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The impact of income on nutrition. A case study of northern Mozambique

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Contents

Abstract

In 2017, Mozambique ranked as one of the least-developed countries in the world by measures of health, education, and income, and had one of the lowest GDP per capita at $1,300. With a minimal income, purchasing adequate food to meet recommended levels of nutrients for a healthy diet is difficult, leaving almost half of the country's population undernourished. This study researched what foods are available during the dry months (hungry season) of May through October in the Nampula province of Mozambique to analyze if it is possible to meet the National Institutes of Health's recommended levels of nutrients from purchasing food, as well as growing supplemental food at home. Three different levels of income were used to determine what percentage of the country could purchase the recommended levels of nutrients. The lowest income group (Income #1) was attained from data from the World Bank and was the estimated 2018 per capita income ($426.22/year), followed by the wage posted by the Mozambican government as their minimum wage (Income #2, $771.71/year), and lastly the minimum wage at New Horizons Farm, a private foreign direct investor in the poultry industry in Nampula (Income #3, $895.46/year). Based on these income groups, a majority of the country would be unable to meet their needs from solely buying food from the market at any time of the year. Those who grow their own food made meeting their nutrient needs more feasible, as they did not need to purchase as much food as households that did not grow their own food. This is troubling for a country who is trying to diversify out of agriculture. Lastly, different models were constructed to analyze the effect of the supplementation of specific vitamins and minerals that are continuously difficult to obtain in Northern Mozambique. Nutrients that were a common binding constraint were removed from the model, eliminating the need to eat food items rich in the binding nutrient. Three different models were selected based on binding constraints: supplementing Vitamin D,

supplementing calcium, and supplementing Vitamin D, calcium, and Vitamin C together. Total annual cost was compared between no supplementation and the three supplemented models. Supplementing only Vitamin D did not reduce the annual cost significantly. The most significant impact from supplementation was of calcium, reducing the theoretical percent of annual income spent on food from 325% to 65% in some scenarios. Lastly, supplementing Vitamin D, calcium, and Vitamin C together did not reduce total cost significantly more than just calcium. Based on these results, some form of calcium supplementation would provide the most value for the region of Northern Mozambique.

Introduction

Mozambique has been one of the most impoverished countries in the world since gaining independence from the Portuguese in 1975 (CIA, 2018). Although the government of Mozambique continues to work to improve the country's economic well-being, as of 2017 Mozambique ranked #222 out of #229 in the world in gross domestic product (GDP) per capita of $1,300 (CIA, 2018). A 2015 estimate found that 46.1% of the country's population was under its own poverty line (CIA, 2018). Poverty lines/levels vary based on region, and below this level a person's minimum nutritional, clothing, and shelter needs cannot be met. Sub-Saharan Africa has a poverty line of $1.90 per day, or $693.50 annually (The World Bank, 2018).

With Mozambique's current standard of living, it can be difficult to meet Recommended Dietary Allowance (RDA), which is defined as "average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%-98%) healthy people" (National Institutes of Health, paragraph 2, 2018). From 2005-2007, it was estimated that nearly 80% of the Dietary Energy Supply (DES) for the population of Mozambique came from cereals and starchy roots such as cassava, sweet potatoes, maize, and wheat (Lourdes, Bader, Razès, & Dop, 2011). The per capita consumption of fruits and vegetables has been cut in half since the 1960's, and is the lowest in the region, and per capita consumption of animal protein and healthy fats from nuts and oils was also estimated to be extremely low (Lourdes et al., 2011). This lack of dietary diversity can be attributed to the destruction of basic infrastructure after the civil war (1975-1992), natural disasters such as drought, infertile soils, and lack of farm investments (FAO, 2010). These barriers to access a holistic diet, along with the economic strife of the majority of the country, contribute to the large number of individuals not meeting their RDA of nutrients.

With the lack of a diverse diet and fruits and vegetables, undernutrition, (defined as "deficient bodily nutrition due to inadequate food intake or faulty assimilation"), is widespread across Mozambique (Undernutrition). In 2013, it was estimated that 43% of the children in Mozambique suffered from moderate to severe growth stunting, which is mainly caused by lack of proper nutrients at a young age (UNICEF, 2013). Micronutrient deficiencies such as Vitamin A, iodine, and iron are prevalent throughout the country, which again can be traced to lack of a healthy, diverse diet (FAO, 2010). In the area around Meconta, close to Nampula, during the hungry season, the time right before harvest, Vitamin A levels were 24% of recommended levels and calcium levels were 49% of recommended levels. (Rose, Strasberg, Jeje, & Tschirley, 1999). In total, roughly 40% of the population of Mozambique were classified as undernourished from 2005-2007 (FAO, 2010).

Problem Statement

Individuals who live under the poverty line in low-income countries are more likely to suffer from nutritional deficiencies and the diseases/problems that can arise from these deficiencies such as anemia, stunting, and osteoporosis. A lack of nutritional knowledge and income limitations contribute to Mozambicans' ability to meet basic nutritional needs. Both factors make it difficult to obtain a holistically healthy diet, given the food available to them, to meet nutritional recommendations. Research has been conducted on what macronutrients and micronutrients are commonly deficient in low-income areas, as well as research on the levels of nutritional knowledge in Mozambique. However, there is a gap in the literature on how one could maximize their purchasing power to meet nutritional needs in northern Mozambique given what is available to eat. This study will assess the feasibility for an individual, under three hypothetical income levels, to satisfy their nutritional needs during the dry season, given what is available to purchase in the local markets and supplemented with at-home production. The lowest income group (Income #1) was attained from data from the World Bank and was the estimated 2018 per capita income ($426.22/year), followed by the wage posted by the Mozambican government as their minimum wage (Income #2, $771.71/year), and lastly the minimum wage at New Horizons Farm (Income #3, $895.46/year). The purpose of this study is to investigate if an individual in Northern Mozambique can attain a portfolio of foods in the dry season that will meet their nutritional needs under each hypothetical income level. Lastly, we will identify specific food items that could effectively 'fill in the gaps' of any nutrient deficiencies which are prohibitively expensive or simply not available to purchase or grow. These results will provide policy makers and NGOs with useful data on what macro and micronutrients are limited in the dry season and the correlation with income and the ability to consume a holistically healthy diet.

Objectives

The objectives of this study are as follows:

1. Record which foods are available locally during the dry season in Nampula, Mozambique.
2. Record the average prices of available foods given a specific metric (per kg, per orange, etc.).
3. Use linear programming to optimally (cost minimization) build a portfolio of foods that would help individuals meet their recommended nutritional needs.
4. Identify possible food items which could be added to the area to eliminate any nutrient deficiencies.

5. Analyze if income is a barrier to obtaining a healthy diet by analyzing three different income scenarios. The three scenarios being the GDP per capita of $426.22/year (Income #1), the government minimum wage of $771.71/year (Income #2), and the New Horizons Farm minimum wage of $895.46 (Income #3).

Literature Review

Mozambique was colonized by the Portuguese in 1505, and did not gain independence until 1975 (Mozambique, 2016). After gaining independence, Mozambique entered into a civil war from 1977-1992 which destroyed the modest infrastructure the country had, and drastically reduced agriculture production, as well as economic output as a whole (FAO, 2010). Since independence, Mozambique has been making progress in human welfare, such as reduction in poverty and malnutrition. In 1997, the population living in poverty, earning less than US $0.40/day, was estimated at 70%, while 36% of Mozambicans suffered from chronic malnutrition (Selvester & Castro, 2003). The United Nations International Children's Emergency Fund (UNICEF, 2013) estimated that during 2007-2011, the percentage of the population living in poverty dropped to just below 60%, which would indicate that Mozambique is slowly improving quality of life (UNICEF, 2013). Because of the loss of infrastructure during the civil war, more people living in rural settings find themselves under the poverty line than those in urban areas as moving goods and services is difficult due to a lack of investment in infrastructure (Lourdes et al., 2011). This is a significant problem, as a majority of the population of Mozambique lives in rural areas, and the FAO found one of the biggest barriers to food security is the access to food in rural areas (FAO, 2010). The Human Development Index, which measures human development based on health, education, and standard of living, scored Mozambique a value of 0.418 in 2016, ranking the country 181 out of 188 countries in the world

(UNDP, 2016). Data collected by UNICEF on children from 2008-2011 found that in Mozambique, 16.9% of children had a low birthweight, 14.9% were moderately to severely underweight, and 42.6% of children had moderate to severe growth stunting (UNICEF, 2013).

When discussing how to improve an individual's nutrition, macro and micronutrients are one of the largest concerns in most low-income countries. Macronutrients provide calories for growth and development, and are categorized as either carbohydrates, fats, or proteins. Both carbohydrates and protein provide four calories per gram, while fat provides nine calories per gram (McKinley, 2014). Micronutrients (vitamins and minerals) also help the body develop, and aid in hormone and enzyme production. Although micronutrients are needed in a smaller amount, the lack of micronutrients can present major health problems, especially in children and pregnant women in low-income countries. Micronutrients are vital for proper development, so it is crucial for children and pregnant women to meet recommended levels to avoid disease such as anemia, blindness, stunted growth, and even death (WHO, 2015). The term "malnutrition" refers to someone who is lacking one or more macro *or* micronutrient(s). In low-income countries, protein is one of the most common macronutrient deficiencies (Schmitt, 1979). Since protein provides calories, if a person is deficient in protein, they are also likely to be deficient in energy (calories). This is often referred to as protein-energy malnutrition (PEM), as the lack of energy comes from the lack of protein (Latham, 1997). However, some argue that examining protein deficiencies is not always a tell-tale sign of malnutrition, as recommended levels of protein vary from person to person (Reutlinger & Selowsky, 1976). Eating a diverse diet containing a wide arrange of macronutrients and micronutrients can help eliminate malnutrition, and can also prevent other chronic diseases, such as childhood blindness, osteoporosis, and growth stunting (FAO/WHO, 2002). Schmitt (1979) suggests, when surveying specific areas of the population's nutrition, the number of calories consumed should be 110% of what is required, as there is unequal distribution of food to all regions (as cited in UN, *Assessment of the world food situation* Rome, 1974). In Sub-Saharan Africa, per-capita caloric intake is mostly stagnant, and even falling in some areas, while the global trend is increasing (FAO/WHO, 2002). The most common deficiencies in the world are Vitamin A, iron, iodine, and PEM (Latham, 1997). In Mozambique, the most common are iodine, Vitamin A, and iron (FAO, 2010). As stated previously, Vitamin A deficiency is most prevalent in low-income countries (WHO, 2009). Vitamin A aids in the function of vision, cell growth, immunity, and reproduction, among other things (WHO, 2009). Increasing the amount of Vitamin A through foods, rather than supplementation, should be an important goal for most developing countries, as this will improve the overall health of the population (WHO, 2009). This can be done by increasing consumption of foods rich in carotenoids. Just 50 grams of cooked carrots would provide most people with the recommended levels of Vitamin A for the day (FAO/WHO, 2001). Iron and zinc deficiencies are abundent in diets that are comprised of mostly cereals and tubers. Although this can be improved with an increase in legumes, it is difficult to meet iron and zinc recommended levels without some form of animal meat (FAO/WHO, 2001). Livestock products provide a high-quality protein, iron, zinc, and even Vitamin A (FAO/WHO, 2002). Increasing meat consumption in low-income countries could reduce some of the largest deficiencies with one single food, although it's often times prohibitively expensive. Along with meat intake, consumption of green leafy vegetables should be important in dietary diversification. These vegetables provide a good supply of Vitamin A and iron, and the Vitamin C found in them will help iron absorption (Latham, 1997). Dietary diversification should be the highest priority when trying to improve nutritional status, but food fortification also helps. Salt iodization is one of the most effective ways to reduce iodine deficiency disorder (IDD). Food fortification can also lower the number of people that lack Vitamin A and iron (Latham, 1997). The use of salt-iodization has even proven to eradicate IDD (FAO/WHO, 2001).

The average diet in Mozambique is similar to other low-income countries in Sub-Saharan Africa. Mozambique's nutritional status is both low in total energy and many micronutrients, and among the poorest in the region (Lourdes et al., 2011). Nearly 80% of the Daily Energy Supply (DES) in Mozambique comes from cereals and starchy roots, which is not considered to be a diverse diet. The DES has not improved in the last 40 years in Mozambique and is one of the worst in the region. This poorly structured diet is lacking in many nutrients, as well as total energy, as 38% of people were classified as undernourished from 2005-2007 (FAO, 2010). Cassava is the main food throughout most of the country (FAO, 2010). Cassava is relatively low in nutrients and has one-third the calories and one-tenth the protein when compared to wheat (Schmitt, 1979). The average Mozambican diet is also low in protein, sugar, and fats (Selvester and Castro, 2003). A study conducted by Hansen (2016) in Northern Mozambique surveyed an area around a large poultry farm to estimate the difference in nutrition between workers and non-workers. The average caloric intake of both groups was 3,054 calories, in which workers consumed 3,236 calories, while non-workers consumed 2,842 calories, implying that individuals with a form of income will be able to consume more food than those without. The largest food group of DES was grains at 40%, and the lowest was fruits and vegetables, particularly those rich in Vitamin A (Hansen, 2016). This reported number of calories consumed is more than most living in Mozambique, showing that those who are gainfully employed are able to attain more food, but there are still nutrient deficiencies, regardless of income in Northern Mozambique.

Most vegetables that are consumed in Northern Mozambique, particularly green leafy vegetables, are consumed along with the staples of cassava and other cereals, and rarely any other times (FAO, 2010). Vegetables are consumed about two times a week (Lourdes et al., 2011). This low per-capita consumption of fruits and vegetables has been cut in half in the last 40-50 years due to drought, and the consumption of animal protein also shows a decreasing trend. The amount of animal-sourced food is the lowest in the region of Zambia, Tanzania, Kenya and Malawi (Lourdes et al., 2011). Because of the lack of dietary diversity and micronutrient rich foods, average levels of Vitamin A are only 28% of recommended levels throughout the year in the Meconta region of Mozambique (Rose et al., 1999). Vitamin A supplementation has been increasing in the country due to National Child Health Weeks, during which children are screened and given vitamin supplementation, and these supplements reached 72% of children in Mozambique between the years 2003-2008 (FAO, 2010). Iron deficiency anemia is also a large concern, and supplementation has not been effective due to poor distribution throughout the country (FAO, 2010). The majority of the iron that is consumed in Mozambique is of plant origin, which is poorly absorbed in the body as opposed to animal-based iron (Rose et al., 1999). An iodized salt policy was implemented in 2000, but little salt is currently iodized, with only 25% of households using iodized salt (FAO, 2010). Salt is the only fortified food in the country, and even that is reaching only a quarter of the population.

Because a majority of food consumed is locally produced, seasonality impacts food consumption. One study in 1996 surveyed households at different times of the year based around the harvest season and found in the hungry season, caloric intake was around 70% of recommended intake, while post-harvest consumption increased to around 105%. Those with the smallest household size ate roughly 600 more calories per day than those in the largest households. This indicates household size also has a large impact on consumption, as the more mouths to feed, the less each person receives. (Rose et al., 1999).

There are many factors that impact nutritional status between individuals. Two of the most significant variables that affect this are income levels and household size, with income causing a 90% variation on caloric intake between households (Knudsen & Scandizzo, 1979). In many low-income countries, as income rises, the amount of staple foods such as cereals and roots decline, while meat and animal products increase (FAO/WHO, 2002). Economic development has empirically shown a decline of nutritional deficiencies and improvement of overall health in a country (FAO/WHO, 2002). The World Bank estimates that for those within 80-90% of calorie recommendations, income growth alone could eliminate malnutrition (Knudsen & Scandizzo, 1979). Previous literature has suggested that as income rises, animal products will increase, beans and vegetables will decrease, and staple foods will stay the same (Lourdes et al., 2011). From these studies, one can conclude that as income rises, people tend to eat more meat and fish, which has previously been shown to contain quality protein, iron, zinc, and Vitamin A, all which a majority of the Mozambican population lack.

In 1979, The World Bank estimated malnutrition in most of the world may be eliminated in 30 years if income continued to grow at the expected rate (Knudsen & Scandizzo, 1979). A similar study estimates that from 1970-1995, income growth led to a 50% decrease in child malnutrition in developing countries (Smith & Haddad, 2002). The World Bank estimates that for every 10% increase in income leads to roughly a 4% increase in food consumption (Knudsen & Scandizzo, 1979). A similar study conducted in Mozambique in 1999 estimated that for each additional U.S. dollar increase in annual household income resulted in around an 8 calorie increase per person per day. This same study found that household size was *the* most important determinant in calorie intakes, stating as household size increases, per capita calories consumed decreases. (Rose et al., 1999). This could be due to larger households in rural settings, as individuals will have more children to have more laborers at home.

The International Food Policy also studied income increase with its relationship to food in Kenya, and found for each increase of income of $0.41, household calories increase by 3 calories per day (Kennedy & Cogill, 1987). This number is small, but similar to those found in Mozambique in 1999. Although small, there is direct casual relationships between household size, income levels, and caloric intake. The question is then, how much money would it cost to meet nutrient recommendations in these areas? A study done in 2003 by the Ministry of Planning and Finance of Mozambique constructed food bundles made of the most common foods eaten in Mozambique and determined how much money per day was needed to meet calorie requirements. The study was separated into 13 different regions of Mozambique. Income needed ranged from $31.56 per day, all the way to $158.50 per day. The average daily income needed per day was $95.03 in 2003 or $132.48 in 2017 (Massingarela, 2003). This amount of money will provide an individual in the area with the recommended number of calories. But, since it is made up of staple foods, which has been shown to be lacking in diversity and many nutrients, this would not help lower malnutrition levels. Animal products and fruits and vegetables tend to cost more than the staple foods, so this average daily income would need be even higher. There has been little to no research on the most significant variables that relate to food consumption, income and household size, and if one could attain a healthy, diverse diet meeting all macro and micronutrient needs given the foods available.

Materials and Methods

Design

Nampula and Zambezia are the two poorest regions in Mozambique. The two regions account for 38% of the country's population and 48% of the country's poor. Between 2003 and 2009, poverty in these regions rose by 5%, while in the remainder of the country the poverty rate declined by 17% (World Bank, 2016). Figure 1 provides a provincial map of Mozambique to illustrate the study area of Nampula. We collected data from Nampula (the city) in the summer of 2018. We then used a linear program to estimate different cost-effective meal(s) that can help individuals meet their recommended nutritional needs, specifically addressing common deficiencies in the area previously identified.

Treatments and Instruments

After data on the cost of available food items was collected while in country, I used previously published data by The World Bank (2018) and Hansen (2016) of Mozambique's income levels and average household size. Once the data was compiled, I used linear programming to build possible "meal templates" that constructed a meal that meets recommended levels of daily nutrients for one individual, and its respective cost. With this, I can determine the cost of meeting daily recommended levels of nutrients, and what percentage of the population can attain this, given their income and household size.

Participation and Sampling

We used the World Bank's per capita GDP estimate for Mozambique as an "average" income ($426.22/year). Because averages are often skewed, we also used the government minimum wage ($771.71/year), as well as the minimum wage at New Horizons Farm, a private employer ($895.46/year), as alternative yearly incomes. We assumed a 40-hour work week for the two scenarios using wage rates. Data on household size is gathered from research done in and around New Horizons Farm in 2015 and was set at 6.6 people per household (Hansen, 2016).

Data and Methods

We used linear programing in Microsoft Excel, specifically the Solver add-in, to build a model of the possible combinations of food available that will meet a household's daily Dietary Reference Intake (DRI) of nutrients, regardless of price, and determined if that is at all possible. DRI values are derived from the National Institutes of Health for various age groups and gender and are listed in Table 1. Family size in Northern Mozambique for an average household, per Hansen (2016), was 6.6 individuals per household. It was assumed that only one person in the household had a salary, which is a realistic assumption given the low formal employment prevalent in Northern Mozambique. Since nutritional requirements vary based on age and gender, different levels were used to simulate a typical household. DRI for a male and female in the age range of 19-30, a male and female in the age range of 14-18, and a male and female in the age range 4-8 were used. Lastly, DRI for a female aged 4-8 multiplied by 0.6 was used to build a household total of 6.6 people. The DRI for the average household is listed in Table 2. Data on food items available during the dry season was collected in various markets in Nampula during June of 2018. These food items would be available to the average Mozambican in the Nampula area. Thirty-one different food items were recorded and are listed in Table 3 along with their nutritional information. A local translator was used to ask vendors their prices for respective items as to obtain the most accurate price for an individual living in the area. Food prices are listed in Table 4. Prices fluctuate across and even within markets for the same food products, but we used the lowest cost we encountered in our models. Data was sourced from a study conducted in the same area in 2015 of food items that were commonly grown in home gardens (Hansen, 2016). Three food items were grown at home that were not available to purchase at the market (cassava leaves, bean leaves, and sweet potato leaves). Prices for these items was calculated by multiplying the price of a similar food item, cabbage, by 1/8. This was done because the food items grown at home would have a small price if available at the market. All prices were converted from Mozambique Meticals to US Dollars at the rate of $1 = 60.84 Meticals. I then used linear programming to estimate the feasibility of healthy diets given different income levels of GDP per capita ($426.22), government minimum wage ($771.71), and New Horizons minimum wage ($895.46) and built possible meals that a person could eat that would meet their daily DRI constrained by the three budget scenarios. The first goal of this study is to determine if a well-balanced meal is attainable given each level of yearly income. That is, we calculate the price of obtaining an DRI sufficient meal for a 6.6 person household daily and multiply that by 365 and compare that to each of the three income scenarios to see if each respective income is sufficient to at least provide healthy meals for the entire household for a year. From these results we will be able identify certain crops/food that could be added to the area that will remove nutrient deficiencies, in hopes to improve the area's overall nutrition profile in a cost-effective manner.

Three different models were used to represent different scenarios individuals may find themselves in in Mozambique (Table 5). Model A, representing the "Urban Consumer" has no constraints on food availability, all food items could be consumed that were found in markets around Nampula. In this model, it is assumed that the individual purchased all their food from the market, and none is grown at home, representing the average urban Nampula consumer. This model would represent the 36% of the Mozambican population that lives in urban areas and does not grow food at home (CIA, 2018).

Model B, representing the “Rural Consumer” has no food constraints, but it is assumed that supplemental food is grown at home. The different prices/serving of food items used in this model were found by subtracting the percentage of households growing the food from 100% and multiplying this value by the market price. For example, 20% of households surveyed grew bananas (Table 4), which have a market price of $0.08/serving. $0.08*(1-0.2)= $0.06/serving. Data for the percentage of households growing certain food items came from a survey of 60 families in the Nampula region in the summer of 2015 (Hansen, 2016).

Model C is similar to “Urban Consumer” in the fact that no food is grown at home, all nutrition is bought. That being said, model C considered seasonality by removing all fruits available on the market from the model, given their obvious seasonality, and represents the “Seasonal Urban Consumer”. Since data was recorded during the summer of 2018, several fruits were available at the markets after their rainy season of December-April (Go2Africa). By removing fruits, “Seasonal Urban Consumer” highlights what is more likely available to purchase during the dry/hungry season.

Three different income levels were used for each of the model scenarios (“Urban Consumer”, “Rural Consumer”, and “Seasonal Urban Consumer”) described above. The lowest annual income of $426.22/year (2017, current US $) was attained from The World Bank and is Income #1 (World Bank, 2018). The next income level of $777.71/year is the government minimum wage for the country for 2018 and is Income #2. Lastly, the minimum wage of a New Horizons employee as of 2018 was $895.46/year and is Income #3. Finally, the feasibility of each model was found by comparing the annual cost for a household given the constraints of each model to the three different income levels.

Results

In “Urban Consumer”, the final cost per household (of 6.6 people) to obtain a diet that meets DRI of nutrients was estimated to be $2,852.09 annually. Shown in Table 6, the results for “Urban Consumer” consist of a diet that is made up of foods which include milk, with its high level of protein, Vitamin A, Vitamin D, and calcium; beans, adding fiber, protein, iron, calcium, and potassium; fish, adding protein, Vitamin A, one of the only sources of B12, Vitamin D, and potassium; oil for fats; and oranges which contribute Vitamin C and fiber (Table 3).

The binding constraints are shown in Table 7, and in “Urban Consumer” include carbohydrates, Vitamin C, Vitamin D, calcium, iron, and calories. In each model, carbohydrates are trying to be minimized, while calories are maximized, so any supplementation in these areas is not needed. Food items high in Vitamin C that are available in the area include cassava and bean leaves (which are only grown at home so are not included in “Urban Consumer” or “Seasonal Urban Consumer”), cabbage, cassava root, limes, potatoes, and Milo drink mix (Table 3). One large problem facing consumers in Northern Mozambique is the lack of foods containing Vitamin D. The only foods which contain Vitamin D are fish, Milo drink mix, eggs, and milk, which are all relatively expensive foods (Table 3). The Milo drink mix has the lowest shadow price, which is how large of a reduction in price for the food to enter the model, of 14% (meaning price would need to be reduced by 14%), while eggs have a shadow price of 68% (Table 8). Food items high in calcium include Milo drink mix, bean and cassava leaves, milk, beans, and cabbage (Table 3). Milo drink mix and cabbage have the same shadow price as mentioned before. Table 3 shows foods high in iron include Milo drink mix, beans, and cassava leaves. The annual cost of $2,852.09 is over 100% of a household's annual income given the three income groups analyzed in this study, being 669% of Income #1, 367% of Income #2, and 319% of Income #3, as seen in Table 9, making "Urban Consumer" prohibitively expensive for all income groups.

In "Rural Consumer", the final annual cost to provide a nutritious diet for a household is $70.30 (Table 6), which is attainable for all three income groups analyzed in this study. The percent of annual income spent on food is 17% for Income #1, 9% for Income #2, and 8% for Income #3, as seen in Table 9. The reduction in cost is associated with food grown at home supplementing market-bought food. Table 6 shows this diet consists entirely of cassava leaves and fish, as this is the least expensive way to meet DRI. This low price is because cassava leaves are grown at home and thus cost very little to attain. Cassava leaves are high in protein, Vitamin A, iron, and calcium, and since they are grown at home, are extremely affordable. Fish provides essential fats, protein, Vitamin D, and Vitamin B12 (Table 3).

Like "Urban Consumer", the binding constraints for "Rural Consumer" were Vitamin D and calories (Table 7). As stated earlier, foods high in Vitamin D include fish, Milo drink mix, eggs, and milk (Table 3). This model is affordable and covers most micronutrients.

Lastly, "Seasonal Urban Consumer" has the highest final cost at $2,913.91 annually (Table 6) which is 684% of Income #1, 375% of Income #2, and 325% of Income #3 (Table 9). This is due to the constraint of seasonality in foods, removing fruits from the market, thus removing low-cost sources of key vitamins and minerals. "Seasonal Urban Consumer" consists of milk, beans, cabbage, and fish (Table 6). The binding constraints are carbohydrates, Vitamin C, and Vitamin D (Table 7).

“Seasonal Urban Consumer” is very similar to “Urban Consumer”; however, “Seasonal Urban Consumer” does not have binding constraints of calcium, iron, or calories that are present in “Urban Consumer” (Table 7). Because there are no fruits available in “Seasonal Urban Consumer”, Table 6 shows “Seasonal Urban Consumer” consists of more milk and beans than “Urban Consumer”, which addresses the constraints of calcium and iron. “Seasonal Urban Consumer” also introduces cabbage to meet micronutrients usually met by fruits. The shadow price for foods high in Vitamin C and Vitamin D are potatoes (99%), Milo drink mix (13%), bell peppers (32%), and eggs (68%) (Table 8).

Supplementation

To reduce the final cost of food for the year, the binding constraints were modeled as being supplemented (either through a Non-Government Organization or a targeted government program), making it unnecessary to purchase these vitamins/minerals. We wanted to assess the viability of a supplementation program on a household’s ability to eat a holistic diet. Since Vitamin D was binding in each model, it was removed from the models and re-estimated to see how the optimal meal plan would change, both with regards to the food items and the associated final cost. This did not change the final price significantly, only changing the percent of income spent on food by 1% in all three models as seen in Table 10. The most significant change came from supplementing calcium. This changed four scenarios (“Urban Consumer”-Income #2, “Urban Consumer”-Income #3, “Seasonal Urban Consumer”-Income #2, “Seasonal Urban Consumer”-Income #3) from not being feasible to being feasible, with the largest cost change (although still not feasible) in “Seasonal Urban Consumer”-Income #1, reducing the percent of income spent on food from 682% to 140% as shown in Table 11. The differences in diet when calcium is supplemented is less milk and leafy greens are consumed, and more oil, cassava root, and maize flour are consumed. One final scenario was modeled by supplementing Vitamin D, Vitamin C, and calcium together. Table 12 shows that there is not a large difference from this scenario as compared to only supplementing calcium.

Conclusion and Discussion

The objectives of collecting data on food available in Northern Mozambique and analyzing said data to determine the cost to meet a households DRI were met, as we were able to find the lowest costs possible to meet DRI of macronutrients and micronutrients for the three different models. The most common nutrient deficiencies were Vitamin C, Vitamin D, calcium, and iron. Other deficiencies that have been found to be common in Mozambique in previous studies, such as Vitamin A, could be avoided with the right knowledge of foods to buy at the market, such as sweet potatoes or pumpkin. The largest reduction in annual cost per household came from supplementation of calcium, which changed the feasibility of four scenarios from being not possible to being possible as seen in Table 11. Foods high in calcium are mainly dairy products, which are costly in Mozambique. Currently there is a product named Milo, which is a powdered drink mix that is high in protein, Vitamin B12, Vitamin C, Vitamin D, iron, and calcium (Table 3). It is shelf stable and calorically and nutrient dense, making it ideal for transportation. One obstacle is the high price of the mix for an average Mozambican. A government subsidy or cost reduction by the company that produces Milo for those at risk of undernutrition, mainly children and pregnant women, would be beneficial. Although seasonality was not a major concern for undernutrition, Milo has no seasonal variability, as it is a manufactured powder mix. In “Urban Consumer” and “Seasonal Urban Consumer”, the price of Milo would need to be reduced by 14 percent and 13 percent, respectively, to enter each model (Table 8). Another similar option would be subsidizing fortified ready-to-eat cereals and/or bread, both of which are already consumed in urban areas. More relevant to rural areas would be the introduction and/or increase in production of crops that are high in calcium such as spinach, kale, collard greens, and similar dark leafy greens. Increasing education on the importance of these foods could be beneficial in homes growing and consuming these vegetables as opposed to cabbage. Further research into what food items that are high in calcium that could be produced in country in an economically efficient manner would have the largest impact for those living in Mozambique.

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Tables

Table 1.

Daily Recommended Intake of nutrients based on age and gender

	0-6 months	6-12 months	1-3 years	4-8 years	14-18 Males	14-18 Females	19-30 Males	19-30 Females	31-50 males	31-50 Females	Unit
Total Fat			54	58	78	78	78	78	78	78	g
Saturated Fat			18	18	20	20	20	20	20	20	g
Sodium	120	370	1000	1200	1500	1500	1500	1500	1500	1500	mg
Cholesterol				300	300	300	300	300	300	300	mg
Carbohydrates	60	95	228	244	325	325	325	325	325	325	g
Fiber	0	0	19	25	38	26	38	25	38	25	g
Protein	9.1	11	13	19	52	46	56	46	56	46	g
Vitamin A	400	500	300	400	900	700	900	700	900	700	IU
Vitamin B12	0.4	0.5	0.9	1.2	2.4	2.4	2.4	2.4	2.4	2.4	µg
Vitamin C	40	50	15	25	75	65	90	75	90	75	mg
Vitamin D	10	10	15	15	15	15	15	15	15	15	µg
Iron	0.27	11	7	10	11	15	8	18	8	18	mg
Calcium	200	260	700	1000	1300	1300	1000	1000	1000	1000	mg
Potassium	0.4	0.7	3	3.8	4.7	4.7	4.7	4.7	4.7	4.7	mg
Calories			1400	1500	2000	2000	2000	2000	2000	2000	kcal

Note: Data retrieved from National Institutes of Health (2018)

Table 2.

Daily Recommended Intake for Household of 6.6

	HH Total	Dad	Mom	Daughter	Son	Daughter	Son	Daughter
Total Fat	474	78	78	78	78	58	58	47
Saturated Fat	128	20	20	20	20	18	18	12
Sodium	9300	1500	1500	1500	1500	1200	1200	900
Cholesterol	1980	300	300	300	300	300	300	180
Carbohydrates	1983	325	325	325	325	244	244	195
Fiber	193	38	25	26	38	25	25	16
Protein	266	56	46	46	52	19	19	28
Vitamin A	4420	900	700	700	900	400	400	420
Vitamin B12	13	2.4	2.4	2.4	2.4	1.2	1.2	1
Vitamin C	394	90	75	65	75	25	25	39
Vitamin D	99	15	15	15	15	15	15	9
Iron	81	8	18	15	11	10	10	9
Calcium	7380	1000	1000	1300	1300	1000	1000	780
Potassium	29	4.7	4.7	4.7	4.7	3.8	3.8	3
Calories	12200	2000	2000	2000	2000	1500	1500	1200

Table 3.

Nutrient values of food items

Food Item	Serving	Total Fat	Saturated Fat	Sodium	Cholesterol	Carbohydrates	Fiber	Protein	Vitamin A	Vitamin B12	Vitamin C	Vitamin D	Iron	Calcium	Potassium	Calories
2% milk	1 litre	20.000	13.000	410.000	80.000	51.000	0.000	33.000	1890.000	5.000	2.000	10.750	0.000	1170.000	1500.000	516.000
Apple	1 kg	2.000	0.000	10.000	0.000	138.000	24.000	3.000	54.000	0.000	46.000	0.000	1.000	60.000	1070.000	582.000
Banana	1 medium	0.400	0.100	1.200	0.000	27.000	3.100	1.300	75.500	0.000	10.300	0.000	0.300	5.900	422.000	116.800
Bean	1 kg	11.000	2.000	120.000	0.000	613.000	152.000	225.000	0.000	0.000	45.000	0.000	67.000	830.000	13590.000	3451.000
Bean Leaves	900 g	9.900		81.000	0.000	126.000	0.000	52.200	72810.000		405.000		36.000	2016.000		810.000
Cabbage	1 head	0.900	0.300	163.000	0.000	52.700	22.700	11.600	890.000	0.000	332.000	0.000	4.300	363.000	1544.000	265.300
Cassava Leaves	900 g	2.610		90.000	0.000	63.000	18.000	36.000	90450.000		1935.000		66.150	1935.000		419.490
Cassava root	1.6 kg	4.800	1.600	224.000	0.000	609.600	28.800	22.400	208.000	0.000	329.600	0.000	4.800	256.000	4336.000	2571.200
Chicken	1 whole bird (1.3 kg)	136.500	39.000	644.000	850.000	1.200	0.000	168.700	8332.000	10.200	23.900	0.000	12.100	101.000	1740.000	1908.100
Cucumber	1 kg	1.000	0.000	20.000	0.000	36.000	5.000	7.000	1050.000	0.000	28.000	0.000	3.000	160.000	1470.000	181.000
Eggs	1 egg	5.000	1.500	70.000	211.000	0.400	0.000	6.300	244.000	0.600	0.000	17.500	0.900	26.500	67.000	71.800
Fish	1 kg	139.000	33.000	900.000	700.000	0.000	0.000	186.000	1670.000	870.000	4.000	3600.000	16.000	120.000	3140.000	1995.000
Green Bell Pepper	1 small	0.200	0.100	3.600	0.000	5.500	2.000	1.000	440.000	0.000	95.700	0.000	0.400	11.900	208.000	27.800
Large Roll	1 roll	1.700	0.300	446.000	0.000	26.500	2.400	5.100	0.000	0.000	0.000	0.000	1.400	15.000	90.000	141.700
Lettuce Head	1 head	0.500	0.100	101.000	0.000	10.000	4.700	4.900	26655.000	0.000	64.800	0.000	3.100	130.000	698.000	64.100
Limes	1 kg	2.000	0.000	20.000	0.000	105.000	28.000	7.000	500.000	0.000	291.000	0.000	6.000	330.000	1020.000	466.000
Maize Flour	1 kg	39.000	5.000	50.000	0.000	768.000	73.000	69.000	0.000	0.000	0.000	0.000	24.000	70.000	3150.000	3699.000
Milo Drink	400 g	40.000	24.400	360.000	71.000	258.000	0.000	47.600	0.000	8.000	176.000	64.400	72.000	3320.000	0.000	1582.400
Oil (rapeseed)	1 litre	1000.000	74.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9000.000
Orange	1 large orange	0.200	0.000	0.000	0.000	21.600	4.400	1.700	414.000	0.000	97.900	0.000	0.200	73.600	333.000	95.000
Peanut Butter	400 g	199.600	32.400	1944.000	0.000	86.400	32.000	96.400	0.000	0.000	0.000	0.000	7.600	180.000	2980.000	2527.600
Peanuts	200 g	98.400	13.600	36.000	0.000	32.200	17.000	51.600	0.000	0.000	0.000	0.000	9.200	184.000	1410.000	1220.800
Pineapple	1 small	1.300	0.000	10.000	0.000	118.000	0.000	5.500	521.000	0.000	169.000	0.000	2.500	130.000	1252.000	505.700
Potatos	1 kg	1.000	0.000	600.000	0.000	184.000	22.000	20.000	20.000	0.000	197.000	0.000	8.000	120.000	4210.000	825.000
Pumpkin	1 kg	1.000	1.000	100.000	0.000	65.000	5.000	10.000	73850.000	0.000	90.000	0.000	8.000	210.000	3400.000	309.000
Rice	1 kg	27.000	5.000	40.000	0.000	762.000	34.000	75.000	0.000	0.000	0.000	0.000	18.000	330.000	2680.000	3591.000
Spaghetti	1 pack	6.000	1.200	24.000	0.000	298.800	12.800	52.000	0.000	0.000	0.000	0.000	5.200	84.000	892.000	1457.200
Sweet Potato	1 kg	1.000	0.000	550.000	0.000	201.000	30.000	16.000	141850.000	0.000	24.000	0.000	6.000	300.000	3370.000	877.000
Sweet potato leaves	900g	2.700	0.900	81.000	0.000	57.600	18.000	36.000	9252.000	0.000	99.000	0.000	9.000	333.000	4662.000	398.700
Tomato	1 kg	2.000	0.000	50.000	0.000	39.000	12.000	9.000	8330.000	0.000	127.000	0.000	3.000	100.000	2370.000	210.000
White Onion	1 kg	1.000	0.000	40.000	0.000	93.000	17.000	11.000	20.000	0.000	74.000	0.000	2.000	230.000	1460.000	425.000

Note: Data retrieved from nutritiondata.self.com

Table 4.

Price per serving of foods available in Nampula Mozambique, Summer 2018, US$

Food Item	Serving	USD/Serving	% of Homes Growing Good	Food Item	Serving	USD/Serving	% of Homes Growing Good
2% milk	1 litre	$ 1.56	0.0%	Maize Flour	1 kg	$ 0.41	15.0%
Apple	1 kg	$ 2.63	0.0%	Milo Drink	400 g	$ 4.93	0.0%
Banana	1 medium	$ 0.08	20.0%	Oil (rapeseed)	1 litre	$ 1.23	0.0%
Bean	1 kg	$ 0.41	41.7%	Orange	1 large orange	$ 0.07	15.0%
Bean Leaves	900 g	$ 0.07	86.7%	Peanut Butter	400 g	$ 2.78	0.0%
Cabbage	1 head	$ 0.58	0.0%	Peanuts	200 g	$ 2.63	66.7%
Cassava root	1.6 kg	$ 0.33	66.7%	Pineapple	1 small	$ 0.14	13.3%
Cassava Leaves	900 g	$ 0.07	93.3%	Potatos	1 kg	$ 0.82	0.0%
Chicken	1 whole bird (1.3 kg)	$ 3.70	31.7%	Pumpkin	1 kg	$ 3.93	0.0%
Cucumber	1 kg	$ 0.90	0.0%	Rice	1 kg	$ 0.66	20.0%
Eggs	1 egg	$ 0.16	8.3%	Spaghetti	1 pack	$ 1.07	0.0%
Fish	1 kg	$ 1.89	0.0%	Sweet Potato	1 kg	$ 3.60	48.3%
Green Bell Pepper	1 small	$ 0.08	0.0%	Sweet potato leaves	900g	$ 0.07	76.7%
Large Roll	1 roll	$ 0.08	0.0%	Tomato	1 kg	$ 1.31	30.0%
Lettuce Head	1 head	$ 2.78	0.0%	White Onion	1 kg	$ 1.97	0.0%
Limes	1 kg	$ 0.33	50.0%				

Note: Data retrieved from Hansen (2016)

Table 5.

Description and objective of each Model A, B, and C

Model A	**Model B**	**Model C**
Urban Consumer	Rural Consumer	Seasonal Urban Consumer
All food bought at the market	Food bought at the market and grown	All food bought at the market, no fruits
Minimize: Total fat, Saturated fat, Sodium, cholesterol, Carbohydrates	**Minimize**: Total fat, Saturated fat, Sodium, cholesterol, Carbohydrates	**Minimize**: Total fat, Saturated fat, Sodium, cholesterol, Carbohydrates
Maximize: Fiber, Protein, Vitamin A, Vitamin B12, Vitamin C, Vitamin D, Iron, Calcium, Potassium, Calories	**Maximize**: Fiber, Protein, Vitamin A, Vitamin B12, Vitamin C, Vitamin D, Iron, Calcium, Potassium, Calories	**Maximize**: Fiber, Protein, Vitamin A, Vitamin B12, Vitamin C, Vitamin D, Iron, Calcium, Potassium, Calories

Table 6.

Number of servings of each food in each model and final annual price

Food Item	Model A Serving	Model B Serving	Model C Serving	Food Item	Model A Serving	Model B Serving	Model C Serving
2% milk	0.64		1.35	Maize Flour			
Apple				Milo Drink			
Banana				Oil (rapeseed)	0.08		
Bean	0.34		0.94	Orange	19.34		
Bean Leaves				Peanut Butter			
Cabbage			0.26	Peanuts			
Cassava root				Pineapple			
Cassava Leaves		9.65		Potatos			
Chicken				Pumpkin			
Cucumber				Rice			
Eggs				Spaghetti			
Fish	0.1	0.1	0.1	Sweet Potato			
Green Bell Pepper				Sweet potato leaves			
Large Roll				Tomato			
Lettuce Head				White Onion			
Limes							

	Model A	Model B	Model C
Final Price/HH	$ 2,852.09	$70.30 ω,α, Ω	$ 2,913.91

ω=Feasible with GDP/Cap Income
Ω= Feasible with Gov. Minimum Wage
α=Feasible with NH Minimum Wage

Table 7.

Binding constraints of nutrients in Model A, B, and C

Nutrient	"Urban Consumer"	"Rural Consumer"	"Seasonal Urban Consumer"
Carbohydrates	Yes	No	Yes
Vitamin C	Yes	No	Yes
Vitamin D	Yes	Yes	Yes
Calcium	Yes	No	No
Calories	Yes	Yes	No
Iron	Yes	No	No

Items not listed are not binding in any models

Table 8.

Shadow Price of each item for models A, B, and C

Food Item	Model A	Model B	Model C	Food Item	Model A	Model B	Model C
2% milk	0%	99%	0%	Maize Flour	NF	88%	NF
Apple	NF	100%	NA	Milo Drink	14%	99%	13%
Banana	NF	98%	NA	Oil (rapeseed)	0%	92%	0%
Bean	0%	83%	0%	Orange	0%	98%	NA
Bean Leaves	NA	3%	NA	Peanut Butter	85%	99%	85%
Cabbage	27%	99%	0%	Peanuts	86%	98%	87%
Cassava root	NF	73%	NF	Pineapple	91%	95%	NA
Cassava Leaves	NA	0%	NA	Potatos	NF	99%	99%
Chicken	89%	99%	89%	Pumpkin	95%	100%	94%
Cucumber	81%	100%	80%	Rice	NF	92%	NF
Eggs	68%	93%	68%	Spaghetti	NF	98%	NF
Fish	0%	0%	0%	Sweet Potato	96%	99%	96%
Green Bell Pepper	89%	100%	32%	Sweet potato leaves	NA	73%	NA
Large Roll	NF	98%	NF	Tomato	93%	100%	89%
Lettuce Head	94%	100%	93%	White Onion	91%	100%	89%
Limes	7%	97%	NA				

NF= Good would need to be subsidized to enter model
NA= Not avaliable for model
0%= Good is already inculded in model

Table 9.

Feasibility (yes or no) of models A, B, and C for each income level and percent of annual income spent on food

No Supplementation

Income Group	Model A	Model B	Model C
GDP/Capita (#1)	No (669%)	Yes (17%)	No (684%)
Government Minimum Wage (#2)	No (367%)	Yes (9%)	No (375%)
NH Minimum Wage (#3)	No (319%)	Yes (8%)	No (325%)

Table 10.

Feasibility (yes or no) of models A, B, and C for each income level and percent of annual income spent on food after supplementation of Vitamin D

Vitamin D Supp.

Income Group	Model A	Model B	Model C
GDP/Capita (#1)	No (667%)	Yes (15%)	No (682%)
Government Minimum Wage (#2)	No (366%)	Yes (8%)	No (374%)
NH Minimum Wage (#3)	No (317%)	Yes (7%)	No (324%)

Table 11.

Feasibility (yes or no) of models A, B, and C for each income level and percent of annual income spent on food after supplementation of calcium

Calcium Supp.

Income Group	Model A	Model B	Model C
GDP/Capita (#1)	No (140%)	Yes (17%)	No (140%)
Government Minimum Wage (#2)	Yes (77%)	Yes (9%)	Yes (77%)
NH Minimum Wage (#3)	Yes (67%)	Yes (8%)	Yes (67%)

Table 12.

Feasibility (yes or no) of models A, B, and C for each income level and percent of annual income spent on food after supplementation of calcium, Vitamin D, and Vitamin C

Calcium, Vitamin D, Vitamin C Supp.

Income Group	Model A	Model B	Model C
GDP/Capita (#1)	No (134%)	Yes (15%)	No (134%)
Government Minimum Wage (#2)	Yes (73%)	Yes (8%)	Yes (73%)
NH Minimum Wage (#3)	Yes (64%)	Yes (7%)	Yes (64%)

Figure 1. Map of Mozambique Provinces (Mozambique)