Orange Fanta vs orange fruit:
A novel measure of nutrition knowledge and women's diet quality in Malawi

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Abstract

This paper introduces a novel survey instrument to identify distinct components of nutrition knowledge, and test for links between knowledge and dietary choices in Southern Malawi. Our first aim is to distinguish respondents' familiarity with recommended behaviors, such as when to start breastfeeding or introduce solid foods, from respondents' factual knowledge about mechanisms, such as whether biscuits or papaya and orange fruit or orange Fanta contribute more to future health. We find knowledge of nutrition behaviors to be strongly associated with more schooling, older age and being female, while knowledge of mechanisms is associated only with training and employment as a health professional. We then test whether this expanded definition of nutrition knowledge is associated with dietary intake when controlling for other factors, and find no significant links in these data. Results point to the need for knowledge surveys and public health behavior-change campaigns to address the kinds of information that might have the most influence on actual behavior, potentially including the mechanisms involved in food composition, food safety and disease transmission.

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Key Messages:

- Existing surveys and programs often target respondents' knowledge of recommended behaviors, with little attention to their factual knowledge of food composition, food safety or disease transmission mechanisms that lead to those recommendations.
- We pilot a novel survey instrument and find that knowledge of recommended behaviors is higher among wealthier respondents, but knowledge of nutrition mechanisms is higher only among those with formal training and employment as a health professional.
- As in previous studies, we find little or no association between surveyed knowledge and nutrition behavior, pointing to the need for both surveys and programs to measure and improve the most influential kinds of nutrition knowledge.

1. Introduction

Despite substantial recent improvements, the prevalence of under-five stunting in Malawi remains among the highest in the world. The most recent Demographic and Health Survey (DHS), conducted in 2015-2016, found a 37% prevalence rate for stunting among children under five, with some districts as high as 45% (National Statistical Office (NSO) [Malawi] and ICF, 2017). Stunted growth begins in utero and is heavily influenced by mothers' actions, so conditions for women of reproductive age are of critical importance for both her own nutrition outcomes as well as for the health, well-being, and potential economic and social contributions of future generations (Black et al., 2013; Özaltin, Hill, & Subramanian, 2010).

Nutrition behaviors and outcomes are affected by numerous factors. In this paper we focus on the role of nutrition knowledge, and the mechanisms through which information and knowledge affect maternal diets. Maternal knowledge and maternal diets are important for the mother herself, and also for infant and child health outcomes including birth weight, maternal and infant mortality, linear growth, and other long-term child outcomes such as obesity and non-communicable diseases in adulthood (Bhutta et al., 2008; Prentice et al., 2013; Victora et al., 2008). Several studies have demonstrated socioeconomic factors and women's empowerment to be associated with women's dietary diversity and nutrition outcomes (Amugsi, Lartey, Kimani-Murage, & Mberu, 2016; Kiboi, Kimiywe, & Chege, 2017; Malapit, Kadiyala, Quisumbing, Cunningham, & Tyagi, 2015; Snapp, Blackie, Gilbert, Bezner-Kerr, & Kanyama-Phiri, 2010). Across settings, significant predictors of women's dietary diversity consistently include wealth (assets, land); income (source, control over); household size; female headship; education; and age (Amugsi et al., 2016; Harris-Fry et al., 2015; Kiboi et al., 2017; Rashid, Smith, & Rahman, 2011; Savy et al., 2008; Shamim et al., 2016; Torheim et al., 2004).

Our concern is with nutrition knowledge and mothers' own dietary diversity, building on studies in developed countries that find mixed evidence on adults' nutrition knowledge and their food consumption (Glewwe, 1999; Khalesi, Sharma, Irwin, & Sun, 2016; Tabbakh & Freeland-Graves, 2016). Numerous studies link maternal nutrition knowledge and education to child feeding and children's nutrition outcomes (Abbi, Christian, Gujaral, & Gopaldas, 1988; Block, 2007; Boyle et al., 2006; Christiaensen & Alderman, 2004; Ruel, Habicht, Pinstrup-Andersen, & Gröhn, 1992; Vollmer, Bommer, Krishna, Harttgen, & Subramanian, 2017; Webb & Block, 2004). To the best of our knowledge there are no studies assessing the role of women's nutrition knowledge on her own dietary diversity or nutritional status in the developing world.

Our research aims to help explain maternal choices in terms of an expanded definition of nutrition knowledge, addressing the large literature on provision and measurement of nutrition information to change behavior, often combined with support for production activities related to livestock and home gardening (Bhutta et al., 2008; HLPE, 2016). Previous studies relating nutrition knowledge to nutrition behaviors, outcomes, or intermediate indicators in developing country populations focus on respondents' familiarity with core nutrition messaging central to most maternal and child health and nutrition interventions (Karmacharya, Cunningham, Choufani, & Kadiyala, 2017). The conceptual framework for what constitutes nutrition knowledge typically includes nutrition and hygiene behaviors stemming from the *Essential Nutrition Actions* (Ahmed, 2013; Angeles, Skiles, Weaver, Mussa, & Sheahan, 2015; Daelmans, Dewey, & Arimond, 2008; WHO, 2013). Such studies do not assess knowledge of the relationships between nutrients, toxins, and health outcomes relevant to undernutrition and food safety in developing countries (Debela, Demmler, Rischke, & Qaim, 2017). In developed countries, the conceptual framework of what constitutes nutrition knowledge follows seminal work by Wardle and Parmenter (Parmenter & Wardle, 1999; Wardle & Parmenter, 2000; Wardle, Parmenter, & Waller, 2000), which includes knowledge domains related to dietary recommendations, sources of nutrients, food choice, and diet-disease relationships (e.g. Williams, Campbell, Abbott, Crawford, & Ball, 2012). Though it includes nutrition literacy and knowledge of important relationships between food choices and health, this framework generally falls short of assessing knowledge of the underlying mechanisms that relate foods to health, which Dickson-Spillmann & Siegrist (2011)call "declarative knowledge". Additionally, this literature tends to focus on overnutrition whereas nutrition concerns in developing countries also include undernutrition of all forms, hygiene and care practices, and food safety (Barbosa, Vasconcelos, Correia, & Ferreira, 2016).

Our proposed framework expands knowledge beyond familiarity with critical behaviors to include respondents' understanding of underlying mechanisms: how foods contribute to daily energy and health (such as eyesight and resistance to disease); the relationship between germs, clean hands, and disease; and the primary food safety issue of public health concern in the region – aflatoxin contamination (Matumba et al., 2014; Matumba, Monjerezi, Chirwa, Lakudzala, & Mumba, 2009; Monyo et al., 2012; Smith et al., 2015). Our approach is closest to that of Debela et al (2017), who decompose types of maternal nutrition knowledge into food ingredients, dietary recommendations, and health consequences of not following recommended dietary practices, noting theirs is the first to examine different types of knowledge. To the best of our knowledge, no studies have examined such factual knowledge in the context of undernutrition, food choice in rapidly changing food environments, and issues of food safety in developing country populations. Particularly as processed foods become more readily available to and consumed by poor, rural households, nutrition outcomes will be influenced by the complex ways in which foods, nutrients and toxins affect health (Black et al., 2013; Ng et al., 2014; Prentice, 2006). As food environments change, consumers may need to more knowledge about functional relationships between food and health to guide their choices (Masters et al., 2015).

This study addresses the role of nutrition knowledge in the context of other factors affecting behavior, notably household wealth and home food production. A broad literature examines the contribution of livestock and home gardening to food consumption and diet quality; findings highlight complex relationships mediated by factors including women's empowerment and access to markets (Hirvonen, Hoddinott, Minten, & Stifel, 2017; Jones, Shrinivas, & Bezner-Kerr, 2014; Malapit et al., 2015). Regarding gardens, studies across multiple settings consistently find households with gardens more likely to consume fruits and vegetables, though these behaviors do not necessarily translate into nutrition outcomes (Herforth, 2010; Jones, 2016; Jones et al., 2014; Kumar, Harris, & Rawat, 2015; Malapit et al., 2015; Ruel & Alderman, 2013; Ruel, Quisumbing, & Balagamwala, 2018). Despite wide recognition of the potential for livestock keeping to contribute directly to nutrition through increased availability of animal-source foods (ASFs), literature testing this hypothesis remains sparse (see Azzarri, Zezza, Haile, & Cross, 2015). The few existing studies find some positive associations between livestock keeping and ASFs consumption, however the results appear to be very animal- and context-specific (Fiorella, Chen, Milner, & Fernald, 2016; Hetherington, Wiethoelter, Negin, & Mor, 2017; Hirvonen & Hoddinott, 2017; Hirvonen et al., 2017; Romeo, Meerman, Demeke, Scognamillo, & Asfaw, 2016).

2. Methods

2.1 Data & setting

Our data come from a survey of the beneficiaries and implementing partners of the United in Building and Advancing Life Expectations (UBALE) program, led by Catholic Relief Services (CRS) in three districts of Southern Malawi. UBALE consists of food transfers and biweekly visits by a community leader (henceforth "leader") to each beneficiary household (henceforth "household") to discuss a curriculum covering hygiene and sanitation, breastfeeding, complimentary feeding, and maternal nutrition. Eligible households had a pregnant woman and/or a child under two years old. A full questionnaire was collected from 54 leaders and 262 households in June-July 2017, employing a cross-sectional quantitative survey with a three-stage cluster sampling design which randomly selected care groups (groups of community leaders coordinated by a community volunteer), 2 leaders per group, and 5 households per leader. We sought primary caregivers, and most respondents were female. Dietary diversity was collected for all female respondents (303); 254 households and 49 leaders. The sample size was determined by budget and CRS goals, and the sample is representative of the household and leader population targeted by the Maternal and Child Health and Nutrition arm of the larger UBALE program.

Basic demographic information and nutrition knowledge were also collected from 44 additional program delivery actors including 26 health volunteers who coordinate community leaders locally and 18 health professionals who are field and office staff of the implementing organizations. These respondents were purposively selected as those responsible for the randomly selected leaders.

2.2 Measures of nutrition knowledge

Nutrition knowledge was measured by responses regarding knowledge of essential nutrition and hygiene actions (14 questions), food composition and contribution of foods to health (6 questions), and knowledge of the nutritional qualities and consequences of mold on grains such as aflatoxins (3 questions). Most included questions were based on the *Essential Nutrition Actions* and correct responses were coded in adherence with WHO recommendations (Daelmans et al 2008; WHO 2013), and also drew from Angeles et al (2015) and Ahmed (2013) due to its extensive nutrition and nutrition-related health information and knowledge questions. Food composition questions were developed by the authors and validated by the interviewers; respondents were presented with a photo of two foods and asked which was more likely to contribute to either their energy for work or future health, with a choice between the two foods, that they are the same, or "don't know". Aflatoxin questions were repeated from earlier research among the same population in 2016 (see Supplementary Materials for full instrument). The 23 questions were coded into 42 dichotomous variables (one variable for each response where respondents selected all that applied), 33 related to behaviors and 9 related to mechanisms, with a value of 1 for a correct answer and zero otherwise. Nutrition knowledge index scores are based on the percent of correct responses given.

Trakman et al (2017) suggest that a well-performing question for a nutrition knowledge questionnaire is one where 20-80% of all respondents answer correctly. We relaxed this recommendation for our analysis and include all questions answered correctly by 10-90% of respondents. Where used as an explanatory variable, we follow Debela et al (2017), normalizing the percent correct to the 95th percentile, such that each respondent is given a nutrition knowledge score ranging between 0 and 1, relative to the most knowledgeable respondents (the health professionals). To assess the sensitivity of results to the composition of nutrition knowledge questions, we separate indexes for behavior and mechanism knowledge questions. We also tested additional measures using all 42 variables, following the most common approach found in the literature (e.g. Barbosa, Vasconcelos, Correia, & Ferreira, 2016; Block, 2004; Debela et al., 2017; Karmacharya et al., 2017; Kigaru, Loechl, Moleah, & Ndungu, 2016; Mbuya, Menon, Habicht, Pelto, & Ruel, 2013), and also strict adherence to the Trakman (2017) criterion that 20-80% of respondents answer correctly, with no significant differences from the results shown.

2.3 Measures of dietary diversity

In resource poor settings, dietary diversity has been established as a feasible and reliable metric by which to assess the micronutrient adequacy aspect of diet quality (Martin-Prével et al., 2015). For children, established methods to measure dietary diversity and a validated dichotomous measure of minimum dietary diversity (associated with consumption of minimally acceptable levels of the key micronutrients of public health concern), Minimum Dietary Diversity (MDD), has been in use for nearly a decade (Martin-Prével et al., 2015; WHO, 2008, 2010). A similar measure has more recently been developed for women of reproductive age, Minimum Dietary Diversity – Women (MDD-W), which is compatible with the MDD for children (FAO & FHI 360, 2016; Martin-Prével et al., 2015).

We employed four measures of women's dietary diversity, stemming from the MDD-W (FAO and FHI360 2016; Martin-Préval et al. 2015). The module elicits yes/no responses to the question "*Yesterday during the day or night, did you eat or drink any*_____" followed by a list of 21 food item categories with common and culturally relevant example foods, but does not collect quantities consumed. The indicator has been demonstrated to reflect micronutrient adequacy across 11 micronutrients[1] (FAO and FHI360 2016; Martin-Préval et al. 2015). Following the prescribed methodology, the food items were combined into 10 food groups (starchy staples; pulses; nuts and seeds; dairy; meat, poultry and fish; eggs; dark

[1] The micronutrients are thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, vitamin A, vitamin C, calcium, iron and zinc. Criteria for the selection of micronutrients included known public health concern and data availability. Data considerations included availability of food composition tables and an estimated average requirement (EAR), for these reasons vitamin D and iodine were not included. While a set of agreed upon nutrients of concern exist for infants and young children (WHO and UNICEF 1998), no such list exists for women and the available information is scarce (Kennedy and Meyers 2005; Martin-Préval et al 2015).

green leafy vegetables; other vitamin-A rich fruits and vegetables; other vegetables; and other fruits) and a dietary diversity score was given as the total number of food groups consumed.

First, the dietary diversity score is an interval measure of the number of food groups consumed, ranging from zero to 10. Second, meeting minimum dietary diversity (MDD) adequacy is a dichotomous indicator defined as having consumed 5 or more food groups the previous day, the adequacy threshold validated as the minimum required to provide adequate micronutrient levels (Martin-Préval et al. 2015). Since only 21% of respondents reached adequacy, we also relaxed the threshold to 4 or more (greater than the median) and 3 or more (the median or greater). There is a large difference in the percentage of respondents consuming more than the median (38%), and those consuming the median or above (74%). Third and fourth we used any ASFs (flesh foods, eggs, dairy) and any MnD-FFVs (dark leafy greens, vitamin-A rich fruits and vegetables), both dichotomously defined as 1 if consumed, zero otherwise.

2.4 Statistical analysis

Our analysis involves two models; in the first we include all respondents to estimate the determinants of nutrition knowledge and the second is limited to female beneficiaries and community leaders to estimate associations between nutrition knowledge and the dietary diversity outcomes defined above. In both models we control for respondent's education, age, and district. For the first model, we also control for program role (beneficiary, leader, a health volunteer, or a health professional) and gender, relative to the baseline responses of a female respondent in a household enrolled in the program. In the second model, we do not include role or gender but do control for household wealth quintile, based on an asset index (Vyas & Kumaranayake, 2006). Education is years of schooling; age is measured in years. Squared terms of education and age are used to capture nonlinearities in the functional form. As robustness checks, we also tested education quartiles and quintiles. The subpopulation of female households and leaders weights the regression in accordance with the survey design. Since the other implementing actors were purposively selected and therefore have no survey weight, the analysis of the full sample does not account for survey design.

The dietary diversity analysis regresses each of the outcomes on wealth quintile, livestock ownership, garden ownership, respondent education, respondent age. The main specification uses all knowledge questions responded to correctly by 10-90% of respondents as the knowledge measure. Livestock is measured in tropical livestock units (TLUs), based on type and number of animals (Chilonda & Otte, 2006). Garden ownership is a dichotomous indicator of having a garden. The additional covariates (wealth, education, age) reflect determinants of women's dietary diversity supported by the literature and are defined as above (Kiboi et al., 2017; Snapp & Fisher, 2014; Torheim et al., 2004).

We treated the dietary diversity score both as count data using a Poisson regression model and then also relaxed the assumption of equivalent distance between food groups and linear functional form using an ordered logit model. The dichotomous outcomes were estimated with logistic regression and odds ratios are reported. As robustness checks, we also used the alternative measures of nutrition knowledge described above, education quartiles and quintiles, limited the sample to women of reproductive age (15-49), and trimmed livestock ownership to the 99th percentile to exclude extreme outliers. We found the results to be robust to the selection of knowledge measures, treatment of covariates, and sample. In all specifications, standard errors are heteroskedasticity-robust and clustered at the care group level.

3. Results

3.1 Responses to nutrition knowledge questions by professional role

Table 1 presents the nutrition knowledge questions and percent answering correctly, by role. Figure 1 shows the distribution of correct responses to behavior and mechanism knowledge separately. Responses to just one mechanism question underscores the rationale for our expanded conceptual framework. When asked which contributes more to their future health: an orange fruit or an orange Fanta, only 51% of respondents answered correctly, no better than random guessing. Notably, 32% chose Fanta and another 17% selected that they are the same. At the same time, most respondents answered correctly to most of the common questions reflecting familiarity with key nutrition behaviors. At each level of the program delivery chain (leaders, health volunteers, health professionals) we observed an increasing percentage of correct answers about the underlying mechanisms relating foods to health. This is to be expected given greater education, however the Pearson's correlation coefficient between education and correct responses to these questions is only 0.35, suggesting education does not fully explain this factual understanding. No group answers all questions correctly, which is consistent with the need for continuing education particularly on topics such as breastfeeding and handwashing.

[Table 1]

[Figure 1]

3.2 Sociodemographic determinants of each nutrition knowledge index

The regression results in Table 2 test for correlations between each index of nutrition knowledge and a variety of sociodemographic factors; columns 1 and 2 provide results for the respondents with dietary diversity data (weighted by survey design), while columns 3 and 4 include all respondents (unweighted). Most importantly, additional years of schooling is associated with a higher knowledge index for recommended behaviors, but not more knowledge of underlying nutritional mechanisms. A similar pattern is observed for age. Among female household respondents and leaders for whom wealth and dietary diversity data were collected, wealth is also associated with behavior knowledge, however the magnitude of this association is small in practical terms with each additional wealth quintile associated with less than 1 percentage point greater knowledge index score. For the full sample, female respondents and respondents who are health volunteers have greater knowledge of recommended nutrition behaviors. None of these are significantly associated with knowledge of nutrition mechanisms, however, as that index is significantly linked only with training and employment as a health professional in column (4).

[Table 2]

The most important result of Table 2 is the difference between the determinants of behavioral knowledge (columns 1 and 3) and the determinants of mechanistic knowledge (columns 2 or 4). Answers to factual questions about food composition, food safety and disease transmission are not significantly associated with wealth, years of schooling, age or other factors, but are associated only with being a health professional. Those individuals score 17 percentage points higher on the mechanism knowledge index than the next lower role category (health volunteers). In contrast, for health behaviors being a health volunteer is associated with 5 percentage points higher behavior knowledge score relative to the household members or group leaders. Our robustness checks found no evidence of heterogeneous effects by wealth or education and the results were robust to the measures of nutrition knowledge and education used.

Results in Table 2 reveal that mechanism knowledge is higher among health professionals, while behavior knowledge is higher among respondents with higher wealth, education and age, and also among health volunteers. Both types of knowledge could potentially lead respondents to consume healthier diets, which we test in Tables 3 and 4 below. Since all kinds of knowledge could potentially be linked to the quality of maternal decision-making, we use the broadest possible combined index over all knowledge questions. Each analysis controls for home production of both livestock and garden products, as well as age and education. The analysis begins with 5 dichotomous dietary diversity outcomes in Table 3, and then considers the number of food groups in Table 4.

3.3 Agricultural and knowledge determinants of maternal diet diversity

As shown in the main specifications of Table 3, household wealth is consistently associated with greater odds of consuming a more diverse diet. These results are robust to the presence of covariates, and the magnitude of the wealth effect is economically meaningful as each additional wealth quintile is associated with 1.4 times higher odds of meeting MDD adequacy. Having a garden is associated with 4 times higher odds of consuming any MnD-FFV, while at the same time it is associated with 0.4 times lower odds of meeting MDD adequacy. We also investigated the possibility of heterogeneous effects of nutrition knowledge by levels of the other covariates, available in supplementary materials. The results were similar across outcome measures, providing suggestive evidence that nutrition knowledge may be more strongly associated with dietary diversity for respondents who are wealthier, older and have a garden; we did not observe evidence of any heterogeneous effects for the associations with MDD adequacy or MnD-FFVs.

[Table 3]

3.4 Agricultural and knowledge determinants for number of food groups consumed

Table 4 presents the results of the determinants of dietary diversity scores, using both the Poisson and ordered logistic regression models. We again find wealth consistently positively associated with greater dietary diversity. The Poisson regression results in column (1) are interpreted as a percent likelihood such that each additional wealth quintile is associated with a 6.7% greater likelihood of consuming the next higher number of food groups, statistically significant at the 1% level. The ordered logit model presents similar results, a one unit increase in wealth quintile is associated with 1.4 times greater the odds of consuming an additional food group, statistically significant at the 1% level. As above, the wealth coefficients were found to be robust to the inclusion of additional covariates, suggesting it is the primary driver among those investigated.

[Table 4]

4. Discussion

This paper introduces a new, expanded definition of nutrition knowledge, adding functional questions about nutritional mechanisms to standard questions about nutrition behaviors, and use the resulting data to test whether maternal knowledge of any type is associated with higher maternal diet quality given the respondent's socioeconomic characteristics. We make a novel contribution in two regards: by expanding the conceptual framework of nutrition knowledge to include both familiarity with behaviors and factual understanding of the underlying mechanisms relating foods, toxins and behaviors to health and disease outcomes and by analyzing the associations between nutrition knowledge, home production, and women's dietary diversity. Though different sociodemographic factors are found to be associated with behavior versus mechanism knowledge, neither are found to be associated with any measures of dietary diversity. Consistent with prior literature, and to be expected, wealth is consistently found to be positively and significantly associated with dietary diversity and consumption of nutrient-dense foods. We find no association between owning livestock and dietary diversity or the likelihood of consuming animal-source foods (ASFs). We do find that owning a garden is positively associated with the likelihood of consuming any micronutrient-dense fresh fruits and vegetables (MnD-FFVs), but negatively associated with meeting minimum dietary diversity (MDD-W), underscoring a potential tradeoff for interventions. Finally, we observe that nutrition knowledge may be a more important determinant of dietary diversity for older women and women in households owning fewer livestock.

Our expanded nutrition knowledge survey starts with a set of 23 questions coded into 33 measures of recommended behaviors for maternity care and diets in pregnancy, infant feeding and child diets, and hygiene and sanitation, plus adds a set of 9 new measures of food composition, food safety, and disease transmission. The new mechanistic questions concern functional relationships that underlie recommended behaviors. Our five new questions about food composition ask respondents to compare equal-size portions of familiar foods, and state which offers more energy for work each day, or which contributes more to their future health. Our three new questions about food safety ask respondents, for instance, whether cooking eliminates the potentially harmful effects of mold on food, and our new question about disease transmission asks whether the purpose of using soap in handwashing is just to help oneself or also to help others.

To identify differences in how the two types of knowledge are formed, we compare their determinants and find that knowledge of nutrition behaviors is significantly associated with household wealth, education, age, and working as a health volunteer, but knowledge of nutrition mechanisms is significantly associated only with being trained and employed as a health professional. This suggests that knowledge of even the most basic nutrition mechanisms is not readily learned through primary and secondary education or public health campaigns, but is consistently available to health professionals. The consequences of lack of such knowledge could be acute, particularly as rural populations increasingly confront more complex food environments and face food safety risks that are imperceptible to human senses. For instance, public health messaging in Malawi emphasizes eating from all six food groups. A respondent could be familiar with this guidance, have a desire to follow it and adequate resources to do so, but if she does not understand the difference between orange Fanta and a real orange, she may well choose the soda while believing she has consumed a fruit. Similarly, aflatoxin is toxic to human health at levels well below what can be detected by the senses and therefore requires factual understanding of its consequences in order to deliberately avoid exposure (FAO, 2004).

Specific questions from our pilot study clearly illustrate how respondents' factual knowledge about nutrition mechanisms might affect their choices, independently of whether they report knowing various recommended behaviors. Our questions were designed to avoid any need for scientific terminology, by focusing entirely on the functional attributes of foods, cooking and soap. To measure respondents' understanding of what is in foods, we gave pairs of foods with markedly different composition in terms of dietary energy and essential micronutrients. For calorie content, for example, we asked "Comparing each of these two foods, which one do you think is likely to give you more energy for work each day: A glass of water, the same size glass of milk, are they the same, or you don't know?" Then for micronutrient content, we asked "Comparing each of these two foods, which one do you think is likely to contribute more to your future health: An orange fruit, an orange Fanta, are they the same, or you don't know?" In both of those cases, villagers' responses were indistinguishable from random guessing: about half got the correct answer, implying that people looking to gain dietary energy or become healthier would not know which to choose. In contrast, 100% of health professionals recognized that future health would benefit more from an orange fruit than an orange Fanta, and 83% of them recognized there would be more energy for work in a glass of milk than a glass of water.

The comparison of fruit versus Fanta provides a benchmark case in which villagers' knowledge was as good as guessing, while all health professionals understood the difference. Two other pairs of food offer polar opposite examples, with the same question about contribution to future health asked about similar-sized portions of biscuits versus papaya, and equal quantities of nsima (cooked maize meal) versus ndiwo (cooked green leafy vegetables). In the first comparison, most people understood that papaya contributes more to future health, with 86% of villagers giving the correct answer, while 100% of health professionals did so. For a starchy staple versus a green leafy vegetable, however, most villagers stated the opposite of the truth; only 36% chose the vegetables. Yet 94% of health professionals did so. Questions regarding food safety and disease transmission provide similar results. When asked “Can cooking a moldy food eliminate any health effects of the mold?” only 54% of villagers gave the correct answer (no), while 72% of health professionals did so. And when asked “What is the purpose of using soap when handwashing?” only 76% of villagers included “to help others by preventing transmission of disease”, while 100% of health professionals did so.

From these comparisons, it is clear that establishing a foundation of factual knowledge about food composition, food safety and sanitation is a different thing than building familiarity with recommended behaviors. Adding our 9 mechanism questions to the 33 behavior questions provides a broader measure of nutrition knowledge than has previously been available in the literature. Future work will be needed to refine and validate questions for use in a standardized version of this instrument, but to illustrate its applicability we use our expanded knowledge index to test whether more nutrition knowledge of any kind is associated with higher diet quality of female respondents. Previous studies that focus on maternal knowledge and child feeding practices, generally finding strong linkages between the two. When choosing foods for herself, however, mothers may face very different pressures than when feeding her child.

Like prior literature, we found wealth to be strongly positively associated with all dietary diversity outcomes measured, and conditional on that we found that nutrition knowledge had no additional explanatory power for women’s dietary diversity measured in a variety of ways (Gewa & Leslie, 2015; Harris-Fry et al., 2015; Jones, 2016; Jones et al., 2014). Consistent with prior studies, we observed that having a garden is associated with greater likelihood of consuming micronutrient-dense fruits and vegetables (MnD-FFVs), but we found that it is also negatively associated with meeting minimum diet diversity (MDD) levels presumably due to the absence of other foods. One explanation for this contrast could be that owning a garden is a symptom of omitted variables that lead households to rely more on their own production, which in turn is associated with lower dietary diversity than households that make more extensive use of markets. That finding presents a potential tradeoff for interventions between targeting the consumption of specific foods important for nutrition, in this case micronutrient-dense fruits and vegetables, and promoting an overall diet diverse enough to provide adequate minimum macro- and micronutrient quantities.

There are several important implications of our findings. First, the omission of factual knowledge of underlying mechanisms linking foods to health in common measures of nutrition knowledge may fail to explain observed behaviors, particularly in complex food and food safety environments. We find evidence that respondents demonstrating familiarity with nutrition behaviors commonly promoted by maternal and child health interventions do not similarly demonstrate an understanding of the mechanisms through which foods and toxins affect health and that the latter is held more by health professionals than households and community leaders. As poor rural populations confront increasingly complex food environments, behavioral messages are likely to be insufficient to equip individuals with the ability to make nutritious and safe food choices as it is impossible to anticipate each of the possible choice sets likely to be faced and tailor behavioral messages accordingly.

Second, our study highlights a potential tradeoff between increasing consumption of MnD-FFVs versus improving overall dietary diversity when those with a garden are more likely to consume MnD-FFVs and less likely to meet MDD adequacy. Gardens require an investment by the household in land, financial resources, and time and could potentially divert resources from other uses that might be more effective in achieving greater diet quality. A better understanding of the potential tradeoffs and opportunity costs for households in constructing and tending gardens would be important to take into consideration in cost-benefit analyses of alternative approaches to improving household nutrition. These forces are also likely mediated by market access, which the present study did not measure.

Third, there may be a disconnect between familiarity with pro-nutrition behaviors and women's own food consumption. As noted above, there is strong evidence that maternal nutrition knowledge and education impact children's dietary diversity. That we do not observe a similar pattern between nutrition knowledge and women's own dietary diversity is concerning given the importance of maternal health for child outcomes. With no other studies of nutrition knowledge and women's dietary diversity, we cannot compare our results to those found by others, yet if true, there are several plausible explanations for our findings. Our nutrition knowledge measure includes more behaviors specific to children relative to those specific to women, and this imbalance could drive our results. Relatedly, most nutrition interventions contain more child-specific messages, which could mediate the relationship between a woman's knowledge and her own dietary diversity in multiple ways. Women could fail to draw connections between the information presented for children and her own health, or, the emphasis towards children's nutrition could influence prioritizing children's diets over women's diets. The interventions themselves could cause such prioritization or could reinforce existing social norms that bias resources towards children and away from women in the household, or some combination thereof. Finally, the relationship is likely mediated by women's empowerment, which our study did not capture. Even where women have little bargaining power, they may be able to exercise more influence over children's health and diets than their own.

This study provides a first effort to quantify individuals' factual knowledge about nutrition mechanisms, in addition to their knowledge of recommended nutrition behaviors, and test for links between this expanded definition of nutrition knowledge and the respondent's own dietary intake. We find great disparities among respondents in both kinds of knowledge, and wide variation across questions in what people know. Future work will be needed to identify the most effective questions for a survey that would compare respondents to the most knowledgeable individuals in any given setting, test for linkages between knowledge and behavior, and be used to design and monitor interventions aimed at communicating knowledge for behavior change.

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Figure 1. Distribution of behavioral knowledge and mechanism knowledge, by professional role

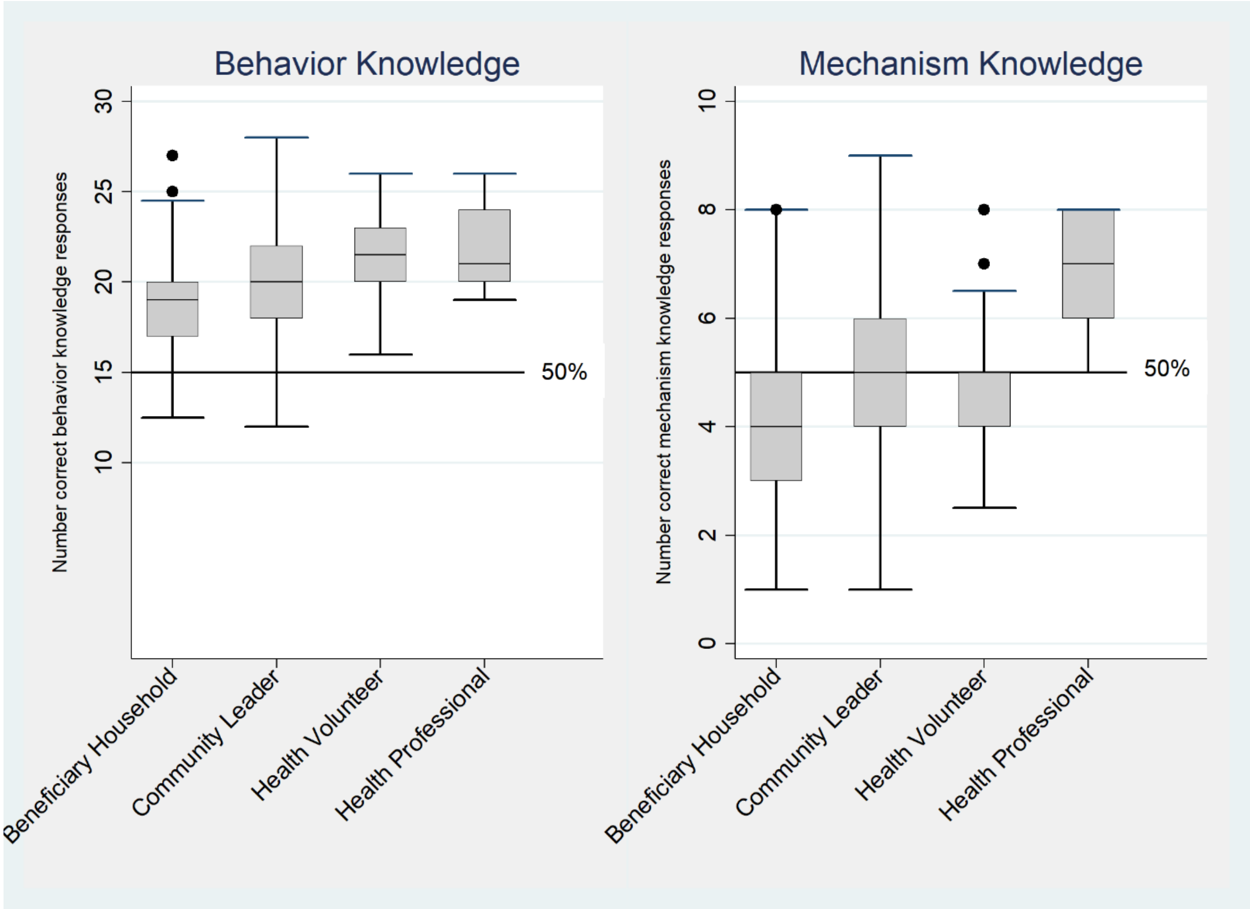

Table 1. Knowledge of recommended behaviors and underlying mechanisms, by knowledge domain

		Percent correct				
Topic	Correct response(s)	All (N=360)	House-holds (N=262)	Leaders (N=54)	Volunteers (N=26)	Profes-sionals (N=18)
Panel A: Nutrition Behaviors						
Infant and young child feeding						
Initiate breastfeeding	Immediately or less than 1 hour after delivery	91	89	94	100	100
Give colostrum	Yes	92	90	96	100	100
Breastfeeding frequency	Whenever the baby wants	9	10	7	8	6
	When you see the baby is hungry	7	7	4	12	6
	When the baby cries	6	8	2	0	0
	Frequently	85	84	96	85	56
	At least 8 times per day	1	1	0	0	0
Exclusive breastfeeding to	6 months	91	88	96	100	100
Introduction of liquids	6 months	82	82	85	88	67
Introduction of solid foods	6 months	66	63	72	81	67
Vitamin A supplementation	Twice per year	30	27	31	31	72
For child with diarrhea:		8	5	6	12	50
Give solid food	Yes	1	1	0	4	11
Amount	Same as usual	77	74	81	85	89
Give breastmilk	Yes	77	74	81	85	89
Amount	More than usual	78	75	83	85	94
Give other liquids	Yes	58	52	72	73	83
Amount	More than usual	99	99	100	100	100
Give ORS	Yes	72	66	80	100	94
Give zinc	Yes	97	97	100	96	100
See health prof.	Yes	91	89	94	100	100
Hygiene & Sanitation						
Occasions to wash hands	When they look dirty*	51	42	65	85	89
	Before preparing food	31	31	31	27	39
	Before breastfeeding	45	40	46	77	72
	Before eating	96	94	100	100	100
	After using the toilet	67	63	70	81	94
	After changing a diaper	10	10	7	8	11
	After working in the fields or caring for livestock	13	11	20	4	17
Purpose of using soap in handwashing*	To help me by removing dirt and improving appearance	76	73	74	96	100
Actions to make drinking water safe†	Boiling for at least 1 minute	78	78	81	77	56
	Adding purification tablets/drops	96	95	96	96	100
During pregnancy						
Visits to antenatal clinic	4-9	88	89	83%	92	67
Food consumption	Eat more food	78	74	85	92	78
Harmful foods	None	47	40	52	73	89
Vitamin supplement	Yes	82	80	83	81	100

Table 1 (continued)

Topic	Correct response(s)	Percent correct All (N=360)	House-holds (N=262)	Leaders (N=54)	Volunteers (N=26)	Profes-sionals (N=18)
Panel B: Underlying Mechanisms						
Hygiene and sanitation (germ theory of disease)						
Purpose of using soap in handwashing*	To help others by preventing transmission of disease	76	73	74	96	100
Food composition (function of nutrients)						
More energy for work:						
Onion or tomato?	Onion	2	3	0	0	0
Water or milk?	Milk	45	43	46	38	83
Contribution to future health:‡						
Orange fruit or a Fanta?	Orange	51	45	52	69	100
Nsima (maize meal) or Ndiwo (greens)?	Ndiwo	36	33	39	23	94
Biscuits or papaya?	Papaya	86	85	87	81	100
Food Safety (control of contaminants)						
Cooking eliminates mold	No	54	53	56	46	72
Animals affected by mold on feed grain	Yes	48	42	59	65	67
Animal source foods affected by mold on animal feed	Yes	41	37	44	54	61

Note: Questions listed are in order asked within each domain.

† A separate variable was coded for each correct response.

* Post-coding generated a variable for at least one of the following: "When they look dirty" as an occasion to wash with soap, "To improve appearance" or "Both" as the reason for handwashing. A second variable was coded for a correct selection of "To prevent transmission of disease" or "Both" as the reason for handwashing.

** “Other responses” were post-coded and any response between 4 and 9 times were coded as correct.

‡ Response options included each food, “they are the same”, and “don’t know”.

Table 2. Determinants of behavioral knowledge and mechanism knowledge, by professional role

	Female Households & Leaders		**All Roles & Genders**	
	Behavior Knowledge (1)	Mechanism Knowledge (2)	Behavior Knowledge (3)	Mechanism Knowledge (4)
Wealth quintile	**0.00945*****	0.0163		
	(0.00313)	(0.0101)		
Female			**0.0548*****	0.00433
			(0.0187)	(0.0308)
Education (years)	**0.0171*****	0.0104	**0.00855***	0.00696
	(0.00592)	(0.00767)	(0.00443)	(0.00861)
Education (years) squared	**-0.000918***	-0.000138	-0.000120	0.000297
	(0.000535)	(0.000619)	(0.000398)	(0.000716)
Age	**0.0127*****	0.00195	**0.00785*****	0.00651
	(0.00453)	(0.00791)	(0.00262)	(0.00572)
Age^2	**-0.000160****	-3.24e-05	**-9.15e-05*****	-9.16e-05
	(6.17e-05)	(0.000124)	(3.40e-05)	(8.53e-05)
Leader	-0.00448	-0.0164	0.00769	-0.0175
	(0.0181)	(0.0301)	(0.0195)	(0.0264)
Health volunteer			**0.0517****	-0.0128
			(0.0225)	(0.0429)
Health professional			0.0561	**0.167*****
			(0.0373)	(0.0624)
Chikwawa district	-0.00191	-0.0340	0.0133	-0.0232
	(0.0281)	(0.0359)	(0.0167)	(0.0280)
Nsanje district	-0.0112	-0.0249	-0.00172	-0.0454
	(0.0319)	(0.0327)	(0.0178)	(0.0289)
Constant	0.272***	0.362**	0.319***	0.334***
	(0.0882)	(0.131)	(0.0575)	(0.107)
Observations	248	248	359	359
R-squared	0.157	0.070	0.201	0.171

Notes: Dependent variables are knowledge indexes, defined as percent answered correctly out of 33 questions about recommended behaviors (such as when to start breastfeeding, and when to start feeding solid foods), and 9 questions about functional mechanisms (such as which foods have more healthful nutrients, whether cooking makes food safer, and whether soap affects disease transmission). Wealth is quintiles of an asset index. Education is years of schooling. Age measured in years. The omitted category is respondents with 0-3 years of education residing in Blantyre Rural District. Columns 3 & 4 are unweighted. Heteroskedasticity robust standard errors (clustered at the care group level for columns 1 and 2) are shown in parentheses, with significance levels denoted *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Determinants of binary dietary diversity outcomes (odds ratios)

	Number of Food Groups				
	5 or more (1)	4 or more (2)	3 or more (3)	Any ASFs (4)	Any MnD-FFVs (5)
Wealth quintile	**1.432*** **	**1.341** **	**1.446*** **	**1.285** **	**1.267* **
	(0.169)	(0.154)	(0.186)	(0.120)	(0.149)
Knowledge (all)	1.395	2.667	2.338	0.494	0.562
	(1.336)	(3.372)	(3.274)	(0.635)	(0.688)
Livestock	0.929	0.959	1.000	1.211	0.943
	(0.151)	(0.109)	(0.122)	(0.177)	(0.0708)
Garden	**0.414*** **	0.720	1.362	0.896	**4.019*** **
	(0.119)	(0.251)	(0.420)	(0.325)	(1.535)
Education (yrs)	1.071	1.040	0.968	1.002	**1.118** **
	(0.0608)	(0.0418)	(0.0482)	(0.0475)	(0.0510)
Age	1.014	0.997	**0.945*** **	0.983	0.987
	(0.0280)	(0.0236)	(0.0135)	(0.0220)	(0.0230)
District fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	248	248	248	248	248
F-test	3.553	2.232	3.433	3.334	4.780
Prob > F	0.0102	0.0695	0.0120	0.0137	0.00213

Notes: Nutrition knowledge index defined as percent answered correctly (out of all questions, behaviors and mechanisms combined) of the questions that were answered correctly by 10-90% of respondents, normalized to the 95th percentile. Wealth is quintiles of an asset-based index. Livestock measured in TLUs. Education is years of schooling. Age measured in years. Constant terms not shown. Heteroskedasticity robust standard errors clustered at the care group level shown in parentheses, with significance levels denoted *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Determinants of number of food groups consumed

	Poisson (Beta coefficient)			Ordered Logit (Odds Ratio)		
	(1)	(2)	(3)	(4)	(5)	(6)
Wealth Quintile	0.0687***	0.0683***	0.0705***	1.409***	1.412***	1.423***
	(0.0213)	(0.0203)	(0.0216)	(0.158)	(0.151)	(0.163)
Knowledge (all)	0.0630			1.608		
	(0.193)			(1.639)		
Knowledge (behavior)		0.0848			1.532	
		(0.178)			(1.488)	
Knowledge (mechanisms)			-0.0451			1.007
			(0.140)			(0.759)
Livestock	-0.00915	-0.00919	-0.00917	0.951	0.950	0.950
	(0.0224)	(0.0225)	(0.0225)	(0.0935)	(0.0932)	(0.0951)
Garden	-0.0685	-0.0666	-0.0674	0.873	0.882	0.871
	(0.0498)	(0.0508)	(0.0508)	(0.218)	(0.230)	(0.233)
Education (years)	0.00804	0.00788	0.00916	1.043	1.044	1.048
	(0.00661)	(0.00659)	(0.00642)	(0.0335)	(0.0337)	(0.0324)
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	248	248	248	248	248	248
F-test	3.22	3.31	2.98	2.29	2.22	2.18
Prob > F	0.0175	0.0156	0.0247	0.0669	0.0747	0.0790

Notes: Nutrition knowledge index defined as percent answered correctly (out of all questions, behavior questions or mechanisms questions only) of the questions that were answered correctly by 10-90% of respondents, normalized to the 95th percentile. Wealth is quintiles of an asset-based index. Livestock measured in TLUs. Education is years of schooling. Age measured in years. Constant terms not shown. Heteroskedasticity robust standard errors clustered at the care group level shown in parentheses, with significance levels denoted *** p<0.01, ** p<0.05, * p<0.1.

Annex of Supplemental Information: Survey Instrument for Nutrition Knowledge

1) How long after birth should a baby start breastfeeding?
   1 = Immediately
   2 = Less than 1 hour after delivery
   3 = Some hours later but less than 24 hours
   4 = 1 day later
   5 = More than 1 day later
   6 = Don't think the baby should be breastfed
   99 = Don't know

2) Should the mother give the baby first milk or "colostrum"? (yes, no, don't know)

3) How often should a baby breastfeed?
   1 = Whenever the baby wants
   2 = When you see the baby is hungry
   3 = When the baby cries
   4 = Other
   99 = Don't know

4) Until what age should a child be expected to breastfeed exclusively? (age in months)

5) At what age should a baby first start to receive liquids other than breastmilk, including water?
   (age in months)

6) At what age should a baby start to receive foods in addition to breast milk? (age in months)

7) How often should a child older than 6 months be taken for vitamin A supplementation?
   99 = Don't know
   1 = Every 6 months / 2 times per year
   2 = One time per year
   3 = One time only
   4 = Other (specify)

8) When is it important to wash your hands with soap and water? [Select all that apply]
   A When they look dirty
   B Before preparing food for children
   C Before preparing food for adults
   D Before breastfeeding
   E Before eating
   F After using the toilet
   G After working in the fields
   H After caring for livestock

9) What is the purpose of using soap when handwashing?
   1 = To help me by removing dirt and improving appearance
   2 = To help others by preventing transmission of disease
   3 = Both of these
   99 = Don't know

10) Which of the following actions make water safe to drink? (Select all that apply)
   1 = Straining through cloth
   2 = Boiling for at least 1 minute
   3 = Adding purification tablets/drops
   4 = Do nothing, all water is safe to drink

11) When a child has diarrhea should you [list item]? [Select all that apply]

A Give any solid food
If so, how much?
1 = Less than usual
2 = Same as usual
3 = More than usual
99 = Don't know

B Give any breastmilk
If so, how much?

C Give any other liquids
If so, how much?

D Give oral rehydration solution (ORS)

E Give zinc

F See health professional

G Do something else?

12) How many times should a pregnant woman go for an antenatal visit at the health clinic during her pregnancy? (Total number of visits)?
1= Never
2= Once
3 = 3 times during pregnancy
4= Four or more times during each pregnancy
5= Every month
98= Other

13) How much food should a woman eat when pregnant compared to when not pregnant to provide good nutrition to herself and her baby?
99 = Don't know
1 = Eat more food
2 = Eat the same amount of food
3 = Eat less food
4 = Other (specify)

14) Are any of these foods likely to harm babies when consumed by the mother, so should be avoided (not eaten) by pregnant women? [Select all that apply]

A Meat
B Milk
C Eggs
D Sugarcane
E Other (specify):

15) Do pregnant women require a vitamin supplement? (yes, no, don't know)

16) Comparing these two foods, which one do you think is likely to give you more energy for work each day?

A. An onion or a tomato?
99 = Don't know
0 = Onion
1 = Tomato
2 = About the same

B. A cup of water or a cup of milk?
99 = Don't know
0 = Water
1 = Milk
2 = About the same

17) Comparing these two foods, which one do you think is likely to contribute more to your future health, such as your eyesight and resistance to disease?

A. An orange fruit or Orange Fanta?

99 = Don’t know
0 = Orange
1 = Fanta
2 = About the same

B. A spoonful of nsima (maize) or of the ndiwo (green leafy vegetables, beans, egg or other relish) served with it?

99 = Don’t know
0 = The nsima (maize)
1 = The ndiwo (relish)
2 = About the same

C. A packet of biscuits or a bowl of papaya?

99 = Don’t know
0 = Biscuits
1 = Papaya
2 = About the same

18) Can cooking a moldy food eliminate any health effects of the mold? (yes, no, don’t know)

19) If animals are fed moldy food, do they experience any effects from the mold? (yes, no, don’t know)

20) If people eat eggs, milk, or meat from animals who have been fed moldy feed, do they experience any effects from the mold? (yes, no, don’t know)