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ABSTRACT

Communities in Tanzania have an extensive history of using wild plants for nutritional and medicinal purposes. The high prevalence of food insecurity and infectious disease, combined with a lack of access to healthcare in rural areas, makes traditional plant sources of food and medical treatment a practical alternative for vulnerable households. In this study, the association between household consumption of wild edible plants and self-reported diarrhea across categories of household food security status was examined. Focus group discussions in four villages in Kilosa, Tanzania, were used to elicit coping strategies, including consumption of wild edible plants, employed during periods of food shortage. Data on household dietary diversity, food security, demographics, self-reported health, as well as socioeconomic status were collected using a structured survey administered to heads of households. The association between self-reported diarrhea and consumption of wild edible plants across categories of household food security status were determined using bivariate and multi-variate statistical methods. Our results indicate that among the moderately food insecure, the odds of a household member having diarrhea was lower in consumers as compared to non-consumers of wild edible plants (OR 0.30 [0.12, 0.75], $p < 0.05$). Consumption of wild edible plants appears to be a potential mediator of diarrheal diseases in food insecure populations, especially among the moderately food insecure. Further research on the contribution of wild edible plants to alleviation of food insecurity and related health outcomes in developing countries is needed.

INTRODUCTION

Diarrhea is one of the ten leading contributors to the global burden of disease (Lopez et al., 2006). In Sub Saharan Africa, more than 17 percent of children less than five years of age die from diarrheal diseases annually (UNICEF-WHO, 2009). Mortality from this health condition disproportionately targets individuals in low- and middle-income countries (Lopez et al., 2006), where food insecurity is highly prevalent (FAO, 2011). By definition, food security is attained when 'all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (FAO, 2001).

Household food insecurity has been associated with diarrhea (Pérez-Escamilla et al., 2009) and other diseases (Pérez-Escamilla et al., 2009; Weigel et al., 2007). The synergistic relationship between food insecurity and poor health is apparent when diets lacking appropriate nutrients reduce the body's ability to resist disease, thus increasing susceptibility to pathogens in contaminated water or food that adversely impact health (Lönnerdal, 2000; Scrimshaw and SanGiovanni, 1997). Wild edible plants, many of which have nutritional (Weinberger and Msuya, 2004; Burlingame, et al., 2009) and medicinal benefits (Irungu et al., 2007; Johns and Chapman, 1995), are frequently underutilized as local solutions to food insecurity and associated health concerns (Flyman and Afolayan, 2006; Kaschula, 2008; Herforth, 2010). Consumption of wild edible plants has the potential to improve the health status of food insecure

populations in developing countries (Flyman and Afolayan, 2006; McGarry and Shackleton, 2009).

Reliance on wild plants in Sub Saharan Africa is based on historical knowledge of the plants, as well as their accessibility, availability, and benefits, during times of inadequate access to nutritious food, health care, and/or conventional medicine (Muthaura et al., 2007; Kitula, 2007). Wild plants provide traditional and culturally-acceptable options for addressing health needs particularly in areas where infectious diseases are highly prevalent and conventional healthcare is elusive (Johns and Chapman, 1995; Kassam et al., 2010). Many wild edible plants have antioxidant and antimicrobial properties (Johns and Chapman, 1995), are perceived to have health benefits (Herforth, 2010; Kassam et al., 2010), and play an important role in supplementing diets in developing countries (Herforth, 2010; Shackleton and Shackleton, 2004), especially during periods of food shortage (Maxwell and Caldwell, 2008; Paumgarten, 2005; McGarry and Shackleton, 2009). Consumption of wild edible plants in Sub Saharan Africa commonly extends beyond periods of food shortage, and contributes to daily diets in many rural communities even when food is abundant (Shackleton and Shackleton, 2004).

Several studies have documented the botanical, nutritional, and/or ethno-medicinal information of wild plants in Tanzania (Weinberger and Msuya, 2004; Herforth, 2010; Kitula, 2007) and other developing countries (Kassam et al., 2010; Muthaura et al., 2007). No studies, however, appear to have investigated the associations between food security status, health outcomes, and consumption of wild edible plants. The purpose of this study was to examine and describe community utilization of wild edible plants during periods of food shortage, and to examine the association between consumption of wild, edible plant material and self-reports of diarrhea across categories of household food security status.

METHODS

This study was conducted under the auspices of UNICEF/Tanzania and approved by Tufts University Institutional Review Board and the Commission for Science and Technology (COSTECH) of the United Republic of Tanzania.

Qualitative data. Focus groups were conducted with 6 to 12 adults in each of four geographically diverse villages in Kilosa District, Tanzania, during the dry season, a period of peak food insecurity. The villages of Rudewa-Gongoni and Madoto were located along main roads, Malangali was surrounded by water during the rainy season, and Tindiga had both sedentary and pastoral populations. Such focus groups have proved a useful means of gaining community perspectives on food security and for survey item development (Maxwell and Caldwell, 2008).

The study employed the Coping Strategies methodology (Maxwell and Caldwell, 2008), using focus group discussions (FGDs) to establish a locally relevant set of coping strategies employed during times of food scarcity and ranked these strategies in terms of perceived severity. After obtaining informed consent of the participants, the focus group discussions (FGD) were conducted in Swahili. Each FGD took between 1.5-2 h to complete and detailed notes were translated into English. FGD participants identified, rated, and ranked strategies they employed to mitigate household food insecurity. The FGD data was used to develop survey items for the food security module.

Quantitative data. The sample of households for survey research was derived from 28 rural villages in Kilosa District of Tanzania using cluster sampling, a standard probability-proportional-to-size (PPS). The four FGD sites were included in the survey sample. Given the original intent of this study, a random selection of adolescents and their respective households were surveyed in each village for a total of 735 households. The survey team included an ethnically and gender diverse group of 14 trained field staff from Kilosa District. Swahili was the primary language used to interview respondents. Self-identified heads of households provided data on demographics, income and assets, food frequency, food security, and health status of individual household members. Individuals primarily responsible for food preparation completed a single 24 h dietary recall on the household's food intake.

Measures. Household Dietary Diversity Score (HDDS), the number of different food groups represented in the diet, is often recommended as a proxy indicator of food security status (Hoddinott and Yohannes, 2002; Swindale and Bilinsky, 2005). Greater diversity in food consumption addresses the issue of diet variety in both macro- and micronutrients, while caloric intake reflects the quantity of food consumed. Using the methodology of Swindale and Bilinsky (2005), household dietary recall data was coded according to a set of 12 food groups and a household dietary diversity score was calculated. The obtained range of food groups in this sample was 1-8. Household food security status was classified by terciles of HDDS (Swindale and Bilinsky, 2006). Households consuming three or fewer food groups were classified as highly food insecure, those consuming four food groups were classified as moderately food insecure and households consuming five or more food groups were categorized as food secure.

Wild edible plants. By combining a literature review of wild edible plants in Tanzania and the identification of wild plants by the local population, all wild edible plants reported by this sample were documented (Table 1). Dietary data was aggregated for each household.

Diarrhea was defined as three or more watery stools in a 24 h period (UNICEF-WHO, 2009). A household was classified as having diarrhea if the respondent reported that at least one household member "had persistent diarrhea now or two or more episodes of acute diarrhea in the past three months."

Statistical analysis. Survey data was analyzed using SPSS version 19.0 with $p<0.05$ denoting statistical significance. Means ± SD and median values were calculated for the household dietary diversity score. Student independent sample t-tests were used to determine the mean differences in household dietary diversity between household consumers and non-consumers of wild edible plants, and across households that reported and did not report diarrhea among members. Pearson's chi Square tests were used to determine the statistical significance of associations between categorical variables for HDDS, wild edible plant consumption, and diarrhea. Main effect logistic regression models examined the linear association between diarrhea (dependent variable) and household consumption of wild edible plants (independent variable) for each category of household food security status. Results of the models are expressed as odds ratios (OR).

Table 1. Nutritional and medicinal uses of a selection of wild plants consumed during food shortage in Kilosa District, Tanzania.

Botanical name	Common name	Vernacular name	Nutritional properties	Nutritional and medicinal uses
Amaranthus spp.	Wild amaranth, Spinach	Mchicha pouri	Protein 4 g, Vitamin C 34 mg/100 g Fe 7.7 mg/100 g, Ca 360 mg/100 g β-Carotene 1700 mg/100 g	Anemia, high blood pressure, diabetes, severe malnutrition, night blindness, headaches, and dizziness.
Musa spp.	Banana (various)	Ndizi, types: Nguruwe, Moshi, & Kicementi)	High in K, Rich source of vitamins	Stomachaches, high blood pressure, digestion, malaria.
Solanum nigrum, S. scabrum, S. americium, S. villosum	African night-shade	Mnavu	Fe 13 mg/100 g K 42.89 mg/100 g	Diarrhea, anemia, high blood pressure, diabetes, sight problems, peptic ulcers, stomachaches, and skin infections
Launaea cornuta	Bitter lettuce	Mchunga/Sunga	Fe 44.6 mg/100 g Zn 0.262 mg/100 g β-Carotene 2.69 mg/100 g	Malaria, measles, hookworms, diabetes, hernia, stomachaches, high blood pressure, temperature regulation, and infections.
Annona senegalensis	Wild soursop	Mtope, Mchekwa	Mg 42.2 mg/100 g, Ca 28.9 mg/100 g	Diarrhea, stomach pain, and abscesses.
Ceiba pentandra	Capoc seed	Masufi, Msufi	Crude protein:282 g/kg Ca 3.3 mg/100 g, P 9.3 mg/100 g Palmitic acid	Powdered fruit with water to treat intestinal parasites & stomachaches. Oil used in culinary dishes, but not advised for health reasons.
Cleome hirta	Bulrush millet	Muhilile/Mhilile	Fe 17.5 mg/100 g, Zn 0.315 mg/100 g β-Carotene 0.95 mg/100 g	Painful menstruation, chest pain, and diarrhea.
Cleome glynandra	Spider flower plant	Mgange	Fe 49.95 mg/100 g Zn 0.407 mg/100 g β-Carotene 2.10 mg/100 g	Headaches, fever, ear problems, common cold, blood pressure, diabetes, anemia, night blindness, toothaches, and stomachaches.
Corchonus tritocularis, C. tridens, C. olitorius.	Wild mlenda, Jute mallow	Mlenda	Fe 4.05 mg/100 g, Zn 0.385 mg/100 g β-Carotene 1.91 mg/100 g Rich source of K, Cu, & Mn.	Cough, eye diseases, and upset stomach.

Sources: Hedberg et al., 1981; Eromosele et al.,1991; Lyimo et al, 2003; Weingerger and Msuya, 2004; Akubugwo et al., 2007; and Herforth, 2010.

In the village of Malangali, FGD participants reported consuming wild plants throughout the year, even when households had sufficient food to eat. In contrast, consumption of wild plants was listed as a coping strategy only during moderate and very severe periods of food insecurity in the other three villages, Rudewa-Gongoni, Tindiga, and Madoto. FGD participants in all villages stated that consumption of the least preferred wild plants was more frequent during periods of severe or very severe food shortage. The median number of food groups consumed by households was four (Table 2).

Table 2. Mean, SD, and median values of household dietary diversity.

Analysis	N	Mean ± SD	Median
Household Dietary Diversity Score (HDDS)	735	4.28 ± 1.4	4

The household prevalence for wild plant consumption was 41%. Pearson's Chi Squared tests indicated no statistically significant differences in the socio-demographic characteristics of household consumers and non-consumers of wild edible plants. Approximately one-fifth (19%) of households reported episodes of diarrhea among one or more household members.

Independent t-tests on samples were done to compare HDDS across households that either reported or did not report consumption of wild edible plants and diarrhea among household members. A statistically significant mean difference in the household dietary diversity scores for consumers and non-consumers, 4.13±1.18 and 4.38±1.52, respectively, of wild edible plants (t_{733} = 2.44, p<0.05) was observed. Similarly, households that reported diarrhea had significantly lower HDDS (4.06±1.27) as compared with those that did not report diarrhea among household members (4.33±1.42) (t_{731} = 2.02, p<0.05). These results suggest that both household consumption of wild edible plants and household prevalence of diarrhea decrease as the number of food groups consumed by households increases.

Pearson's chi square tests were statistically significant for the associations between HDDS and consumption of wild edible plants (p<0.05). No significant difference in the prevalence of diarrhea among household members by consumption of wild edible plants was observed. HDDS was associated with household prevalence of diarrhea at the p=0.16 level of significance, with moderately food insecure households reporting the lowest prevalence rate.

Further analyses found a statistically significant association between wild edible plant consumption and diarrhea, after controlling for household dietary diversity (Figure 1). The association was observed only among moderately food insecure households, where Pearson chi square tests indicated that household consumers of wild edible plants were more likely than non-consumers to report a lower household prevalence of diarrheal diseases (χ^2 =7.15, n=733, p< 0.01). No association between wild edible plant consumption and diarrhea among highly food insecure or food secure households was observed (Figure 1).

Separate logistic regression bivariate models were run for each category of food security status (i.e. highly food insecure, moderately food insecure, and food secure) to test whether households that consumed wild edible plants had a significantly higher odds of having at least one household member with diarrhea. Results confirm observations from earlier Pearson's chi square tests (Figure 1). The odds of a household reporting at least one household member with diarrhea was significantly associated with consumption of wild edible plants among moderately food insecure households, but not among highly food insecure and food secure households. Among moderately food insecure households, the odds of diarrhea reported at the household level were 70% lower for household consumers of wild edible plants than for non-consumers (OR 0.30 [0.12, 0.75], p <0.05) (Table 3).

Table 3. Binary logistic regression models for the odds of diarrhea at the household-level.

Household consumption of wild edible plants[1]	Household Dietary Diversity (HDDS)		
	Model 1	Model 2	Model 3
	Highly Food Insecure	Moderately Food Insecure	Food secure
	(n=258)	(n=178)	(n=297)
	1.31 (0.73-2.34)	0.30 (0.12-0.75)[a]	1.07 (0.57-2.02)
Pseudo r^2	0.0047	0.0697	0.0003
P	0.37	0.01	0.83

[1]Statistical significance assessed by p <0.05

Figure 1. Wild edible plant consumption and prevalence of diarrhea in household.
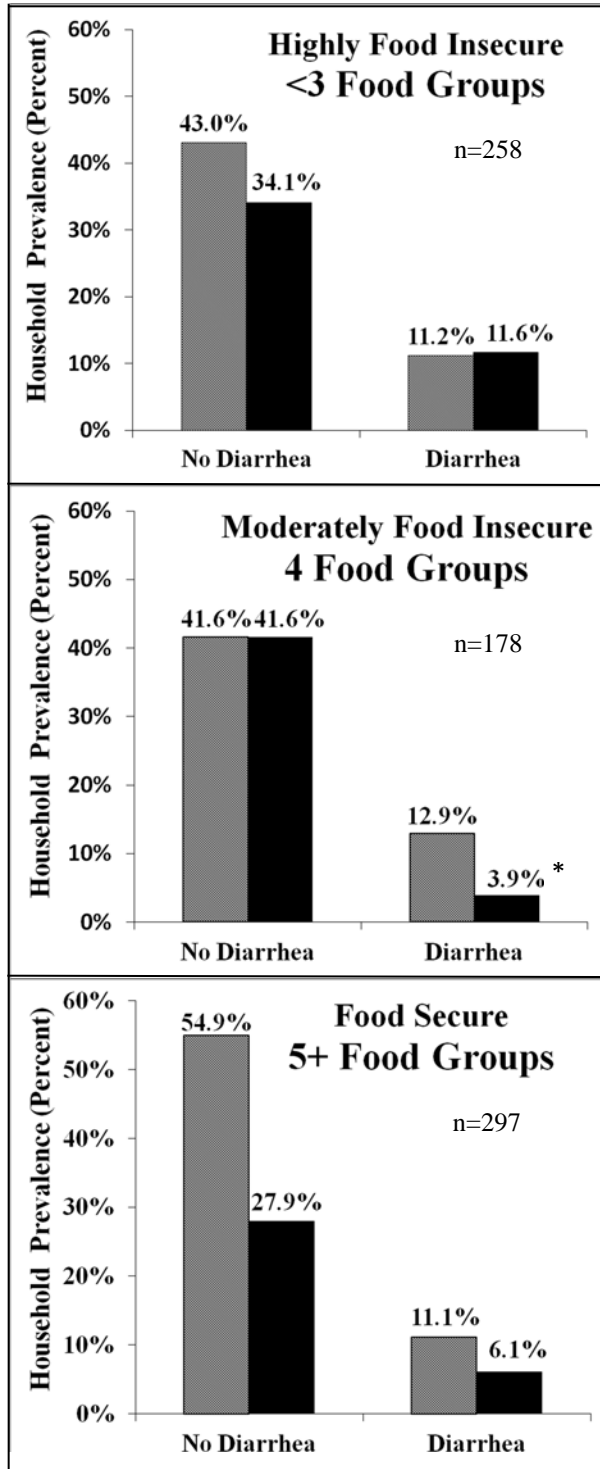
Wild plant consumption: ▨=Non-consumer, ■ = consumer. Food security was based on number of food groups; presence of diarrhea was indicated by current or 2 episodes in past 3 months. $P_{\text{Non-consumer-consumer}} = 0.007$; $P_{\text{No diarrhea-diarrhea}} = 0.160$; * = significantly different from non-consumer at $P \leq 0.05$.

DISCUSSION

Diarrhea, the excretion of loose or watery stools under acute, persistent, or chronic conditions for the affected individuals, is a leading cause of morbidity and mortality in Sub Saharan Africa (UNICEF-WHO, 2009). While multiple factors contribute to diarrheal diseases, bacterial and pathogenic infections are a major cause of this disease in developing countries (UNICEF-WHO, 2009). The household prevalence of diarrhea observed in this study was consistent with other studies in Tanzania (Tumwine et al., 2002; Pickering et al., 2012).

To survive and regain health, individuals with diarrhea require additional fluid and nutrients both during and after episodes of diarrhea to replace the heavy losses sustained by the disease (Lönnerdal, 2000). Nutritional deficiency can increase risk for further infection, severity of illness, and mortality from diarrheal and other diseases (Scrimshaw and SanGiovanni, 1997). These issues place particular emphasis on wild food and medicinal plants as the primary sources of traditional medicine in most of Sub-Saharan Africa (Irungu et al., 2006; Kitula, 2007). A recent survey in the New Dabaga Ulongambi Forest Reserve of Tanzania indicated that rural populations gathered some 45 plant species to treat up to 22 diseases (Kitula, 2007).

In addition to being rich sources of micronutrients (Weinberger and Msuya, 2004), several wild edible plant species have antimicrobial and antioxidant properties (Kitula, 2007), all of which are essential to disease prevention and optimal health. Wild plants, harvested from largely uncultivated land, including forests, wetlands, and bushlands which have not been depleted of minerals, offer an alternative source of micronutrients for cultivated crops (Welch and Graham, 2004).

Survey interviews suggested that at the household level, consumption of wild edible plants might be an important mediator of diarrheal diseases. The categorization of wild edible plants in this study was conservative, and inclusion of underutilized indigenous cultivated crops may have yielded more robust results. This study, however, indicates that consumption of wild edible plants may play a role in reducing the prevalence of diarrhea among food

insecure households and, potentially, have a greater effect on individuals living in moderately food insecure households than those living in highly food insecure or food secure households.

The mechanism through which wild edible plants mediate diarrheal disease outcomes needs further exploration. The associations observed in this study suggest two possible hypotheses: the micronutrient content of the wild edible plants enhances immune system responses to enteric pathogens, thus preventing or, in cases where individuals contract the disease, promoting rapid recovery from diarrheal illnesses. Several wild plants consumed by households were rich sources of zinc, iron, and β-carotene, and clinical trials have determined that diet supplementation with zinc can reduce the risk of diarrhea among children (Lazzerini and Ronfani, 2008). The second hypothesis proposes that some wild edible plants have antimicrobial, and hence antidiarrheal, properties that act against enteric organisms (Rani and Khullar, 2004), thus preventing disease.

Individuals living in moderately food insecure households apparently had sufficient dietary diversity and nutritional adequacy to promote the bioavailability and absorption of micronutrients from the plant materials, and/or could utilize the antimicrobial properties of, wild edible plants and hence prevent infection and diarrhea. In comparison, highly food insecure households may have not attained such a threshold for optimal use of the nutritional and health benefits of these plant materials. In addition, highly food insecure individuals may have already been malnourished (Cordeiro, 2007), and thus be more susceptible to a higher frequency and severity of co-morbidities (Scrimshaw and SanGiovanni, 1997). Malnourishment could well compromise the ability to benefit from any antidiarrheal agents in wild plants (Scrimshaw and SanGiovanni, 1997). Food secure households did not exhibit the same effects as their moderately food insecure counterparts, possibly due to their low reliance on wild edible plants, improved living conditions, and better access to health care.

The current research suggests that wild edible plants should be considered in studies examining health concerns in food insecure populations. This initial inquiry supports the need for further investigation of wild edible plants, and by association, medicinally active plants and their traditional uses for the prevention and treatment of diarrhea and other illnesses in food insecure populations. Documentation of these plants, their traditional uses, ecological status, seasonal availability, and nutritive and medicinal properties, could benefit the health of populations in Africa and other locations.

Knowledge of the health benefits of indigenous plants can lead to increased consumption of traditional foods and improved nutritional status of the populations (Johns and Chapman, 1995; Herforth, 2010). Such information is particularly timely in Tanzania, where a rapid loss of plant biodiversity is occurring due to population growth, deforestation, and expansion of farmland, all of which threaten many indigenous plant species. As a source of micronutrient rich foods and antimicrobial agents, wild edible plants could prove clinically useful for improving the health and disease outcomes among the food insecure in Sub Saharan Africa.

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