loan holders	0.2	17.0	3.9
P-values			
Comparing loan-holders and non-loan holders	0.269	0.855	0.140
Comparing men and women	<0.001	0.388	0.108
For the interaction between sex and loan holding	0.394	0.083	0.116

[1]Three respondents were excluded due to missing covariate data.

Table 7. Qualitative themes related to dairy consumption.

Theme	Summary	Illustrative Quote(s)
Cow productivity	Farmers consider the productivity level of each cow when determining how much milk is consumed in the household. This is impacted in turn by the quality of the cow, weather or climatic factors, availability and affordability of land, water, fodder, access to veterinary care, and the farmers knowledge.	*"The amount of milk you get depends on the cow's feed, so you don't always get the same quantity. On average, I sell about four liters of milk per day. The amount I use at home can be two or one and a half liters, depending on the number of people at home that day."*
Family size	Farmers identified family size as an important factor that dictates how much milk to keep at home.	*"I would use more milk based on the situation of my family. For example, when the children are not at home, maybe it's just me and my husband, or there's a worker. I'll be using a little milk. But if the whole family is at home, I have to reduce what I sell and keep more at home."*
Family composition	Within the household, returning children and grandchildren, sick household members, or members who had recently given birth were sometimes prioritized for milk consumption. Most farmers mention that milk is mostly consumed by children and grandchildren. Despite the quantitative findings, few mention that the male household head consumes more milk than other members.	*"Milk consumption can significantly increase if there's a patient, a guest, or if a woman has recently given birth. After using one liter, you might find yourself using all of it."*
Meeting loan obligations	Farmers reported that meeting their loan obligations was a high-priority. Many loanholders, FPO leaders and local government officials have noted that the productivity of their cows was lower than expected. Consequently, there was not enough milk available for them to repay their loans and achieve their desired household consumption levels.	*"Yes, but for those whose cows produce less milk, some bring one liter, others one and a half liters. When calculated, it often doesn't meet the repayment amount. Even if it does, when someone receives 60,000 shillings and we deduct 50,000 shillings, they complain significantly and leave dissatisfied. It feels like we haven't helped them, but rather caused them harm."*

Qualitative insights

Across our 20 FGDs and 15 KIIs, farmers revealed key insights into their decision making among milk consumption. Decisions around dairy consumption were made at two levels, first households decided how much milk could be kept at home for consumption. Second, households decide how to allocate milk within the household. Milk production was cited as a major factor that influenced the decision to sell or consume milk with several up-stream factors, such as quality of the cow or access to fodder. On the other hand, family size, household composition, and the need to repay loans also impacted farmers decisions on how much milk to consume. Key findings are summarized in Table 7.

Farmers mention three primary ways in which they utilize the income obtained from milk sales: meeting household needs such as children's education expenses and farm necessities, reinvesting in dairy farming, and investing in other income-generating activities. Notably, in the qualitative study, there is no discussion among farmers about expanding or altering their diet. While some mention using the money to purchase food items, the emphasis is on covering the costs of basic staples like cooking oil, salt, and tea, rather than on enhancing the diversity or quality of the diet.

Two themes related to market access were focused on challenges related to accessing food markets while the remaining seven specifically focused on accessing markets to sell their milk (Table 8).

Table 8. Qualitative sub-themes related to market access.

Theme *Sub-theme*	Summary	Illustrative Quote(s)
Accessing food markets *Transportation*	Farmers face challenges with transportation to food markets, including distance and road quality. Women more likely to travel by foot than men.	*"The main challenge is the distance to the markets, compounded by the poor condition of our roads. Even if you can't use any form of transport and have to walk, the fluctuating prices at the market add to the difficulty."*
Accessing food markets *Insecurity*	Farmers sometimes report facing security concerns while traveling to and from food markets, such as theft. However, only 2% of women and 7% of men reported having experienced safety issues when commuting to the market.	*"Like losing money, someone can approach you as if they are with you, and you may drop your phone. Someone else may pick it up, and they might see you, but they won't tell you. For example, theft."*
Accessing milk markets *Milk Storage*	Farmers reported facing challenges with milk storage, citing issues such as the quality of milk containers or a lack of sufficient containers for milk storage.	*"Yes, during sales, you can go there and find that the milk containers are not sufficient. So, you may be told to wait until maybe a vehicle comes with additional containers, so you find a place to pour your milk."*
Accessing milk markets *Transportation*	Farmers mention facing challenges transporting milk to the market due to distance, especially during the rainy season when access to the milk market becomes more difficult.	*"The distance from here to there is quite far, requiring transportation like a bicycle or a motorcycle."*
Accessing milk markets *Low milk prices*	Farmers report challenges with the low buying price of milk, noting that it is insufficient to cover production costs and generate a profit.	*"The price of milk is very low, i.e., TZS 800 per litre. Even paying the employee is a challenge, and if you only rely on delivering to the FPO, you cannot pay the employee."*
Accessing milk markets *Milk Spoilage*	Dairy farmers express significant concern about milk spoilage.	*"Sometimes you might find out that your milk, initially deemed safe, is returned after two or three days because it spoiled. When it's returned, the milk has been mixed with others, making it impossible to determine if the spoiled milk was yours or someone else's."*
Accessing milk markets *Quality Assessments*	Farmers express significant concern about the quality assessments of milk.	*"When delivering milk, I sometimes face challenges with its perceived quality or consistency. If the milk is rejected for being of poor quality or too thin, it sets us back because we have to take it back."*
Accessing milk markets *Delays in receiving payments*	Farmers report experiencing delays in receiving payments for milk, with some delays extending up to two weeks or more.	*"We agreed payments should be made between the 1st and 5th of each month, but sometimes it's delayed until the 15th, affecting employees' salaries and rights."*
Accessing milk markets *Inability to process milk*	Farmers cite a lack of equipment hindering milk processing at home, necessitating reliance on large processing companies to collect their milk before spoilage.	*"I have never processed milk because I lack the knowledge and equipment to do so. To process milk, you need a refrigerator. Sometimes the milk spoils at the station. If we were experts in processing, we could have prevented this."*

Discussion

We observed that increased dairy production was only weakly associated with increased dietary quality or dairy consumption. Although these differences were statistically significant in some cases, the magnitude of this difference is very small. Our finding that milk productivity is only weakly associated with dietary outcome is similar to what has been previously reported regarding livestock ownership, an important determinant of dairy production. While other researchers have reported significant associations between livestock ownership and improved diet (Bellows et al., 2020) as well as the number of livestock owned and improved diet (DeLay et al., 2020; Hadley et al., 2007; Häsler et al., 2018), the reported effect sizes have also tended to be relatively small.

The relationship between dairy production and diet was not impacted by market access. Furthermore, our study finds no evidence of an association between better market access and improved individual dietary quality. Previous research in Tanzania has found that crop diversity, but not livestock diversity, is associated with improved diet quality and that the

magnitude of the association is strongest for those living closest to food markets (Madzorera et al., 2021). However, the population in that study was substantially closer to the nearest market (median distance 1.1 km) than observed in our population. It is possible that proximity to food markets only matters at very close distances or that the patterns of association are different for crop and livestock production.

Our study also found that loan holders do not appear to have significantly different dietary quality or dairy consumption than non-loan holders. Previous studies in East Africa have found associations between membership in milk markets or dairy group, which may suggest that support from formal institutions can improve productivity and diet quality among dairy farmers (Lenjiso et al., 2016; Walton et al., 2014). It is important to note that in our study, both the loan holders and non-loan holders are members of FPOs, so the additional benefit of the TADB/TI3P loan on diet quality may be smaller in this population than if similar loans were awarded to independent farmers. It is also important to note that while TADB/TI3P loans alone do not appear to be associated with dietary quality.

While our study suggests that dairy production does not appear to be an efficient strategy to meaningfully achieve high dietary quality, it also underscores the importance of identifying more promising strategies to improve diet quality in this population. On average, both men and women in the sample have a moderate risk of poor dietary quality and low dietary diversity as measured by the GDQS. Women consumed on average only 3.8 out of 10 food groups, falling below the recommended 5 food groups needed to achieve adequate minimum dietary diversity. Generally, we find that the local availability of diverse foods was poor in the areas in which TADB/TI3P disburses loans, with the average farmer needing to walk 9.7 kilometers to reach a high-quality market. Previous research in Tanzania has identified that education level of the household head, being part of a female headed household, and receiving food and nutrition training are associated with household dietary diversity while women's control over assets and income are associated with improved dietary diversity for women and children (Galiè et al., 2019; Ochieng et al., 2017). Leveraging additional trainings around food, nutrition, and women's empowerment could be a complementary strategy.

Our qualitative data provides additional insight into the relatively weak associations between dairy production and diet. First, cow productivity was not always perceived as sufficient to allow farmers to consume the desired amount of milk and also to repay their loans. Second, income from milk sales was used to cover a wide range of essential household expenses and to re-invest in dairy farming, and expanding the quality or diversity of the diet was not generally a priority. This finding aligns with nationally representative data from Tanzania from 2008 to 2019, which found that although real household expenditures, a common proxy for income, have risen, the proportion of expenditures allocated to food has fallen while diet quality has remained stable (Ignowski et al., 2023). Our data similarly suggests that dairy farmers also express a preference to sell, rather than consume, the milk they produce and for loan-holding farmers, that decision was often influenced by the need to meet their loan obligations. Only 58% of men and 47% of women reported consuming milk or milk products the previous day. While this consumption is much higher than the national average – only 30% of households in Tanzania reported consuming dairy in the previous week (Ignowski et al., 2023)– these results still point to a pattern where milk is diverted for sale rather than consumption.

Qualitative data also suggested that farmers face several challenges in accessing dairy markets, especially as it relates to bringing their milk for sale, such as milk storage and transportation, low milk prices, spoilage and poor quality of milk, delays in payment, and the inability to process milk. For both dairy and food markets, farmers report transportation challenges, such as lack of transportation means and long distance. Similar barriers have previously been raised by dairy farmers in Tanzania, highlighting the importance of capital for infrastructure to support milk storage and transport as well as for cows (Häsler et al., 2019).

This study has a number of limitations. First, this observational, cross-sectional study did not include randomized assignment to TADB/TI3P. Although our analysis did adjust for systematic difference between loan holders and non-loanholders, it cannot conclusively demonstrate any causal effect of the loans. Similarly, due to the cross-sectional nature of the study, this work is vulnerable to reverse causality. Second, we collected data from loan holders who have been in possession of the loan for a minimum of six months. While we do believe it is plausible to see some shorter-term effects (e.g., diet changes, control over income) within our timeframe, we have assumed that there has not been sufficient time for receipt of TADB/TI3P loans to lead to measurable impacts in terms of long-term household socioeconomic status and access to high-quality markets. Third, this study uses cross-sectional data from only one time period. Therefore, we are not able to capture any effects of seasonality on dietary quality, income, dairy productivity, or market access. Fourth, in order to create a valid comparison group for TADB/TI3P loanholders, our study region is limited to the four regions where TADB has already begun distributing TADB/TI3P loans. While focusing on these reduces the possibility of bias, it also means our findings may not be fully generalizable to all regions in Tanzania. In particular, there may be different patterns observed in nascent milk markets, which are not included in this study.

While improved dietary quality is not an original objective of the loan program, our findings suggest a number of opportunities for TADB and other agricultural institutions to improve their product and promote improved diet quality. First, it is possible to highlight the nutritional benefits of dietary diversity through existing information channels such as FPOs or include additional interventions that seek to address behavior change in consumption of dairy and dairy products or a separate marketing campaign. Second TADB may seek to explore strategies to promote best practices for dairy cattle management and boost the productivity of cows to ensure that farmers can consume more milk at home. These strategies could include improved training for farmers or the provision of higher-quality cows through the FPOs and the livestock extension workers.

Reporting guidelines

Access to the STROBE checklist for this paper are available at: OSF. Association between productivity, market access, and financing on consumption of dairy products and diet quality among dairy farming households in Tanzania. https://doi.org/10.17605/OSF.IO/SG83Y (Barnhart 2024).

Ethics and consent

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Tanzanian National Institute for Medical Research on the 31st of July, 2023 (approval NIMR/HO/R.8z/Vol.IX/4371) and Tanzania Commission for Science and Technology. Written informed consent was obtained from all respondents.

Data availability

Data are available from: OSF. Association between productivity, market access, and financing on consumption of dairy products and diet quality among dairy farming households in Tanzania. https://doi.org/10.17605/OSF.IO/SG83Y (Barnhart 2024). Note that GIS coordinates and other identifying details are not included in this dataset to protect the identities of human subjects.

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