ORANGE-FLESHED SWEET POTATO: THE HISTORY, ADOPTION, EFFECT AND POTENTIAL OF A NUTRITIONALLY SUPERIOR STAPLE CROP IN MOZAMBIQUE

by

Mica Jeanette Jenkins

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DEDICATION

To my family. For your tireless support of my wandering, and always welcoming me home when it’s time.

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ABSTRACT

The purpose of this research is to understand the history and effectiveness of orange-fleshed sweet potato (OFSP) interventions in Mozambique as well as to identify factors that influence the adoption and retention of this crop. To achieve this purpose, an in-depth literature review was conducted to collate a time line of events surrounding OFSP introduction. Primary research was carried out to explore remaining challenges associated with improving adoption and retention levels and involved interviews and focus groups with 95 participants including farmers, consumers, and market vendors of OFSP. Field research was carried out in three provinces of Mozambique over a nine month period in 2015 with funding provided by the Fulbright US student program. Interviews and focus groups were translated and transcribed verbatim by the researcher and were analyzed by a team of authors to understand the site-specific factors affecting farmer willingness and ability to procure, preserve, cultivate, and distribute OFSP varieties, with a particular interest in the retention of planting material over time. Diffusion of Innovations Theory was utilized in the research design, analysis, and reporting. Results indicate that a wide variety of factors influence adoption and retention of orange-fleshed sweet potato, including: awareness of health benefits; organoleptic qualities and taste preferences; access to planting material; perceived difference in agronomic traits, including pest and drought resistance, time to root maturity, and vine development; dependence on non-government organizations or neighbors for planting material; lack of access to capital for inputs and labor; unstable markets and fluctuating prices; and varying levels of sharing of information and planting material across farmer networks. Future research should focus on mechanisms to increase year-round availability of planting material, improved drought and pest tolerance for OFSP, understanding farmer preference for vine and leaf development, renewed emphasis on nutritional benefits and cooking methods for sweet potato derivatives, gender dynamics of sweet potato commercialization, and farmer training on improved agricultural techniques that highlights the agronomic similarities between OFSP and WFSP to avoid perceptions that OFSP production is more labor intensive.

CHAPTER ONE

INTRODUCTION

A Brief History of OFSP in Mozambique

White-fleshed varieties of sweet potato, introduced by the Portuguese to Mozambique in the 16th century,[1] are an important food security crop[2] particularly in times of devastating drought and flood.[3] Rural farmers as well as city inhabitants rely on sweet potato as a staple food crop and year-round source of dietary energy. Sweet potato is produced by men, women, and children alike and is an important source of income for many families[4]. Orange-fleshed sweet potato (OFSP) varieties, high in beta-carotene, a precursor to vitamin A in the human body, were introduced for testing at the Umbeluzi national research station in Mozambique in 1997.[5] Since that time, a wide variety of collaborating partners and funders from government agencies and non-government organizations (NGOs) have worked together to support the breeding and dissemination of OFSP, with notable successes including significant reductions in low vitamin A intakes[6] and vitamin A deficiency (VAD) as indicated by serum retinol concentrations.[7,8] Successful pilot projects to promote and disseminate OFSP have led to scaled-up interventions to increase the production and consumption of OFSP across the eleven provinces of Mozambique.[56,7,8,9] Despite the important advances that OFSP has made in Mozambique over the past 18 years,[10,11] there is much potential for growth in the availability and consumption of this nutritionally superior staple crop.

Statement of Purpose

The purpose of this research is to understand the history of OFSP interventions in Mozambique as well as to identify factors that influence the adoption and retention of this crop. To achieve this purpose, an in-depth literature review was carried out to collate a time line of events regarding OFSP interventions. Primary research was then carried out to explore the remaining challenges associated with improving adoption and retention levels of OFSP through in-depth interviews and focus groups with farmers, consumers, and market vendors of OFSP in three provinces of Mozambique.

Limitations

The researchers chose to conduct a systematic literature review in order to build a complete picture of the introduction and implementation of OFSP in Mozambique. While many critical resources were available through internet databases, the authors found it difficult to obtain certain resources identified through snowballing, such as NGO reports and publications from research institutes within Mozambique.

Several key limitations to field research in Mozambique included: working with translators in local languages, which potentially contributed to loss of meaning in some cases; limited transportation to reach remote locations, and; working with government and NGO extension workers who could have potentially influenced participant responses.

Operational Definitions

Vitamin A deficiency: a lack of the essential micronutrient vitamin A in the human body

Beta-carotene: a pigment found in plant foods that acts as a precursor to vitamin A in the human body

Decentralized vine multiplier (DVM): farmers contracted and compensated to multiply sweet potato vines for distribution at the community level

Dietary diversity: the consumption of a wide variety of foods needed to satisfy daily requirements for macro- and micronutrients

Food-based approach: addressing mal- and undernutrition by encouraging the availability of and access to a variety of foods, preferably those which can be produced locally

Preservation: the process by which sweet potato vine segments are cut and transferred to moist areas during times of intense heat and drought in order to maintain planting material for the next cycle

Retention: long-term preservation of sweet potato by farmers

Staple crop: foods that are essential or important to regional diets

Xerophthalmia: dryness of the eye, often associated with vitamin A deficiency and potentially leading to blindness

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CHAPTER TWO

ORANGE-FLESHED SWEET POTATO: SUCCESSES AND REMAINING CHALLENGES OF THE INTRODUCTION OF A NUTRITIONALLY SUPERIOR STAPLE CROP IN MOZAMBIQUE

Contribution of Authors and Co-Authors

Manuscript in Chapter 2

Author: Mica Jenkins

Contribution: Mica Jenkins is the lead author on this article and was responsible for literature search, screening and final selection of articles, structure and content of the manuscript, creation of tables and figures, editing, and final submission.

Co-Author: Dr. Carmen Byker Shanks

Contribution: Dr. Carmen Byker Shanks provided disciplinary expertise, constant guidance in literature search, screening and final selection of articles, and multiple edits of the manuscript, figures, and tables.

Co-Author: Bailey Houghtaling

Contribution: Bailey Houghtaling assisted in article screening and final selection and provided multiple edits of the manuscript, figures, and tables.

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Abstract

Background: Chronic vitamin A deficiency affects both women and children in Mozambique and populations worldwide and cannot be addressed through supplementation alone. Food-based approaches encouraging the consumption of vitamin A-rich foods, such as the orange-fleshed sweet potato (OFSP), have the potential to positively affect vitamin A status. A range of OFSP varieties have been introduced in sub-Saharan Africa in rural and urban environments and emergency and nonemergency contexts.

Objective: To highlight the successes to date and remaining challenges of the introduction of OFSP to increase vitamin A consumption in Mozambique, collating a time line of key events.

Methods: A systematic review of literature using The Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Results: The systematic search resulted in 20 studies that met inclusion criteria. Data extracted include author and year, study location and duration, project partners, project title, sample size and characteristics, objectives, methods and measures, and outcomes.

Conclusions: Orange-fleshed sweet potatoes are widely accepted by Mozambican farmers and consumers, and various studies show a positive impact on vitamin A status due to the introduction of this nutritionally superior staple crop. Remaining challenges include vine preservation, pest and disease management, market development, and storage and processing.

Introduction

Although vital to preventing disease, disability, and death among vulnerable populations, interventions that focus on increasing micronutrient intake through a single mechanism, such as supplementation, are tenuous if not paired with complementary approaches such as food fortification and dietary diversification.[1] In countries where chronic malnutrition is widespread, food-based approaches emphasizing the consumption of a wide variety of vitamin-rich foods are crucial to reducing the occurrence of life-altering and often fatal micronutrient deficiencies.

Since 1999, the government of Mozambique has distributed supplements in order to combat high levels of vitamin A deficiency (VAD), especially among women and children.[2] In Mozambique, ‘‘the supply of micronutrient-rich foods is dramatically low,’’ resulting in persistent malnutrition.[3] The ubiquity of cereals and starchy roots, particularly cassava, has led to extremely low dietary diversity, and the lack of available energy in the food system resulted in undernourishment levels[3] of 38% between 2005 and 2007. In particular, VAD has been a severe public health obstacle in Mozambique, and lack of this crucial micronutrient results in xerophthalmia, blindness, growth limitations, weakened defenses, susceptibility to infection, and increased mortality.[4] Despite government supplementation coverage, which reached 44% of children of age 6 to 59 months in 2003, VAD continues to be a major concern.[2] A 2005 study showed that VAD affects 71% of children between 6 and 59 months of age in Mozambique,[2] and the World

Health Organization estimates that over 200 million women and children worldwide are affected by this preventable condition.[5]

The introduction of orange-fleshed sweet potato (OFSP) is one food-based approach that has great potential to decrease VAD in Mozambique.[6] Although most varieties of sweet potato commonly grown in sub-Saharan Africa (SSA) are white-fleshed and lacking in vitamin A,[6,7] OFSP offers high levels of this important micronutrient and is both drought resistant and easily cultivated.[8] Supporting data confirm that OFSP is a highly affordable source of vitamin A: ''in 2004, meeting the recommended daily allowance for a child under 6 years of age (300-500 RAE) with OFSP cost less than 1 US cent.''[9(pS268)]

Many published articles and reports have focused on the efficacy of OFSP as an emergency crop and/or a combatant to VAD in SSA,[6,8-12] sensory properties and consumer acceptability of OFSP roots and enriched products,[8,9,13,14] retention of b-carotene after processing and storage of OFSP varieties,[15-18] farmer willingness to pay for and grow OFSP,[19-21] and consumer willingness to pay for OFSP.[22] The purpose of this systematic literature review is to summarize successes and remaining challenges of the introduction of OFSP in Mozambique to date. This review collates a time line of events, beginning with the identification and distribution of varieties with high b-carotene content in the 1990s and continuing to include published evidence of success from recent years. Remaining challenges and plans for future research into the promotion of OFSP will be discussed in detail.

Methods

Study Selection

The goal of study selection was to identify published articles that contribute to building an accurate portrait of the successes and challenges of the introduction of OFSP in Mozambique to date. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram was used to guide the search for relevant literature[23] (see Figure 1). Articles identified in this systematic review were extracted from the following databases: Science Direct, ProQuest Agricultural Science Collection, Web of Science, AgEcon Search, and PubMed. The following key words and key word phrases were used: orange (or orange-flesh), sweet potato (or sweetpotato as one word), vitamin A deficiency, Africa, Mozambique. The authors also used Google search to identify reports and articles from nongovernmental organizations (NGOs) highlighting key findings of the OFSP intervention. Finally, reference list snowballing was used to further identify important sources that did not appear in research databases. The articles included in this review were chosen due to their focus on OFSP interventions and research in Mozambique. No year limitations were used as the authors intended to analyze the entire scope of the OFSP project in Mozambique since its inception. Full journal articles, conference papers, posters, and theses were considered.

Article titles were first screened by the lead author, followed by a screening of abstracts, and concluding with full-text consideration. Two other authors then independently

screened the articles, first by title, then proceeding to abstracts and full-text. Articles were included or eliminated after consensus by all authors had been reached.

Studies were excluded for the following reasons: study focused on a country or region other than Mozambique or did not specify location, study focused on structure and processing of OFSP, and/or study scope was too broad, for instance, focusing on biofortification or food-based approaches overall.

Per the guidelines found in the Cochrane Handbook for Systematic Reviews of Interventions,[24] studies were included if they met the following quality criteria: (1) focus on key scientific developments substantiating the efficacy and effectiveness of OFSP as an intervention food for increasing vitamin A intake in Mozambique, (2) focus on sensory acceptability of OFSP to Mozambican consumers, (3) focus on farmer acceptability and market development of OFSP in Mozambique, and/or (4) detailed description of key developments surrounding the introduction of OFSP in Mozambique.

Data Extraction

The data extracted in Table 1 include first author and year, study location and duration, project partners, project title, sample size and characteristics, objectives, methods and measures, and outcomes.

Results

The initial database search using multiple combinations of the selected key terms yielded 12,199 results (see Figure 1). The removal of 21 duplicates resulted in 12 178 results. Reference list snowballing and Google search revealed 19 other studies of potential relevance. Ten studies identified as potentially relevant through reference list snowballing were ultimately inaccessible to the authors as they were published by research institutions in Mozambique and not available on the Internet. Of these results, 71 were identified as potentially relevant. A full-text examination of these studies resulted in the exclusion of 51 studies, which did not meet the inclusion criteria. Twenty-six studies were excluded because they did not focus specifically on Mozambique. Ten studies were excluded due to focus on structure and processing of sweet potato. Fifteen studies were excluded because the scope was too broad, focusing for instance on biofortification or food-based approaches in general. Twenty studies met the inclusion criteria and are included in Table 1.

The results of this systematic review reveal that key contributors to research and reporting on the introduction of OFSP in Mozambique include Jan Low of the International Potato Center (CIP), Alan de Brauw of the International Food Policy Research Institute (IFPRI), Regina Kapinga of CIP, Abdul Naico of CIP, and Christine Hotz of Nutridemics. Of the 20 articles chosen for final review, Low was the lead author on 5, de Brauw on 3, Kapinga on 2, Naico on 2, and Hotz on 1. The interventions

discussed in this body of work span 2001 to 2009 and include Vitamin A for Africa (VITAA; note 1), Toward Sustainable Nutrition Improvement (TSNI; note 2), and Reaching End Users (REU; note 3).

All of the studies took place in Mozambique, though several also examined efforts in other countries of SSA. The key organizations involved with funding and implementation (see project partners column in Table 1) include but are not limited to the Bill and Melinda Gates Foundation, the Micronutrient Initiative, the United States Agency for International Development, the Rockefeller Foundation, the HarvestPlus project led by IFPRI and the International Center for Tropical Agriculture, CIP, Michigan State University, Southern African Root Crops Research Network, World Vision, Helen Keller International, and the Agricultural Research Institute of Mozambique.

Methods and measures commonly occurring throughout the studies listed in Table 1 include household surveys, dietary recall, anthropometric measurements, and choice experiments. Common interventions include technical agricultural assistance (such as vine distribution and pest management), nutrition awareness and demand creation campaigns, and market development.

Discussion

Why OFSP

Sweet potato has long been an important food security crop in SSA,[31] serving a key role as an energy-dense food often in postdisaster contexts.[10] Sweet potato can be vegetatively propagated, or multiplied through the cutting and replanting of vine segments. It is a hardy crop that often succeeds when other crops succumb to stress and is not as labor intensive as many other staple crops.[32] While the white sweet potatoes typically grown in Mozambique do not contain b-carotene,[6,7] orange varieties are high in this precursor to vitamin A.[6] Once consumed, b-carotene is easily converted into the retinoids required by the body for eye, skin, and immune health.[33] A child who is 5-year-old or younger needs to consume only 100 g/d (half-cup) of OFSP roots in order to receive the recommended daily amount of vitamin A.[34]

Vitamin A Intakes and Serum Retinol

Since the implementation of VITAA26 from 2001to 2006, OFSP interventions have focused on women and children as target beneficiaries due to their vulnerability to VAD and due to women's role in the production and marketing of sweet potato. Not only has OFSP been demonstrated to be highly acceptable to Mozambicans based on its sensory and agronomic characteristics, its introduction into communities has been shown to dramatically increase vitamin A intake among children.[8,9] Toward Sustainable Nutrition

Improvement, a 2-year intervention beginning in 2002, assessed the effects of OFSP availability on vitamin A intake and serum retinol concentrations especially among young children.[8,9,25] At the end of TSNI, >50% of intervention children consumed OFSP 3 or more days per week[8] and VAD, as indicated by serum retinol levels, was reduced from 60% to 36% among otherwise healthy intervention children.[25] Reaching End Users, a large-scale intervention that took place from 2006 to 2009, found that vitamin A intake from OFSP increased in both models across intervention groups of all ages compared to the control.[11] Orange-fleshed sweet potato also accounted for a much greater overall percentage of sweet potatoes consumed in the intervention groups compared to the control, 47% to 60%, and 20% to 24%, respectively. The varieties cultivated in this trial had significant b-carotene content, higher than raw pumpkin, green leafy vegetables, mango, and ripe papaya.[11] The end line data collected after both TSNI and REU have helped to narrow the knowledge gap surrounding food-based approaches to nutritional improvement in Mozambique, and these experiences can be applied in other countries similarly affected by micronutrient deficiencies.

Sensory Qualities of OFSP

The introduction of nutritionally superior varieties of staple foods, also known as biofortified foods, can be complex due to a variety of factors including culture, tradition, and dietary preferences.[35,36] Various studies have shown that OFSP is accepted in Mozambique[14,20,22,25,37,38] and will not be rejected due to its orange color.[9,11] However, the image of sweet potato as a staple of poor households and a women's crop persists in Mozambique[28] due to its use in postdisaster contexts to improve food security.[10] It is also important to note that consumer perception of existing varieties is geographically specific. For instance, the Resisto variety that is cultivated widely in SSA is well liked in Mozambique,[9] considered to be watery in Tanzania,[39] and was determined to be less watery than several cream flesh varieties in a South African study.[40]

In 2002, the TSNI project was launched in Mozambique to promote OFSP as a food-based approach to combatting VAD.[9] This was based on a conceptual framework that included 3 pathways: access to high-yielding, b-carotene-rich OFSP planting material, demand creation and empowerment through knowledge, and market development for fresh roots and processed products to ensure sustained adoption.[25] The results of TSNI demonstrated that 5 of the 9 varieties introduced were acceptable to both men and women based on taste and agronomic performance.[8,9,25] Further, the Golden Bread that is made by substituting 38% of wheat flour with boiled and mashed OFSP was popular and profitable among participants in TSNI,[9,13,25] who demonstrated ''a strong preference for Golden Bread over white wheat flour bread because of its heavier texture . . . superior taste, and attractive golden appearance.''[13(p103)]

Varieties and Breeding

Research has shown that consumers are willing to pay >50%more for varieties of OFSP that possess similar eating qualities to traditional varieties, the most important of which is dry matter content.[22,41] Multiple studies have shown that African consumers typically prefer sweet potatoes with high dry matter and low water content.[42-44] A choice experiment conducted in 2008 in 2 provinces of Mozambique revealed that willingness to pay for high dry matter content (associated with a firm, starchy potato) was almost twice that of willingness to pay for the color of pulp, even when consumers received information about the health benefits of consuming OFSP.[22,41] The Resisto variety has been shown to be popular in Mozambique due to its taste, dark-orange color, growth structure, and high yields but was found to be less drought-tolerant than the light-orange Jonathan variety.[9,25] These findings have been essential for sweet potato breeders who have subsequently worked to create new OFSP varieties that are high in b-carotene, drought tolerant, resistant to pest and disease, and suitable for Mozambican dietary preferences. In response to the lack of drought tolerance observed in the first 8 varieties released in Mozambique in 2001, breeding trials were undertaken from August 2005 to December 2009, resulting in the release of 15 improved varieties[45] in 2011. The time required to create new varieties has been reduced from 8 to 4 years due to a new technique known as ‘‘accelerated breeding,’’ and from 2000 to 2012, the number of countries in SSA with sweet potato breeding programs grew from 2 to 12.[46]

Market Dynamics

Several studies included in this review emphasize the importance of including a market development component to ensure the successful introduction of OFSP into communities.[8,9,11,13,25] Although many Mozambican consumers have demonstrated a preference for OFSP, low-purchasing power is a major constraint for enhancing dietary diversity.[13] One key challenge identified during TSNI was the creation of a market development strategy that assures significant home consumption of OFSP while still allowing surplus for sale at markets.[9] Proximity of households to markets and agroecological conditions are both key variables to the success of market development. The success of the pilot marketing component of TSNI encouraged researchers to suggest the inclusion of a strong marketing component in future efforts to scale-up the production and consumption of OFSP.[9] By the end of the TSNI project: 90% of intervention households were growing OFSP, 30% of which were selling OFSP (up from 13%); sweet potato plot sizes were nearly 10 times larger, and OFSP was the cheapest source of vitamin A on local markets.[8] This last finding is especially important, as a very slight price increase in OFSP has been associated with a decrease in utility for potential consumers.[22] However, the final report for the REU project, which employed a

conceptual framework adapted from that of TSNI, indicates that the market development component did not significantly affect adoption rates or vitamin A intake.[27]

Storage and Processing

Orange-fleshed sweet potato is generally available in Mozambique between March and August; mangos are an important complementary source of b-carotene but are usually available only between December and February. Because seasonality is a limiting factor of OFSP availability and consumption,[11] it is important to understand methods of storing, cooking, and processing that maximize b-carotene retention. Fresh roots can be stored in protected pits for 1 to 5 months, but this practice is not common in Mozambique.[13] While b-carotene content of some varieties remains relatively stable during storage, it begins to decline after 12 weeks of indoor storage and 22 weeks of in-ground storage. An on-farm evaluation in Mozambique in 2011 found high losses of carotenoids during storage of dried OFSP chips, leading to a recommendation that chips be stored no longer than 2 to 4 months depending on the variety.[16] Staggered planting and improved fresh root storage, therefore, are important solutions to extending the availability of this nutritious crop.[13]

The bioavailability of b-carotene is affected by the method of processing: for OFSP, ‘‘raw < baked < steamed/boiled < deep fried”.[47] Consumption of OFSP in conjunction with small amounts of fat can increase b-carotene bioavailability by up to 20-fold. A 2006 study examined b-carotene retention in boiled, mashed OFSP of the popular Resisto variety.[48] Results showed that the most successful way to retain b-carotene (up to 92%) was by boiling for 20 minutes with the lid on. When boiled with the lid off, the potatoes took longer to cook through and lost slightly more b-carotene (retention of 88%).

One use for boiled, mashed OFSP is as a partial substitute for wheat flour in Golden Bread. In addition to being well liked by consumers and an excellent source of vitamin A, Golden Bread can provide an important source of income for bakers, whose profit has been shown to increase by up to 92% as the result of using locally available sweet potato to replace expensive imported wheat flour.[13] Using dried OFSP chips to make Golden Bread is currently not cost effective as 4 kg of fresh roots are required to produce 1 kg of chips, and revenues are greater from selling fresh roots. However, seasonal fluctuations in supply could be largely mitigated if the use of dried chips from darker orange varieties with higher b-carotene content became economically viable.[13]

Farmer Networks

While sexual propagation is used to create new varieties of OFSP, the crop is commonly propagated vegetatively, meaning the vines can be cut and replanted to create new root systems. Researchers of OFSP integration into rural Mozambican communities have

recognized that free vine distribution by third parties, such as NGOs, has the potential to discourage vine preservation by farmers with limited resources.[9] However, these vine distributions are critical to introducing improved OFSP planting material into communities, and research shows that OFSP technology may be diffused from direct beneficiaries to reach indirect beneficiaries,[11] helping to control the cost of interventions.[27]

Agronomic Challenges: Vine Preservation and Weevil Infestation

Various studies included in this review indicate that one of the greatest remaining challenges involved in the introduction of OFSP is limited access to quality vines for planting due to drought and flood and lack of sufficient planting material at the beginning of the season.[12,19,20,25,28,27] Multiplying vines requires considerable labor and access to water. Farmers have been encouraged to reproduce and share vines through small-scale commercial networks,[25] but reoccurring drought and flooding makes maintaining vines in the offseason difficult. In the third year of REU, the use of trained decentralized vine multipliers was determined to be a successful mechanism for increasing the availability of planting material at the community level.[29] A promising new method known as ‘‘Triple S’’ also enables farmers with limited access to water to preserve small, healthy sweet potato roots in buckets of sand during the dry season, with the intention of re-sprouting the roots in protected seed beds before the rains begin.[49] The 2011 release of 15 improved varieties of OFSP in Mozambique was an important step toward improving the quality of available planting material and increasing the utility of the crop for producers; recent research has highlighted the importance for breeding efforts to continue to focus on greater drought tolerance.[30] Additionally, sweet potato is highly susceptible to pest and disease,[25,27,28] necessitating preventive measures such as disinfection of vines and hilling-up (note 4) of sweet potato plots.[27]

Models of Different Intensity Produced Similar Results

The TSNI project operated for 4 growing seasons from 2002 to 2005 and was designed to test the efficacy of OFSP in maintaining vitamin A status among children who received capsules.[25] In 2006, a 1-year financing arrangement known as Eat Orange was implemented to test a new approach and serve as a bridging project between TSNI and REU.[27] Although Eat Orange incorporated changes to lower the cost per beneficiary, the conceptual framework for TSNI was used to design the subsequent REU project, a scaled-up intervention implemented[11] from 2006 to 2009. The REU project employed two intervention models of different levels of intensity, which produced similar results at end line, leading researchers to conclude that the lower intensity model was more cost effective and should be used in future interventions to encourage the production and consumption of OFSP.[11,27] A 2013 report on the impacts of REU in Mozambique in

Uganda showed that by the end of the project, 75% of Mozambican farmers in model 1 and 79% in model 2 were growing OFSP, compared to only 9% of farmers in the control group.[12] This study concluded that access to vines was the most important factor in the impact of OFSP on vitamin A intakes, and that the effect of nutritional knowledge on adoption of OFSP was very limited.

Conclusion

Through conversations with individuals currently working to promote OFSP in Mozambique and exploration of the Sweetpotato Knowledge Portal,[50] the authors were able to identify several recent interventions focusing on OFSP, including the Sweet Potato for Profit and Health Initiative, The Sweetpotato Action for Security and Health in Africa (phases 1 and 2), the Office of US Foreign Disaster Assistance distribution of planting material in response to drought and flood, Reaching Agents of Change, Nutritious Orange-Fleshed Sweet Potato for Niassa, and Scaling Up Sweetpotato Through Agriculture and Nutrition. Reports on these interventions are not included in Table 1, as they did not appear during the systematic search for literature; however, these interventions are included in the time line in order to help develop a clear picture of OFSP activities in Mozambique from the 1990s to date (see Figure 2). Although she was not captured as a lead author in the systematic search for literature, the work of Maria Andrade of CIP has been essential to OFSP breeding and supported the work of many key contributors in this review.

Many organizations have worked in partnership to promote OFSP as a nutritionally superior staple crop in Mozambique over the past 15 years, including NGOs, government organizations, and private funders. There have been notable improvements in the vitamin A status of the participants involved in these projects, and the food environment has benefited from the addition of this b-carotene-rich crop. However, VAD persists, and many Mozambicans do not have regular access to or knowledge of OFSP and its potential markets.

In a 2013 case study provided by reviewers of the current manuscript but not captured in the systematic search, 4 major lessons are identified as emerging from the OFSP experience in Mozambique to date: OFSP is acceptable to people of all age groups and can have an important impact on vitamin A intake and status; adults and children may have different varietal preferences, as adults tend to prefer higher dry matter content; the availability of high-quality planting material at the beginning of the rainy season is a key constraint to OFSP expansion; and breeding efforts in Africa should be enhanced to ensure a supply of regionally appropriate varieties.[49] A chapter from the 2013 Handbook of Food Fortification and Health also offers a concise summary of the lessons learned

from 14 years of OFSP implementation in Mozambique as well as 10 critical steps to guide the design of OFSP interventions.[46]

Future research should include follow-up studies to determine which OFSP varieties are accepted in specific communities, as varietal preference has been demonstrated to vary significantly across regions of Mozambique.[11] In addition to the baseline and end line surveys that are typically conducted during project implementation, researchers should interview key informants to better understand the social and technical challenges associated with long-term retention of OFSP planting material after distributions. These interviews will help to determine the factors that may affect farmer willingness and ability to conserve and distribute vines within their own networks, such as access to water, cost of labor, pests and disease, gender dynamics, consumer preference, market potential, and dependence on distribution of vines from NGOs.

Awareness of OFSP and its nutritional benefits exists in some regions of Mozambique; however, the market for OFSP must be formalized in order to improve access to OFSP and its derivatives. Innovation in product development, such as bread and juice, as well as commercialization facilitated by grading of sweet potatoes according to variety and quality are important methods for stabilizing these markets.[25]

Preventive measures must be taken to control weevil infestation,[27] in addition to continued efforts to improve drought tolerance.[30] There is also a considerable need for continued research in the area of storage and processing of OFSP to better understand the retention and loss of b-carotene.[13,51] Future studies should focus on improved storage technology for fresh roots, staggered planting as a mechanism to extend availability, and crop rotations that maximize the growing potential of OFSP. Formal studies should also be conducted to analyze the rate of conversion of b-carotene from sweet potato leaves into retinol, as well as studies to clarify the effect of environmental variation and time of harvesting on b-carotene content of popular sweet potato varieties.[51]

Linking OFSP promotion with other health interventions including increased fat consumption and deworming has been shown to have positive outcomes in clinical settings[52] and could therefore be a useful strategy at the community level in Mozambique.[51] The OFSP can also potentially play a greater role in supporting the nutrition and income of households affected by HIV/AIDS.

Finally, recent broad-scale disseminations of OFSP in Mozambique have taken place without adequate resources to measure impact at the household level.[49] Research must be conducted to determine the best pathways for scaling-up OFSP delivery systems, with an

emphasis on developing monitoring and evaluation plans that ensure that impact can be accurately measured.[51]

As key donors begin to recognize the need for integrated approaches to improving agriculture and nutrition, OFSP is increasingly recognized as an important mechanism to improving food security.[46] Food-based approaches to alleviating micronutrient deficiencies are complex due to the initial setup involved and the behavior change required to measure success; however, proponents of this approach believe that it has greater potential to affect long-term health outcomes than an approach that relies solely on supplementation.[46] Radio and television coverage, demonstration events, and farmer testimonies have all helped to increase government support for OFSP in Mozambique, thereby encouraging continued donor investment. Understanding the production, distribution, and consumption of vitamin A-rich OFSP in Mozambique has important implications for other food-based interventions focused on increasing micronutrient intake within regionally specific cultural contexts. Agronomic challenges, regional differences in consumer preference, postharvest handling and the creation of value-added products, and linkages between food producers and consumers through marketing efforts all make a distinct difference in the likelihood of adoption. Population-level improvement in the intake of specific micronutrients through food-based interventions requires consideration of regional, community, and individual contexts to provide long-term solutions to decreasing chronic micronutrient deficiencies.

Authors' Note

Mica Jenkins is the lead author on this article and was responsible for literature search, screening and final selection of articles, structure and content of the manuscript, creation of tables and figures, editing, and final submission. Carmen Byker Shanks provided disciplinary expertise, constant guidance in literature search, screening and final selection of articles, and multiple edits of the manuscript, figures, and tables. Bailey Houghtaling assisted in article screening and final selection and provided multiple edits of the manuscript, figures, and tables.

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Notes

1. Vitamin A for Africa was a 5-year project (2001- 2006) to combat vitamin A deficiency in sub-Saharan Africa using orange-fleshed sweet potato (OFSP). By 2003, 377 000 families in 4 provinces of Mozambique had received support from rapid multiplication sites, which produced high-yielding and early maturing varieties of OFSP.
2. Toward Sustainable Nutrition Improvement was a 2-year project (2002-2004) in Mozambique to increase vitamin A intake particularly among young children through improved access to and demand for OFSP. By the end of the project: 5 of the 9 OFSP varieties introduced were accepted by men and women; vitamin A deficiency was reduced from 60% to 36% among control children; and 90% of intervention households were growing OFSP.
3. Reaching End Users was a 3-year project (2006- 2009), which disseminated OFSP in Mozambique and Uganda. By the end of the project, vitamin A intakes doubled among all intervention groups and >85% of consumers stated that they would buy OFSP in the future.
4. Hilling-up refers to the prevention of weevil attacks by covering exposed roots and cracks in the soil.

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Figures

Figure 1 PRISMA Flow Diagram
Orange-Fleshed Sweet Potato: Successes and Remaining Challenges of the Introduction of a Nutritionally Superior Staple Crop in Mozambique

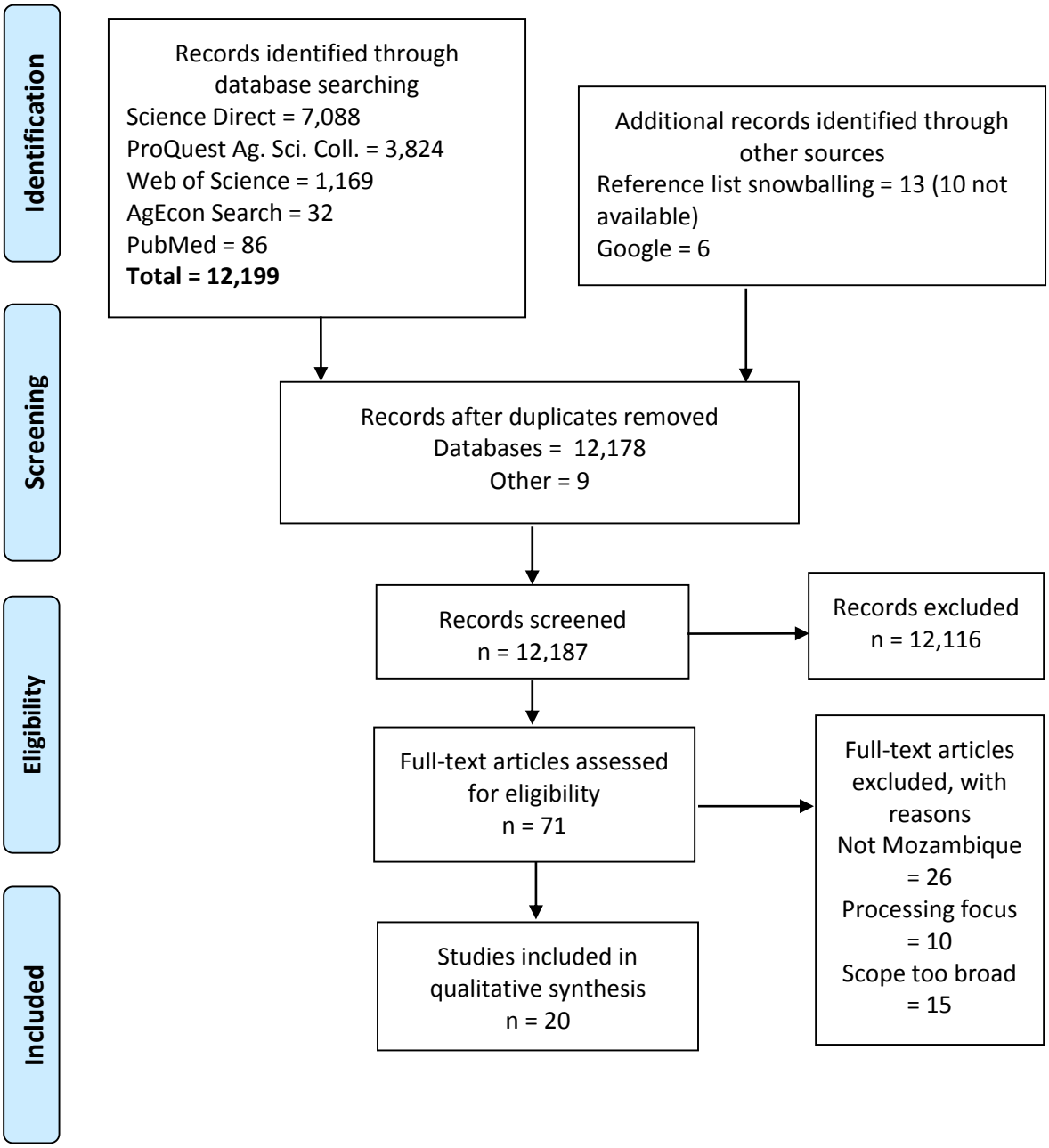
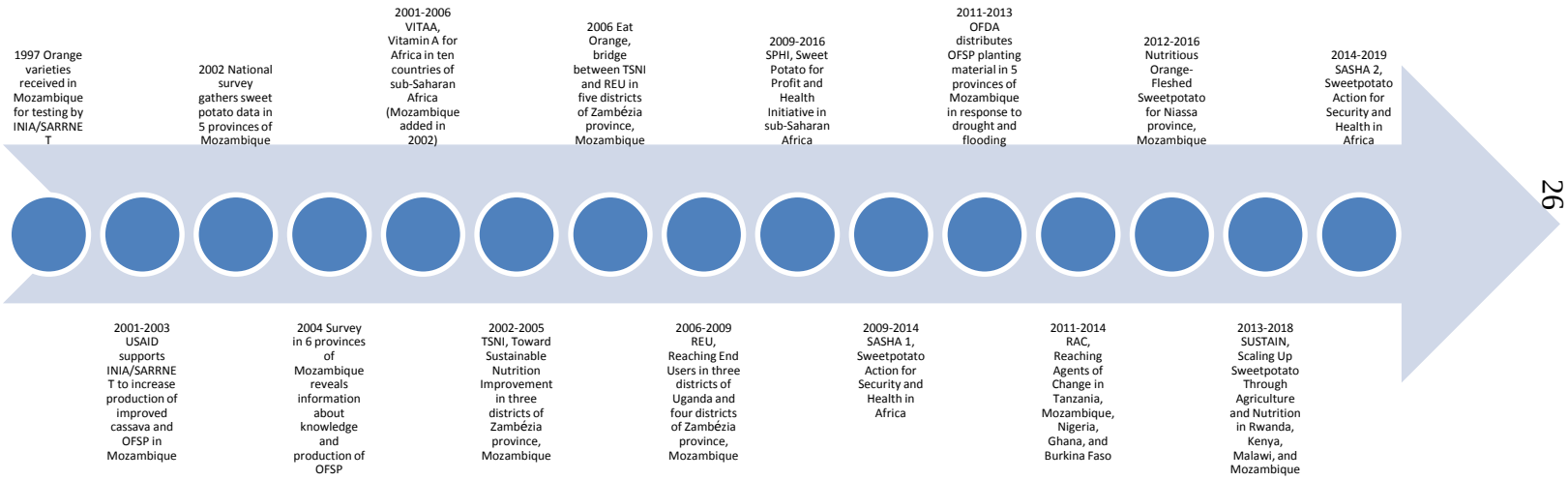


Figure 2 Time line of OFSP in Mozambique



Tables

Table 1 Results from the Systematic Search for Orange-Fleshed Sweet Potato (OFSP) Interventions in Mozambique

First Author, Year	Location	Duration	Project Partners[a]	Project Title	Sample Character-istics	Objectives	Methods / Measures	Outcomes
Low J 2000	Mozam-bique	Review[b]	MSU (Michigan State Univer-sity)	None	Review[b]	Summarize why orange-fleshed sweet potato (OFSP) is ideal to combat food insecurity and vitamin A deficiency (VAD) in Mozambique.	Review[b]	• Sweet potato used as a food security crop; production controlled by women • Variety testing in Mozambique began in 1997 • OFSP varieties higher yielding, not more labor intensive • 23% population eat roots or leaves 1x/week
Kapinga R 2005	Mozam-bique; Uganda	Review[b]	Oxfam, South African Root Crops Research Network (SARRNET), etc.	Vitamin A for Africa (VITAA)	Review[b]	Summarize the role of OFSP in disaster mitigation using case study from Mozambique in 2000, when worst floods in 5 decades	Review[b]	• Rapid introduction of OFSP • Widened genetic diversity • 377,000 families benefited from resistant, high-yield planting material

Table 1 continued

						displaced 450K and 1000 died.		• 34.3% farmers using OFSP
Low J 2005	Zambézia province, Mozam-bique	2003-2005	MSU, Micro-nutrient Initiative, the United States Agency for Inter-national Develop-ment (USAID), etc.	Toward Sustainable Nutrition Improveme nt (TSNI)	741 households (HHs) and children (498 intervention, 243 control); children age 6mos – 4yrs	Summarize key findings from TSNI project.	• Three major component s to conceptual framework of interventio n: agricultural ; demand creation/ behavior change; marketing/ product developme nt • Surveys • 24-hour dietary recall • Food frequency questionnai re • Morbidity recall • Blood sampling • Anthropo-metric data	• 5 of 9 varieties accepted by farmers • Increase in nutrition knowledge larger among intervention women than control women • Median vitamin A intake 8.3x higher among intervention children • VAD (defined by low serum retinol) reduced from 60% to 36% among healthy intervention children • VAD in intervention children was 10% lower compared with control • 90% intervention HHs growing OFSP in final year • 68% sweet potato grown was OFSP

Table 1 continued

Kapinga R 2007	Mozam-bique; other countries	2001-2006	CIP (Interna-tional Potato Center), CARE, USAID, National Institute of Agro-nomic Investi-gation (INIA), Inter-national Institute of Tropical Agri-culture (IITA), SARR-NET, etc.	VITAA	Young children and their mothers	Analyze the 5-year implement-tation of VITAA.	• Field assessment • HH surveys • Feeding programs • Distributio n of planting material • Nutrition education and awareness campaigns	• OFSP has played a key role in food security post-disaster • Sweet potato 3rd most important crop; used in 6 forms • Farmers consumed products 2-3 x week • Sweet potato generally preserved up to 50 days • Identified culturally appropriate recipes with OFSP • Farmers exhibited product at annual agricultural shows • Rapid multiplication sites supported 377,000 families in response to drought/flood • Improving adoption depends on access to planting material, market development and

Table 1 continued

								post-harvest handling and processing
Mazuze F 2007	Gaza province, Mozam-bique	Three planting seasons from 2002 to 2004	Agricultural Research Institute of Mozam-bique (IIAM)	None	150 Farmers	Assess socio-economic and institutional factors associated with adoption of OFSP by smallholders.	• Key informant interviews and growers survey	• 83% aware of nutritional benefits • 40% reported low drought-tolerance of OFSP; many reported losses of vines to drought • 70% respondents planted >75% white sweet potato (WSP) • OFSP ranked positively for yield, root size, taste, cooking time and negatively for off-season propagation, dry matter content of roots, tolerance to drought, pests • Positive relationship between number of OFSPs received and adoption levels
Low J 2007a	Zambézia province,	2003-2005	MSU, Micro-nutrient	TSNI	741 HHs and children (498	To examine farmer willingness to	• See Low 2005 above	• See Low 2005 above

Table 1 continued

	Mozam-bique		Initiative, USAID, etc.		intervention, 243 control); children average age 13 months at baseline	adopt sweet potato varieties with a visible trait, child willingness to consume OFSP, and potential of OFSP to serve as an entry point for diversified diets.		
Low J 2007b	Zambézia province, Mozam-bique	2003-2005	MSU, Micro-nutrient Initiative, USAID, etc.	TSNI	741 HHs and children; (498 intervention, 243 control) children average age 13 months at baseline	Increase vitamin A intake and serum retinol concentrations in young children.	• See Low 2005 above	• See Low 2005 above
Low J 2008	Zambézia province, Mozam-bique	2003-2005	MSU, Micro-nutrient Initiative, USAID, etc.	TSNI	95 tasters, 112 market shoppers	Determine if substituting 38% of wheat flour in bread buns with OFSP from fresh roots or dried chips would produce economically viable beta-carotene-rich products acceptable to	• Survey • Modification of local recipes and training of bakers to incorporate OFSP • Sensitivity analysis	• Products with 15ug/g of trans-beta-carotene are good source of vitamin A • Only chips made with Resisto yielded product with sufficient beta-carotene • 110g bun excellent source of vitamin A for

Table 1 continued

						rural consumers in Mozambique.		children and adults • Strong preference for golden bread over white wheat • Boiled mashed product preferred over chips • Bakers profit increased 92% due to lower cost inputs • Use of dried chips currently not economically viable
Labarta R 2009	Zambézia province, Mozam-bique	January 2008	Harves-tPlus	Reaching End Users (REU)	121 farmers from 6 villages; 20 HHs each village; have not participated in vine distribution in at least 3 years.	Evaluate farmer willingness to pay (WTP) for OFSP planting material.	• Real choice experiment ; farmers received 6 meticais to spend on 10 choice scenarios • Survey questionnaire	• Farmer WTP higher for OFSP than WSP, and higher than traditional subsidized price of vines • All OFSP varieties considered superior in terms of taste • Reported difficulty conserving vines for several varieties

Table 1 continued

Naico A 2009	Gaza and Maputo provinces, Mozam-bique	June-July 2008	Ford Foun-dation, Willard Sparks Endowed Chair	None	308: 190 (urban) and 118 (rural) market shoppers	Determine consumer WTP for sweet potato attributes (color, dry matter, size, price) in Mozambique.	• Choice experiment administered through in-person survey	• Dry matter content most important (75% utility), then pulp color • OFSP not competitive with WSP in terms of dry matter • WTP higher for OFP in 7/8 scenarios • Participants with knowledge of nutritional benefits chose OFSP more often than those without information • Higher priced options less likely to be chosen • Smaller size roots preferred • Importance of controlling for hypothetical bias in choice experimentation • WTP for OFSP in rural areas higher than urban (21.02 MT vs 12.02 MT)
Naico A 2010	Gaza and Maputo	June-July 2008	Ford Foun-	None	308: 190 (urban) and	Generate information on	• Choice experiment	• See Naico 2009 above

Table 1 continued

	provinces, Mozam-bique		dation, Willard Sparks Endowed Chair		118 (rural) market shoppers	consumer demand for OFSP to inform market strategies and improve production using choice experiment. Determine Mozambican consumers' willingness to consume/pay for OFSP.	administered through in-person survey	• WTP for OFSP 51.3% more when other factors constant
de Brauw A 2010	Mozam-bique; Uganda	2006-2009	World Vision (WV), Helen Keller Interna-tional (HKI), Harvest-Plus (Interna-tional Food Policy Research Institute [IFPRI], Internatio nal Center for Tropical	REU	144 villages; 12,000 farm HHs; 100 HHs per unit of observation; 10,800 direct beneficiaries ; Children 6-35 months	Evaluate the REU project in East and Southern Africa.	• Conceptual framework adapted from TSNI • Diagnostic analysis • Randomize d control trial, two interventio n models • Qualitative interviews • Baseline and endline surveys included demograph ics, income, production,	• 66-69% point increase in probability of OFSP adoption • Substantial substitution of OFSP for other sweet potato varieties • Vitamin A intakes doubled among young children (45g/day), older children (70g/day), and women (145g/day) • Vitamin A intake roughly equivalent to 100% estimated

Table 1 continued

			Agriculture [CIAT]), Gates Foundation, USAID, etc.				consumption, social networks, dietary intake, etc.	average requirements • Intervention intakes higher than control • OFSP contributed 71-84% total vitamin A intakes • Adoption probability increases as kilograms of vines received increases • OFSP 25% of sweet potato in markets • >85% consumers would purchase OFSP in future • No difference in impact in cheaper model of intervention • Yields of OFSP similar to WSP
Bechoff A 2011	Mozambique	Not specified	Harvest-Plus	REU	Two OFSP varieties	Evaluate carotenoid retention after simple low-cost drying and storing chips made from Resisto and MGCL01 varieties of	• Chip drying • Carotenoid analysis • Dry matter determination	• Total carotenoid losses during drying low, 9.2% average • Carotenoid losses during storage high after 4 months, 83.7%. • Shade drying best option for

Table 1 continued

						OFSP under rural conditions, on-farm setting.		Mozambican farmers, less carotenoid loss than open air • Shade dryer not suited for thicker, handcut slices (traditional way) due to longer drying time • Chip size had a significant effect on drying but not storage • Variety affected both drying and storage • Higher level of technology does not necessarily lead to greater carotenoid retention
Brito L 2012	Mozam-bique	Review[b]	EU ResIST	ResIST	Review[b]	Discuss key concepts relating to sweet potato biotechnology and its diffusion in Mozambique.	Review[b]	• Sweet potato largely a staple of poor households • All provinces except Niassa received distribution of OFSP cultivars in 2007 • USAID invested $500k in OFSP

Table 1 continued

								tissue culture laboratory • Market for vines increasing; shortage of quality vines • Regional variation in consumption of OFSP, least frequent in Cabo Delgado • Breeding more expensive than dissemination • Informal sharing of vines key to access • Benefits from sale of OFSP not evenly distributed, larger farmers producing more for market
Hotz C 2012	Mozam-bique	2006-2009	WV, HKI, Harvest-Plus (IFPRI, CIAT), Gates Foun-dation, USAID, etc.	REU	144 villages; more than 12,000 farm HHs; 100 HHs per unit of observation; 10,800 direct beneficiaries; children 6-35 months	Learn lessons about scaling up OFSP.	• Conceptual framework adapted from TSNI • Randomized control trial, two intervention models • Baseline and follow-up surveys	• Vitamin A and OFSP intake greater in both models (47-60% of all sweet potatoes consumed) • OFSP provided 71-84% of total vitamin A across all ages

Table 1 continued

							• Six OFSP varieties chosen for distribution	• Inadequate intakes of reference children decreased 32 and 55% in both models; similar results for women • Median intake for all intervention children 46g • 77% HHs adopted OFSP for cultivation • 56% sweet potato grown was OFSP • Two models had similar impact
Harvest-Plus 2012	Mozam-bique	2006-2009	WV, HKI, Harvest-Plus (IFPRI, CIAT), Gates Foun-dation, USAID, etc.	REU	14,000 farm HHs targeted	Summarize outcomes of REU from 2006-2010	• Conceptual framework adapted from TSNI • Randomized control trial, two intervention models • Baseline and follow-up surveys	• See de Brauw 2010 above
de Brauw A 2013	Mozam-bique; Uganda	2006-2009	IFPRI	REU	36 community organizations in separate villages, goal 20 HHs	Compare impact of REU intervention within and across Mozambique	• Randomized impact evaluations • Causal mediation analysis	• 2/3 mothers named OFSP as source of vitamin A • 75-79 % farmers grew OFSP at

Table 1 continued

					per village - achieved in most villages. Actual at baseline: 703 HHs and 441 children. Actual at endline: 628 HHs and 409 children. Producers and consumers of OFSP.	and Uganda on OFSP adoption, knowledge of vitamin A, and dietary intake of vitamin A by children.		endline (9% control) • Substantial substitution of OFSP for conventional white/yellow • Growing OFSP influences vitamin A intake regardless of amount produced • Intervention children consumed almost twice as much retinol activity equivalent (RAE) at endline compared to control (600 vs 350 micrograms), fully attributable to OFSP • Diffusion rate of 0.32 in Mozambique, helps to lower cost of intervention
Maquia I 2013	Maputo province, Mozam-bique	2006-2008	CIP, Ministry of Science and Technolog	None	44 sweet potato accessions, 28 genotypes	Characterize the Mozambique sweet potato germplasm collection by 1)	• Field trials conducted over 2 seasons	• High level of diversity in Mozambique germplasm

Table 1 continued

			y, Universidade Eduardo Mondlane (UEM), etc.			genetic, morphological, and agronomic diversity, and; 2) agronomic potential toward drought tolerance.	• Morphological and agronomic characterization • Random amplified polymorphic DNA analysis	• Good source of traits for breeding • 6 Mozambican varieties and 4 others have highest drought tolerance • Majority perform best under irrigation
de Brauw A 2014	Zambézia province, Mozam-bique	2009	IFPRI	REU	439 HHs, 682 farmer respondents	Explore risk preferences related to sweet potato production among Mozambican farmers.	• Uses data collected during final REU survey to test several models of risk preference	• On average, sample is risk averse, but does not follow standard constant relative risk assumption utility function
Carvalho I 2014	Mozam-bique	Not specified	Swedish International Development Cooperation Agency (SIDA)	None	134: Sensory panel of 50 volunteers from UEM (students and staff). Untrained panel of 84 regular consumers of *garri*, or flour made of roasted cassava (farmers,	Develop a porridge acceptable to consumers that incorporates roasted grated OFSP and shredded sun-dried cassava.	• Roots collected, dried, and processed to create porridge • Mechanical characterization of porridge consistency • Color measurements/ microscopy	• Porridge made solely from OFSP unappetizing • Sensory test of consistency: mixed OFSP and cassava porridge ranked first of 5 porridges • Overall sensory test: mixed OFSP and cassava porridge was significantly preferred over simple cassava

Table 1 continued

					market shoppers).		• Sensory ranking of consistency • Sensory acceptability of multiple attributes	porridge for all attributes • Flour made from grated OFSP and shredded sun-dried cassava improves perceived consistency and energy density compared to traditional cassava porridge

[a]Partners include funders and implementers. For projects that include many partners, all may not be listed in table.
[b]Article did not specify methods but rather focused on a review of literature and/or events.

CHAPTER THREE

FACTORS AFFECTING FARMER WILLINGNESS AND ABILITY TO ADOPT AND RETAIN IMPROVED VARIETIES OF ORANGE-FLESHED SWEET POTATO IN MOZAMBIQUE: A QUALITATIVE APPROACH

Contribution of Authors and Co-Authors

Manuscript in Chapter 3

Author: Mica Jenkins

Contribution: Mica Jenkins is the lead author on this article and was responsible for research design and methodology, field research including interviews and focus groups, translation and transcription for all interviews, construction of the coding template, coding of transcripts, structure and content of the manuscript, creation of tables, editing, and final submission.

Co-Author: Dr. Carmen Byker Shanks

Contribution: Dr. Carmen Byker Shanks provided guidance in research design and methodology driving field research She also participated in coding template development, coding of transcripts, writing and multiple edits of the manuscript and tables.

Co-Author: Dr. Roland Brouwer

Contribution: Dr. Roland Brouwer provided guidance in research design, in-country support for field research, and multiple edits of the manuscript and tables.

Co-Author: Bailey Houghtaling

Contribution: Bailey Houghtaling provided coding of transcripts and a final edit of the manuscript and tables.

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ABSTRACT

Objective

The objective of this research is to understand factors that affect Mozambican farmer adoption of orange-fleshed sweet potato (OFSP) varieties, with a specific interest in the retention of planting material.

Design

Qualitative inquiry was used to assess participant progress through the five stages of the Innovation-Decision process proposed in Rogers' Diffusion of Innovations Theory.

Setting

Field research was conducted in three provinces of Mozambique during 2015. Provinces with different intervention histories were selected to allow for the identification of site-specific factors and the impact of variable intervention approaches over time.

Sample

Ninety-five producers, consumers, and market stakeholders of OFSP were purposively sampled.

Method

Semi-structured in-depth interviews and focus groups were conducted. All interviews were de-identified, translated and transcribed verbatim. Data analysis consisted of the separation of meaning units, independent coding, and resolution of themes and subthemes.

Results

Results indicate that a wide variety of factors influence adoption and retention of OFSP, including: organoleptic qualities and taste preferences; access to planting material; agronomic traits; dependence on others for planting material; lack of capital for inputs and labor; unstable markets and fluctuating prices, and; varying levels of sharing of information and planting material across farmer networks.

Conclusion

Current OFSP varieties are highly acceptable to Mozambican farmers and consumers, but their adoption faces many challenges to reaching critical mass. These challenges are discussed in detail and should be considered in future planning for OFSP interventions in Mozambique and other regions with similar contexts.

Keywords: orange-fleshed sweet potato; vitamin A deficiency; nutrition; Mozambique; farmers; food-based approach

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INTRODUCTION

VAD in Mozambique

Vitamin A deficiency (VAD) affects over 200 million women and children worldwide[1] and 71% of children between 6 and 59 months of age in Mozambique despite periodic efforts by the government to distribute vitamin A supplements.[2] Lack of this essential micronutrient can lead to weakened immune systems, growth limitations, xerophthalmia leading to blindness, and increased mortality.[3] The risk of death for children under age 5 with VAD is 1.75 times more likely than for children without VAD.[4] VAD is a highly preventable condition that can be mitigated with the consumption of vitamin-A-rich foods that contain preformed vitamin A in the form of retinol or beta-carotene, a precursor to vitamin A.[5,6] Retinol is derived from animal foods and beta-carotene is found in plant foods, including orange-fleshed sweet potato (OFSP), which has been utilized as an important food-based intervention in areas with chronic VAD.[7,8,9]

Rationale for OFSP Introduction

The Portuguese introduced white-fleshed sweet potato (WFSP) to Africa in the 16th century.[10] Today, it is an important energy-dense food security crop in Mozambique,[11] where cyclical drought and flood are common.[12] Economically, the sweet potato (SP) is the third most important staple crop in Mozambique after cassava and maize[13]; production levels for 2012 were estimated at 900,000 metric tons (MT).[14] Generally, the sweet potato is a hardy crop that often succeeds when other staples fail[15]

and can be produced multiple times a year with access to water and proper vine management. Sweet potato is vegetatively propagated, and in times of intense heat and drought, vine segments must be cut and replanted in moist lowland areas to prevent drying and loss of planting material. This preservation process, when properly conducted over time, can lead to long-term retention of OFSP planting material in communities. While the WFSP varieties commonly grown and consumed in Mozambique are low in beta-carotene,[5,16,17] OFSP is rich in this precursor to vitamin A. Further, several authors have reported that OFSP is well-liked by Mozambican consumers and farmers[7,8,9,16,18,19,20] and the crop can be easily incorporated into current food systems.

The Introduction of OFSP to Mozambique

Beta-carotene rich varieties of OFSP were first introduced to Mozambique in 1997, when 38 varieties were received for testing at the Umbeluzi Research station outside of Maputo.[5] Since that time, a wide variety of government and non-government organizations, as well as international funders, have been involved in the breeding and promotion of OFSP. More information about the history of OFSP and organizational involvement can be found in Low et al.,[21] Low,[22] and Jenkins et al.[23] Medium for promoting OFSP production, use, and consumption have included vine distributions, rural agricultural and nutrition extension workers, training on improved agricultural practices and cooking methods, billboards, radio announcements, community drama, specific market stalls for OFSP, and the distribution of bright orange *capulanas* (fabric), shirts, and hats.

Despite considerable progress made after fifteen years of research and collaboration by government agencies and the international public sector to promote OFSP as a food-based solution to VAD in Mozambique, including the 2011 release of 15 drought-tolerant varieties of OFSP bred in Mozambique,[22] there are several remaining challenges that have prevented this crop from reaching critical mass. These challenges include: preservation of planting material and retention of OFSP during drought and flood; pest and disease management; market development for OFSP; and storage and processing for OFSP roots. The objective of this research is to explore factors affecting Mozambican producers' willingness and ability to procure, preserve, cultivate, and distribute OFSP varieties using the Diffusion of Innovations Theory,[24] with a particular interest in the retention of planting material seasonally and over time. We were also interested in the formal and informal interpersonal channels that may lead to the adoption or rejection of OFSP technology. The results of this research may be used to inform the design of future food-based approaches to alleviating micronutrient deficiencies in geographically specific contexts.

RESEARCH DESIGN

The variable adoption of OFSP in Mozambique directed the research team to apply the Diffusion of Innovations Theory[24] to determine the factors affecting the spread of OFSP and related technology throughout communities. The Diffusion of Innovations Theory was used to guide the development of primarily qualitative methods, including

semi-structured interviews and focus groups, coding, and data analysis and interpretation in order to assess participant progress through the Innovation-Decision process.

Rogers (2003) analyzes adoption of innovation through five stages: knowledge, persuasion, decision, implementation, and confirmation (See Table 1).[24] These five stages are referred to collectively as the Innovation-Decision process and include exposure to the technology or idea, opinion formation, experimentation with and use of the new technology or idea, and finally the decision whether or not to continue using the technology or idea in the long-term. Furthermore, relative advantage, similarity with current practices, ease of use, ability to experiment with before adoption (i.e. trialability), and tangible results of an innovation influence the pace of adoption and the decision-making processes of current and potential producers, consumers, and market stakeholders.[24] For example, because WFSP varieties are widely grown in Mozambique,[5,16] the orange varietal is not an entirely new technology, and is believed to be at an advantage for adoption due to its similarity with current practices.

Table 1. Measures for Assessing Participant Progress through Five Stages of Innovation-Decision Process in Qualitative Study Designed to Understand Orange-Fleshed Sweet Potato (OFSP) Adoption in Mozambique, 2015

Diffusion of Innovations Stage (Rogers, 2003)	**Measure**
Knowledge: exposure to an innovation and understanding of how it functions	• When and how did you learn about OFSP? • When did OFSP first appear in markets?
Persuasion: formation of favorable or unfavorable attitude toward the innovation	• Why is SP (OFSP and/or WFSP) important in your community? • Is SP a respectable crop? • How are WFSP and OFSP similar and/or different?

Table 1 continued

Decision: engaging in activities that lead to a choice to adopt or reject the innovation	• When and how did you begin to produce OFSP? Why did you start? • When did you first eat OFSP?
Implementation: putting an innovation to use	• What is the area of your OFSP production? • Are you a landowner? • How is OFSP used in your home? • Are SP leaves used in your home? • Which OFSP varieties are used in your community? • Who decides how OFSP will be produced, harvested, and sold? (Man, woman, child?) • How do you plant OFSP and WFSP? Together or separately? • Do you use fertilizers, tractors, and/or hired laborers? • How many times a year do you plant and harvest WFSP and OFSP? • How are vines preserved? • What is the post-harvest process for roots? Do you have storage for SP? • Is there a difference in the amount of water needed for OFSP and WFSP? Which is more resistant to sun? To bugs? • Which SP produces faster? • Is there a difference in the work involved with OFSP and WFSP? Is one harder to produce than the other? • Why does planting material sometimes disappear?
Confirmation: seeking reinforcement of decision already made; may reverse previous decision if exposed to conflicting messages about the innovation	• What is the SP that you and your family prefer? • Have you shared OFSP with other people? • How can a person obtain OFSP vines? • Do you sell SP? Where? What is the price of OFSP and WFSP? • Which is the SP that market clients prefer? • How can SP projects improve in the future?

SETTING

Field research took place from January to October 2015 in three provinces in Mozambique that differ in terms of agro-ecology, culture, socioeconomic realities, market norms, and intervention history: Manhiça in Maputo Province, Macate in Manica Province, and Gúruè in Zambézia Province (See Table 2). The sites were chosen on the basis of the following parameters: (1) the occurrence of recent involvement with OFSP promotion efforts, such as International Potato Center (CIP) vine distribution activities through the Scaling Up Sweet Potato Through Agriculture and Nutrition (SUSTAIN) project and/or (2) previous distributions of OFSP planting material conducted by CIP and other organizations including ActionAid, Africare, and World Vision. The first author spent approximately one month in each of the three locations to conduct in-depth semi-structured interviews and focus groups.[25] The third author facilitated site relationship. Coding and data analysis was conducted by the first, second, and fourth authors and reporting was conducted by all authors from Maputo, Mozambique and from the United States.

Table 2. Characteristics of Research Sites in Study Designed to Understand Orange-Fleshed Sweet Potato (OFSP) Adoption in Mozambique, 2015

District, Province	*Geographic Context*	*Population*	*Key Commodities*	*OFSP interventions past and present*[e]
Manhiça, Maputo	80 kilometers northeast of Maputo city	160,539[a]	corn, cassava, beans, peanut, sweet potato[b]	CIP-SUSTAIN[f] (current); ActionAid (2001 forward)
Macate, Manica	25 kilometers east of Chimoio city	Newly designated district, population data unavailable	corn, beans, sorghum, cassava, peanut,	CIP-SUSTAIN (current); CIP/OFDA[g] disaster relief

Table 2 continued

			rice, sweet potato[c]	effort (2012-2013); Africare (2002-2006)
Gurúè, Zambézia	In the Namuli Mountain Range	299,565[a]	tea, corn, beans, sorghum, cassava, rice, sweet potato[d]	REU[h] (2006-2009); Eat orange (2006)

[a]*Recenseamento Geral da População e Habitação*. Maputo, Moçambique: Instituto Nacional de Estatística; 2007.
[b]*Perfil do Distrito de Manhiça*. Maputo, Moçambique: Ministério da Administração Estatal; 2005.
[c]*Perfil do Distrito de Gondola*. Maputo, Moçambique: Ministério da Administração Estatal; 2005.
[d]*Perfil do Distrito de Gurúè*. Maputo, Moçambique: Ministério da Administração Estatal; 2005.
[e]Not an exclusive list. For more information about OFSP interventions see Low et al. 2013, Low 2013, Jenkins et al. 2015.
[f]International Potato Center project Scaling-Up Sweetpotato through Agriculture and Nutrition
[g]A collaborative effort by the International Potato Center and the Office of Foreign Disaster Assistance of the United States Agency for International Development
[h]Reaching End-Users project in Zambézia

SAMPLE

Random sampling of participants in three communities of focus was deemed inappropriate for this research, as the objective of the research was to understand the causes and mechanisms driving retention and not to obtain an overall understanding of retention of OFSP in research sites. We employed three purposive sampling strategies to recruit interview and focus group participants: critical case sampling of participants with specific experiences; key informant sampling of participants with special expertise; and snowball sampling of participants identified by other informants.[26]

Participants were identified by: contacting individuals who have been involved with CIP, including current staff, decentralized vine multipliers (DVMs), and project beneficiaries; seeking the assistance of local government extension workers; engaging in conversations with the leaders of farmers' associations; visiting local markets; and through word-of-mouth.

METHODS

The Institutional Review Board at [blinded institution] approved all stages of this research and verbal informed consent was obtained from all participants before proceeding with research. Basic demographic information was gathered through a simple questionnaire (See Table 3). The script for in-depth semi-structured interviews and focus groups was designed to assess individual progress through the five stages of the Innovation-Decision process (See Table 1).

Table 3. Demographic Characteristics of Participants in Interviews and Focus Groups Designed to Understand Orange-Fleshed Sweet Potato (OFSP) Adoption in Mozambique, 2015

Variable	*Mean (±SD) or %*
Region	Manhiça=26.3% Macate=50.5% Gurúè=23.2%
Age	Sample=39.1 (±15.2) F=35.1 (±11.8) M=45.7 (±17.8)
Sex	F=63.2% M=36.8%
Married[a]	Sample=81.1% F=76.7% M=88.6%
Number of children	Sample=4.7 (±2.9) F=4.2 (±2.5) M=5.5 (±3.5)
Education level	Sample=5.0 (±3.1) F=4.2 (±3.1) M=6.4 (±2.7)
Occupation	Producer=87.4% Vendor=7.4% Other=5.3%
Holds a leadership position	Sample=42.1% F= 25% M=71.4%
Involved in community organizations	Sample=93.7% F=95% M=94.1%

[a]The remainder of the sample was unmarried (9.5%%) or widowed (9.5%)

Interviews and focus groups were conducted at or nearby participant homes or the homes of community leaders. Focus group participants were segregated by gender when possible to adhere to normative cultural practices. When the researcher felt it would have been inappropriate to exclude those who demonstrated a desire to participate or there was not sufficient time or number of participants to segregate genders, the focus groups were conducted with both males and females (n = 9).

Interviews and focus groups were conducted in Portuguese by the first author or in local dialects with facilitation by translators, dependent upon the context and the preference of the participants. Female participants depended on translation more often than male participants, which may be attributed to the fact that male participants averaged a greater number of years of formal education (See Table 3). All interviews and focus groups were recorded with participant verbal consent to ensure that all information was captured. The first author also kept a detailed field log with notes from interactions with NGO staff and government extension workers, informal conversations with OFSP stakeholders, plans for interviews and focus groups, and lists of recurring themes of research. Notes from this log have been triangulated with findings from interviews and focus groups, contributing to the overall validity of results.[27]

Qualitative data analysis was ongoing as interviews and focus groups proceeded; interviews were de-identified for anonymity, transcribed verbatim, and translated into English by the first author. The first author chose to translate interviews from Portuguese into English simultaneously while transcribing due to a high level of fluency with the Portuguese language and also to ensure efficient use of limited time and resources.[28]

Meaning units (MUs), or distinct data constituting a single idea, were separated into fragments and organized in a coding template developed by the researchers.[29] Once all interviews were complete, the first, second, and fourth authors independently coded the fragments for appropriate themes and subthemes, using a deductive approach and the five stages of the Innovation-Decision process as main constructs.[24] Coding authors worked from a codebook of 79 subthemes developed by the first author and agreed upon by co-authors, while also allowing for additional subthemes to emerge during coding. Once independent coding was complete, the first author took note of all discrepancies between coders in the constructs (n = 1,105) and subthemes (n = 1,088), suggesting a resolved construct and subtheme for each MU. These resolved categories were then approved or rejected by the other two coding authors, resulting in a smaller number of discrepancies in the constructs (n = 0) and subthemes (n = 13) that were resolved by coding authors. Finally, the 79 original subthemes were discussed by co-authors and collapsed into 23 themes, outlined in the results section of this manuscript. This rigorous coding process ensured a high-level of interrater reliability.[30] Data was disaggregated by study location and number of MUs that appeared in each category and subcategory was calculated. Findings from the three locations are compared below to provide insight as to how the varying factors in these locations may affect the adoption or rejection of OFSP technology.

RESULTS AND DISCUSSION

Participants included OFSP producers, vine multipliers, consumers, and market stakeholders with varying levels of exposure to and experience with OFSP. Ninety-five participants (F = 60, M = 35) were included as individual informants (n = 15) or focus group participants (n = 80, FG = 15). Meaning units contributed by males and females were equally represented, regardless of imbalance in the number of participants. Interviews and focus groups lasted a maximum of 87 minutes and a minimum of 28 minutes, with an average of 55 minutes (SD±15.8). In total, 3,015 meaning units emerged across 23 themes and 79 subthemes, all organized under the five Diffusion of Innovations constructs. Table 4 exhibits the final themes and subthemes categorized under the Diffusion of Innovations constructs, along with sample meaning units. Additionally, the number of meaning units generated from Manhiça, Macate, and Gurúè are shown in order to explore regional differences.

Table 4. Theory Constructs, Themes, and Subthemes in Qualitative Study Designed to Understand Orange-Fleshed Sweet Potato (OFSP) Adoption in Mozambique, 2015

Construct	Theme	Subtheme	MUs, No.			Example MU
			Manhiça	Macate	Gurúè	
Knowledge	Expertise	Friend or family	3	13	3	P31: Then when I saw this type of vine, it's when I asked, 'This vine, what type of vine was it?' It's when she started to explain to me that this vine is orange pulp. Then I liked those potatoes…she took out those potatoes, left that vine, I took those seeds. It's when I already started to plant this potato, after.
		Vendor Knowledge	7	0	5	P1: They don't know the difference [in varieties]. We that are the vendors here know the difference. P87: When a client arrives that wants orange, if you give yellow, tomorrow they're not going to buy with you. P86: Then you can't, yes, you're going to mess up your business.
		Government or NGO	20	69	24	P2: This here was the government that gave us - it was an NGO. That gave us vines to…plant afterward, each one was given…three varieties.
		WFSP produced previously	3	21	12	P66: Eh many years yes…Already I don't know, but it's many years even.
	Time	1 year or less	10	48	9	P94: I started this same year. Translator for P52: …she started this year. It's the beginning this year.
		2-5 years	2	11	8	P93: Here, it started in…2012. Yes for my part that I started then to multiply.
		6-9 years	4	2	5	P83: This is the 6th year. I started in, yea. I started in 2010.

Table 4 continued

		10+ years	8	7	10	P13: That was in 2000, 2002…Then, as soon as it was planted, it was applied, and people started to eat it.
	Genetic variation	Variation w/in OFSP varieties	9	16	20	P32: And CIP brought many varieties…Just that in each, in each DVM already they received around five varieties… For example in my house, I received five varieties.
		Discussion of non-OFSP varieties	3	10	3	P1: It's white flesh, this, because it had a, thre, on the side, like, a little yellow, not the white one. But there inside, already white white, just like an egg. P31: We already said that you have a thing of three, three groups of vines. This white exists, this orange pulp exists, and this one that we already said exists, very well known here in Africa… 'Secai'…then it also has, it's full of flour. Eh, one potato only for you, already it's enough.
	SP terminology	Terminology surrounding SP	4	4	13	P82: While this [WFSP] original, this ours… P31: Also it [OFSP] was a novelty also for me. P29: That it's a new potato…It's special yes.
		Names of varieties	7	22	13	P13: Ah the names, it's not possible to know them all…I don't know Tia Amelia, something like that…They give a name, the communities, name that isn't, isn't that that when it's received, you know. P68: Eh, they are eight varieties. In this year it was Lurdes, Melinda, Namanga, Jane, Cecilia, Ininda, Tio Joe, and Delvia.
Persuasion	Human Health	Illness	6	6	3	P2: ...children, when sick children eat it, they return quickly as possible…we like it a lot because it helps us in the sick children.
		Vitamin	10	26	8	P39: We learned that there is a difference…between white pulp and of orange pulp. Of orange pulp, it's a potato that has vitamin, vitamin A? Translator for P70: ...because we heard that the same potato…brings us nutritious, eh, the vitamin A, also, it makes children grow well with health…from 0 – 5 years forward. Then, also, it also gives, eh, vision, in the visions.
		Medication	5	2	2	P75: In the actual potato, it serves also as, medicine in your body, it works a lot.

Table 4 continued

		Nutrition and health	12	23	14	P1: I have to eat this potato. Because I know in the body it's good for me. P36: It makes good health for people. P39: It's good also for the children.
		Energy	0	6	1	P35: When you use it for breakfast, then the children, joined with them, they eat it, after they have energy to do other work. P29: It's a food for energy. It gives us strength and energy to be able to manage the strength to work.
		Food security	8	13	12	P83: The orange pulp, at times, during two, two months, it already has tubers below. It can come to help in the time, already that we're going in the time of hunger, in the months of, of hunger because from November to January, February, it's the time of hunger. While this, of thing, ours, from here, regional…It takes longer. It can take around six months.
	SP respectability	SP respectability	7	17	9	P13: They are, they are [respected]. Because they are the first, now that it's ending, the time of flooding is ending, the first crop that is applied in the land is the vines of sweet potatoes.
	SP organoleptic qualities	SP 'like bread'	3	1	1	P82: Because sweet potato you can just roast, you can cook it. Yes, for this, it's our bread here. Translator for P4: He says, as they don't have a bakery here, eh, close, it's the quicker bread, accessible, that you can find.
		Color	3	5	3	P2: We have this our potato that has, has colors. But they're very different. Mm, they're different.
		Flavor	10	23	12	P50: Eh, the difference maybe is in the flavor. That one seems very, eh it's very, a little sweet in relation to this our one. This our white one. Translator for P56: She says that orange pulp is better…It's better in the flavor, it has flavor. Translator for P60: P60 says the difference that is, but also, this of orange pulp, the flavor is very good, it's good even, when you are consuming it.

Table 4 continued

		Aroma	3	2	2	P50: This has an agreeable smell also, this orange, this orange pulp, it has a smell a little agreeable…Yes it has an agreeable smell in relation with that white.
		Texture or Wateriness	4	4	7	P29: That potato there [WFSP] brings a dry pulp, not very liquid. P85: [OFSP] it's not watery. Translator for P80: Yea she is saying that, the difference is that the orange pulp is good, when a person cooks it, no, it doesn't get very watery, while that white, a person cooks it, in a little while, it's normal also for it to be crushed there even. P31: The white has, it has a lot of flour. While orange pulp doesn't have a lot of flour.
		Sap	0	0	5	P75: Because, another thing that the people noted, they saw that that white pulp had a thing that seemed like glue, in the mouth. After you, eh, you eat it, it seemed already, it glued the lips…While this new varieties, no. You eat it as if it was even, a simple food. P83: This local, when you eat it, here, here in the mouth, it has…sap here. Yes, who sees it is going to know that that person already ate sweet potato. While this orange pulp doesn't bring anything here in the mouth.
	SP important for business	SP important for business	3	27	6	P28: A lot a lot, the important of that there, we just use it just to sell. P53: If it was in quantities, for sale also to be able to have money.
Decision	Experimentation	Experimentation	10	21	6	P85: Our group, we have that thing of, when we cultivate, our producers come…we start to cook, then, to try, which is the potato that is worth it, that isn't worth it. Translator for P53: She says that she still doesn't, doesn't know, they are still observing to compare when it's going…to come out first.

Table 4 continued

	Training	Training	5	9	6	P29: In the training we learned the planting of OFSP…Of how you can prepare the soil. For your planting. And from there, we learned about nutrition.
Implementation	Culinary practices	Cooking method	27	42	40	P49: We, it's just, to dig, after digging, wash, put it in the pot, put salt and send it to cook. After peel it, start to consume. P23: Sweet potato, the value of it in this zone, it has two plates only. To make 'xiguinha' and cook, drink tea with it. Only. It has two plates only. P15: And she does everything with that sweet potato, because even cake, you can make.
		Family consumption	6	6	10	P91: Ah I ate, until at home already there's a little left that I conserved, that the children are eating. Translator for P5: She says that everyone eats it [SP] at home. P1: When I have potatoes, I have OFSP, I make 3 potatoes or 4, I take one I give it to my daughter, I take another give it to the other, I also eat one, another potato for the father.
		Leaf consumption	7	16	26	P88: Because the white potato, when a person cooks it, the leaves don't taste good. P89: Also, it has a thing that gets a little bitter. P88: Yes yes, now that there, that one that's there, that leaf. It's very tasty. That one there, orange pulp potato.
		SP used for which meal	5	24	17	P13: We use it to take tea. Translator for P25: Yes she was saying that sweet potato, they don't, don't have the habit to use the sweet potato for lunch and dinner. Generally the sweet potato is for breakfast. Make a tea that they drink in the afternoon, when they get back from the farm for example. P83: Some people that make it for lunch…Principally when not having, not having curry on that day.
	Agricultural inputs	Fertilizer	9	21	9	P69: I didn't use [fertilizer] but I wanted to use, just that only the conditions to buy…for a big farm…Yes it's due to money.
		Soil	12	27	12	P29: We have a soil mixed with a bit of sand a bit of, of clay…it enjoys a lot more in that part, that soil that has…a bit of, of sand, a bit of clay. P93: It's necessary a, a mixed soil. Yes. That red a bit also black. A mixture yes.

Table 4 continued

		Transportation	6	25	6	P23: Eh, the road also isn't good…there is a river…a lake that you cross, there are no boats.
		Water use	19	20	13	P13: Because they think it's not going to produce well because there is a lack of water to water. While that other one [WFSP] doesn't need water. P26: When the rain falls well, it doesn't have that it's orange flesh, it's, it's white, it just grows the same, it's going to depend on the rain.
	Human inputs	Children's role	0	8	4	P28: He's going to do what he wants with the money…Eat cakes, I don't know, many things. Now, to say to me 'Papa, I want to buy cake'. Ah, I don't give. 'Make a farm, you make, then, you do what you want.' And he does it. P62: We are seeing a large impact in the sweet potato, because even a youth of ten years, but s/he already knows the importance of sweet potato, s/he is going to produce, to sell to make his/her money.
		Women's role	15	11	12	P66: A lot a lot, they are, they are the mothers. We are the mothers yes. Yes…Eh, these fathers say 'eh we have a lot of work', or 'it's not our work'.
		Men's role	6	12	24	P27: Children are children, men are the ones who save the seeds…Men save seeds. Children, women, ah they don't manage…Just, just good to eat only. To save, it's men that save this crop, seeds.
		SP is anyone's work	2	23	13	P74: They have to do, doesn't matter if it's man, doesn't matter if it's woman. If it's woman, if it's not woman, you have to do it if you have strength in your body.
		Hired labor	1	12	8	P50: Then, I had to give to some people to help me make seed beds, because to make a seed bed is somewhat hard work. P31: I have people that, it's not really employees, I ask for 'ganho-ganho' (/day labor/)…When I need it…Yes yes. Because alone I'm not able to do it even.
		Role of traders	2	27	8	P27: In Chimoio, when you arrive, at the foot of Chimoio, you have those that are called 'jorijo' those. It costs a lot, that man that does 'jorijo', takes it, only, sells it, while you, it's little, him in the middle, he didn't do agriculture, he, he takes more money. I, finish a year, take it, don't even

Table 4 continued

						have money… He just picks it up. Picks it up only. Sells it there, he buys it from me, he sells it there, then he takes more money, I take a little.
		Labor intensity of SP	14	21	24	Translator for P35 and P36: It's to say that white pulp is easy in relation to orange pulp, because the orange pulp needs that, that maintenance, that, that attention there. Translator for P37: She is saying that the white pulp, even with weeds, mixing the soil and weeds, it's possible to put the, the vine. But as to the orange pulp, it's necessary to prepare, take it out, take out those trunks, also roots of, of, of weeds, it's necessary to take it out, to have only clean soil.
		Dependence on organizations for inputs/support	14	22	31	Translator for P77: Then what she is asking for, she is asking if there is a possibility, to exist a project that can come. In another way, like they did a long time ago, to make the group develop and lift up. That's what she is asking. Because the potatoes, the vines, they already know, but it's necessary even to exist a strong lift, and that they are asking for project support.
	Environmental conditions	Drought	2	2	23	P30: The drought, white resists more…For example here where you are seeing, I already planted, already four or five years passed, when I did potato here. But I try to weed for it to come out, it doesn't come out. No no…Yes it resists. It doesn't come out of here. Here I haven't planted, already five years have passed...Five years vines, but I am accustomed to try, 'epa', to weed and maybe it already passed, but it's going to germinate more…It's strong, it resists more.
		Flood	27	2	7	Translator for P21: Then his problem, of our zone, is that, we are producing, but, what makes us sad is that, when you produce, annually, floods have to come. Take all our crops.
		Resistance to sun	3	9	10	Translator for P55: If you harvest and don't take out the [OFSP] vines to go put in the lowlands, where there is moisture, it doesn't manage to endure outside. While the white pulp endures outside.
		Seasonality	2	42	25	P32: While it's very important to have the vines in the beginning of the rains, because that first potato is the one that also has a bit of an elevated price. Then the tendency is to, is to go buy even, even this of white pulp, to

Table 4 continued

						have…some seed…until in the beginning of January, or the end of January, you're already going to take out that potato, while there still isn't a lot of quantity of, of potato.
		Pest and disease	4	35	25	P69: Yes the bugs here attack even in the same form. Yes, how they attack the potato, of orange pulp, of white pulp, yes it's the same thing. P33: She says that the pulp, the white pulp, is very easily attacked, with bugs. But the orange pulp, it's, it's a bit normal, it's not attacked in any way. Translator for P55: She says that the orange pulp is more frequent the bugs…Than white.
	Land use	Plot size and dispersal	5	42	43	P88: This year I produced twenty meters by twenty… Of sweet potato. P29: At my house the field is…a bit, a bit small. But, eh, I can say, it's 0.25 hectare. P31: Yea hectares, I can say something like five…Of sweet potato. P81: I have another [plot] there, another there, another there.
		Land ownership	0	3	11	P74: It's my land… I didn't take out any document, they just gave it as family.
		Other crops	5	25	22	P23: When you hear...the flood…then you no longer have time to take out, eh, sweet potato vines. You have to run take out, the, the crops that are more important. Which is peanut. It's corn. That is in front. P74: Yes yes because… you do sorghum, it doesn't come out, he does rice, it doesn't come out, we trust in cassava.
	SP growth	Root growth/size	5	10	2	P50: That orange pulp, because at times it develops…it is longer, no? The actual potato is longer…While this white pulp…it's more round. P49: [WFSP] it's just voluminous…But that orange pulp, eh, it's long.
		Time to root maturity	14	14	12	P30: The difference that exists, this white pulp, when we plant it, it delays. Mm? It delays to arrive to the time to take it out. While orange pulp no. When you plant it, after a month, it's already two, when you take it out like this, a little, you're already going to see, it already has, it already has potato below. And pulp, this white no. It has to stay there the same.

Table 4 continued

		Vine and leaf development	4	2	6	P74: Orange pulp doesn't need a lot of water…Now this white pulp, it doesn't manage, because it takes a lot of vines…They are longer, they go farther, and they are big…They're thick and they have many vines…They need water…They [OFSP vines] are smaller.
	SP preservation	Curing of roots	0	5	4	P30: When you take it out, you have to put it in the sun a bit…afterward take it out, to the shade. Translator for P36: P36 is saying that there is another system of saving. If you want to save, it's the question of taking it out of the seed bed, then, put it a little to dry…in the sun.
		Storage of roots	17	50	42	Translator for P70: To use for consumption, I have done, digging a hole, a hole like this. I put it, I introduce it there, I cover it…Then, just to use for breakfast. My use. Of all, all, all the potatoes I'm going to sell, but I stay with a bit, no? Beneath the soil.
		Vine preservation	15	43	20	P50: If you see that the temperature is very elevated, just after doing the harvest, take that seed, leave it in the lowlands. Where's there's moisture. It always develops…All types [varieties]. P89: It can only resist when a person transfers to the marsh. Take it out above to go plant…In the lowlands.
		Vine retention	5	26	19	P66: I don't lose vines of potato no…No, I plant all, all the varieties, I have…it's not hard yes, it's not hard at all. P87: Yes it still exists…If it was that there wasn't a shortage, this year, this rain, you would find this whole wall full of potato. P81: We kept producing potato and we make enriched porridge also. We didn't stop.

Table 4 continued

		Loss of planting material	6	6	15	P83: They don't manage to conserve, because I when I receive the vines, later, to go put it in the lowlands. To not dry. While they, they don't manage to do all this…I don't know why. P90: I lost one time, and I went to look with other neighbors. They offered me. P88: They don't control the vines, when they eat sweet potato, eh, they don't control, and don't, don't transfer to the lowlands. P85: They lose vines…when they dig, they don't respect the vines. It's just enough to dig, they leave them to dry. They don't want them to multiply. And another year they're going to want to repeat. But a lot it can't be like this…when you dig those vines, to respect. Put in a, in a shade here, later, go also put it in another place to not lose your vines. Yes.
	Agricultural practices	Improved agricultural techniques	9	62	21	P13: The care, if you produce orange sweet potato, in any form, doesn't produce that fruit that you needed. You need to control, mm, no, other, other vines of sweet potato, apply four vines. In a hole. It's what we grew up doing. But while this one here, it's just with one vine. Afterward you take out 4 or 5 big potatoes. You see what is the difference. P47: This orange pulp you measure. Now this of, of white pulp, it's just to put it…Ah you plant it, you don't measure. P39: And to plant [OFSP], you have to measure, plant in respect, in his rules. Now, this of pulp, white pulp, it's just plant it in any way, we can't measure anything. Planting in any way it also comes out, it doesn't, it doesn't have a lot of complication.
		Mixing or separation of varieties in field	8	23	17	Translator for P15: She is saying that they plant them together here, just that you shouldn't put it in the same place. You have to separate. Because it's not born in the same way, and also, no, no, potato doesn't come out at the same time. That one [OFSP] is fast, the other [WFSP] takes time.
Confirmation	SP preference	I prefer OFSP	3	16	9	P74: The more tasty potato is this, orange pulp…Because, it has, thing, it has, thing, it's more tasty, flavorful. It brings more strengths… Than the white.
		I prefer WFSP	1	0	0	Translator for P6, P4: Then, but in terms of liking it, they prefer more the local variety.

Table 4 continued

		Children like/prefer OFSP	7	7	10	Translator for P77: She says, when the children see that orange pulp potato, the child doesn't leave anything, they eat it until it runs out. They eat it willingly, yes.
		All flesh colors are acceptable	8	4	6	P85: All potato is good even. (laughing) There's not a potato that I would say 'this potato is bad'. Nah, all these potatoes are good even.
	SP popularity	WFSP more popular/sought after	0	1	0	P29: They prefer [WFSP]
		OFSP more popular/ sought after	10	27	27	Translator for FG2: They are saying that, uh, it's not easy, because, each person wants that pulp, because the pulp is good. It's not like that, those [WFSP]. It's not easy to find seeds also. P2: And when we sell OFSP, and that one ours, what, what goes out as fast as possible is the OFSP, that goes out as fast as possible. Than that our one.
		WFSP more common	12	19	3	Translator for P3: The white ones are a lot, almost…She says they have them…The white ones…our vine they have in all places.
		OFSP more common	2	2	10	P75: White pulp already disappeared…Some already have it. But the truth, it seems like it's disappearing. The pulp that is queen is this orange.
	SP economics	Root sale	23	51	28	P25: But it's also important because you can sell the potato. Selling the potato, you can buy, you have a way to buy sugar… Buy soap. Buy oil. Buy tomato. And other things that they can in this way help in their feeding.
		Vine sale	5	34	9	P30: They arrived, 'We are asking to buy.' Because here, vines, you buy. I said 'At first I bought also. Then, if you guys want, buy it also.' Then they are already buying.
		Price of SP	10	41	21	P31: For example if it's that first time there, first time, these that we are saying, November…then, you can make at least 500, 450 [meticais]. The price, one sack like that there…Then, this group of red [skin], you can sell 300, 250 [meticais]…But orange pulp doesn't accept even to be until 250…It has a lot of competition even… Always, we can say that…orange pulp always a price a little advanced. Yes yes.

Table 4 continued

		Unstable markets	5	17	2	P67: It differs, differs like this for, for the movement, at times, eh, ah, you find, find it full there in the market, then, also the price is reduced.
		Mixing or separation of varieties in sale	6	17	11	P30: Last year, when I produced a lot of potato, then, I went to mix. I mixed, it was, this white, orange pulp, then I mixed…Yes inside the sack. When I arrive in [market] 38, they grabbed that sack, potato, potato, after, they went to see, then dumping it out…'Eh, Mama, only potato no no, we're going to choose…I only want orange pulp…Then I went to see that ah, it doesn't have advantage this white…Now I already don't mix. P89: Yes, you mix. This and this, no problem.
	Sharing	Root sharing	6	5	5	P95: No I already gave to my friends….No they liked it. They even come to ask. 'Is there any left?' P1: At times when I fill up a tub, I could sell them but I don't sell them…here at home, I'll put them in plastic and send them to my family in Maputo. That are in Xai Xai. I start to distribute to them. For my sisters.
		Vine sharing	26	60	35	P26: Ah, here in the community, it's to give…It's give because you, also in another year, you can lose, also you're going to ask also from him. Yes yes. We work like this. P89: If you don't have the vines, the time arrives, you can make your seed beds, go ask from any person, they give. P28: Ya, white, who wants to come take can just take even. It doesn't have interest.
		Information sharing	4	7	10	P13: Because it's like this, messed up, the things, unorganized… no one is controlling that…while they have there, you can think they don't have, don't have vines of sweet potato, while they have, just that it's *there* hidden there. When the moment arrives, he's not going to say that 'I have', he's going to continue to do his part.
	Desire to produce OFSP in the future	Desire to produce OFSP in the future	3	9	6	P69: But I have curiosity of what, to produce more. Just that only what makes me are the conditions, the conditions. Yes. I should create conditions for what, to have a large strip, yes.

Knowledge

Expertise

The large majority of participants reported learning about OFSP through the government or an NGO, while a small number reported learning through a friend or family member. This result is not surprising as government and NGO staff and extension workers identified many of the participants. It is very possible that levels of diffusion through the mechanism of friend and family are higher in non-study participants due to recruitment bias.

Time

In Macate, the majority of participants had received vines for the first time in 2014 or 2015. Conversely, in Gurúè and Manhiça, relatively more participants reported having worked with OFSP for six or more years. There was a notable difference in interviewee awareness of OFSP and confidence in making byproducts in Gurúè compared to the other two districts, attributable to the intensive efforts of World Vision and partners to promote OFSP in Zambézia through multiple projects from 2003-2009.[7,31]

Genetic Variation

Several participants, especially DVMs, spoke at length of the variation between the OFSP varieties they have received, noting differences in flavor, color, root size, and leaf shape. Some participants preferred specific varieties, depending upon the recipe. Other participants shared information on yellow and white varieties; in Macate many

farmers emphasized the importance of the WFSP variety known as ‘Secai’, which is considered to be drought tolerant, flavorful, and pleasingly high in dry matter content. This variety could be useful in future breeding efforts to cross OFSP with local varieties with positive attributes.

SP Terminology

Many participants used the phrase “our potato” to describe WFSP, while this terminology was not used to describe OFSP. WFSP was also repeatedly referred to as “the old potato”, “natural”, “local”, “regional”, “original”, or “traditional” while OFSP was referred to as a “novelty”, “new potato”, or “thing of honor”. The tendency to use such terminology to distinguish between sweet potato flesh colors indicates a lack of perceived ownership of OFSP that could potentially have a significant impact on adoption levels.

Relatively few participants, aside from DVMs, were able to recall the names of the varieties of OFSP that they had received and were currently producing. For example, participants in Gurúè reported that they had received the varieties Irene and Gloria during World Vision’s 2003 distributions, which is not possible as these varieties were also released in 2011. Such statements were repeated with other varieties and point to the fact that most farmers do not correctly distinguish between varieties using the names given by breeders. This confusion could be attributed to distortion of information as it is passed from DVMs to vine recipients.

Some interviewees also reported that they rename the varieties used in their communities rather than using the original names, a form of reinvention that could potentially lead to faster adoption and sustainability.[24] The terminology used to describe sweet potato flesh color was regionally variable and often related to color. In Manhiça and Macate, orange varieties may be referred to as "carrot potato", while participants in Gurúè were unfamiliar with this colloquialism. One participant in Macate also compared orange varieties to pumpkin. Similarly, yellow or orange potatoes were sometimes referred to as "egg potato" in Portuguese and in local language due to the color of the yolk. In Gurúè, the name for "orange sweet potato" translates to "egg potato" or "orange" or "red potato". The spectrum of what was considered by some to be a "yellow" potato was very broad, ranging from very light yellow to decidedly orange. While some simply used the word "yellow" to describe any flesh color that was not white, those who had been exposed to the terminology "orange-fleshed sweet potato" were often able to decipher between orange and yellow.

Persuasion

Human Health

Participants in all districts were familiar with OFSP and its relative advantage over WFSP in terms of nutritional value and vitamin content; many reported that OFSP is good for pregnant women and children and should be used in a variety of recipes including enriched porridge, juice, bread, and cookies. WFSP is consumed after boiling or roasting and is not used to create such byproducts to promote human health.

Several participants and market informants mentioned that OFSP is “medicine,” a belief that stems from the fact that it is promoted as a food to help prevent blindness and promote immune health and proper growth and development, especially in pregnant women and young children. The perception that individuals with outward signs of sickness should consume OFSP could lead to the formation of negative attitudes (persuasion) toward OFSP among individuals who do not display sickness. Conversely, the belief that OFSP is medicine could potentially lead to the formation of positive attitudes (persuasion) and increase consumption levels among those who believe OFSP prevents certain illnesses, increasing its relative advantage over WFSP. The health and nutrition awareness component of OFSP interventions is largely dependent on extension workers who are assigned to spread messages about vitamin A and blindness prevention.

SP Organoleptic Qualities

Many participants reported a preference for OFSP roots and leaves due to superior flavor; relatively few mentioned texture or wateriness as a factor distinguishing OFSP from WFSP. This is an important finding that indicates that the 15 improved varieties of OFSP released in 2011 are compatible with typical Mozambican taste preferences, and that those who have tasted OFSP may easily be persuaded to experiment with the crop and eventually move to the implementation phase of the Innovation-Decision process.

Participants in Macate and Gurúè noted negative side effects of eating WFSP leaves and roots, including a bitter taste, stomach pain, and sores on the lips or “gluing” of the lips resulting from contact with the sweet potato sap, which contains latex. These

participants reported that consuming OFSP does not provoke such discomforts, further contributing to perceptions of relative advantage. Multiple participants also noted a pleasant aroma associated with cooking OFSP roots. Still others in Manhiça reported that the use of fertilizers negatively affected the flavor and texture of any variety of SP.

SP Respectability

Previous research has suggested that SP may be perceived as a poor person's crop.[32] Participants in this study stated that SP was respectable and they enjoyed producing and sharing it. Further research should explore this potential change in perception further, as it is an important aspect of attitude formation toward OFSP.

SP Important for Business

In all districts, and especially Macate, participants emphasized that SP is increasingly seen as a crop for business and not just home consumption, especially OFSP which was reported by nearly all participants to be of higher value and more competitive than WFSP.

Decision

Training

Several interviewees reported that they had received training from the government or an NGO on how to produce and prepare OFSP for consumption; engaging in such

activities is an important step in the decision-making process and may lead to implementation and eventual confirmation that the innovation is indeed useful.

Experimentation

It is clear that experimentation is a critical step in farmers' decision to adopt or reject OFSP. Several participants who were producing OFSP for the first or second time mentioned that they wanted to compare it to WFSP, especially in terms of drought tolerance and time to root maturity; others were keenly interested in obtaining more varieties of OFSP for comparison sake. Many participants recalled cooking sessions organized by government or NGO workers that allowed them to compare the flavor and texture of a variety of OFSP roots and leaves.

Implementation

Culinary Practices

In an effort to increase intakes of OFSP, CIP has followed the strategy to present sweet potato as an alternative to Irish potato to encourage consumption at lunch or dinner in addition to breakfast. This strategy may not be entirely compatible with Mozambican dietary norms as the majority of participants reported that sweet potato is a breakfast or snack food, and some feel that since sweet potato is a sweet food, it does not pair well with savory items such as fish or meat. However, others said OFSP could be eaten at any time of day, even mentioning recipes that involve onion and tomatoes cooked with sweet potato roots or leaves. Still others reported that sweet potato might be eaten for lunch or

dinner, but only when other more typical food items are not available. Several interviewees compared sweet potato to bread, indicating that it was an important substitute in areas that do not have access to a bakery or the ingredients to make bread. It is often consumed as an accompaniment to tea, as bread would be, and is considered a snack food that is quick and easy to prepare.

This difference in use of SP flesh colors could have a negative or positive impact on OFSP consumption levels. Several participants in Macate displayed confusion surrounding the preparation of OFSP, asking “what can I do with this potato” or “how can I prepare it”, indicating that they considered it to be a distinct food from WFSP and perhaps more complex. If not resolved, this perception could result in diminished consumption of OFSP roots. However, as participants learn to use OFSP in a diverse set of preparations, consumption levels could increase.

Agricultural Inputs

Multiple participants voiced concern that they cannot expand their production due to a lack of inputs, particularly labor and fertilizers, and requested help for acquiring these inputs. This constraint seems to describe their overall experiences as subsistence farmers rather than specifically with OFSP; however, several participants noted that all SP varieties are labor intensive due to the need to dig furrows, and therefore difficult to plant in large quantities. Others noted that the work of multiplying vines is difficult when beginning with a small amount, and requested support to receive larger quantities of

vines. Some stated that even without expensive fertilizers, they managed a successful SP crop.

Human Inputs

Reports regarding the responsibilities of men, women and children in the production of SP varied considerably. Interviewees in all three districts reported that OFSP can be cultivated by both men and women; however other participants in Manhiça and Macate indicated that SP is a woman's crop.

Two male participants in Macate, where SP is an important cash crop, noted that high levels of unemployment have led men of all ages to focus on SP for their livelihoods. Other men in Macate, and both men and women in Gurúè, reported that while anyone could grow SP, vine preservation was the responsibility of men. Other participants in Gurúè reported that men control the decisions regarding sweet potato production and sale and are also largely responsible for farm preparation and vine preservation, while women mainly participate in the harvest.

Still others in Macate and Gurúè reported that the sale of SP was a male responsibility, or that the woman becomes responsible only when the man has other work to do. However, women also reported high levels of responsibility for production, sale, and vine preservation, indicating themselves as autonomous decision makers for this crop. Various women in Gurúè reported that while their husbands might be responsible for the production and vine preservation of SP, the women are responsible for the sale.

It is clear that both men and women in all districts engage in the cultivation, preservation, and sale of OFSP. Due to the wide variability of responses in each district about gender role questions, further research needs to be conducted to understand geographically specific gender norms as a factor affecting the adoption or rejection of OFSP. Gender norms have important implications in the implementation phase of a new innovation; a possible strategy for future interventions could be to focus on women's role as vendors of SP, especially in Macate where the crop is perceived as highly important for business.

Farmer opinion on the role of traders was variable, and interviewees in Macate were particularly interested in discussing their experiences with middlemen. Some farmers are highly concerned that traders drive down prices, often using dishonest techniques, such as convincing farmers that the markets are full of SP and that the price is low when this is not the case. Others spoke lightly of traders coming to their farms in search of OFSP, in some cases even offering to harvest roots themselves. It was reported various times that selling on-farm is less profitable; however, farmers who attempt to take their own SP to market for sale may be intercepted in transit by traders who encourage them to sell their potatoes to them directly at low prices before arriving to the market.

Although DVMs and other innovators indicated a feeling of pride associated with their production of OFSP and acknowledged its healthful properties, they also reported low levels of motivation among some community members to produce OFSP, and especially to preserve vines. Many participants mentioned a need for tangible items such as t-shirts and *capulanas* (colorful patterned fabric), as well as vine distributions,

nutrition education, and/or market support. DVMs reported that community members must be encouraged to produce OFSP again in the future if their crop is unsuccessful in one year, and some believe that without their continued efforts to preserve and distribute vines, it would be very unlikely that OFSP would persist in their communities. While participants in all districts reported some level of dependence on NGOs and government for OFSP support, this subtheme was most pronounced in Gurúè, potentially due to the long term influence of the scaled-up Reaching End Users project that was implemented in Zambézia from 2006-2009.[9,31]

Environmental Conditions

Each region reported the impacts of annual flooding, drought resistance, pest and disease, and resistance to sun on SP and other crops in variation. The negative impact of flooding was reported more often in Manhiça than in other districts. In Manhiça OFSP is grown in the valley of the Nkomati River which is prone to cyclical drought and flood, resulting in price fluctuation for OFSP roots.[33] In Gurúè, a higher elevation zone, participants generally emphasized drought as the main climatic constraint to production, though intensive flooding across Zambézia province this year, followed by early cessation of rainfall, has led to grave concern for the food security of many communities. Participants in Gurúè also emphasized that flooding followed by early cessation of rain this year resulted in very low yields of OFSP, while WFSP is still available, further validating claims that WFSP varieties are more drought resistant. This perceived effect of

weather patterns on OFSP yield could potentially lead farmers who have only begun to implement the crop to reject it if they believe that WFSP is more resistant to drought.

Opinions on pest resistance of SP varied. Some participants reported that rats, moles, or bugs were a major obstacle to the production of all colors of SP, while others reported that one color suffered worse than the other. Some participants believed OFSP varieties are inherently more vulnerable, while others stated that WFSP was more vulnerable due to the fact that it takes longer to mature than OFSP.

Farmers in all districts emphasized the importance of seasonality and its effect on the price of both WFSP and OFSP. The height of SP availability varies across regions due to climate and weather patterns and crop rotations. In Manhiça, participants reported that all SP was available beginning in August. In Gurúè, participants reported that OFSP is available mainly between March and July due to the challenges associated with storing it in the field past its time (i.e. it rots faster), with WFSP having better year round availability. This difference is potentially attributable to the fact that OFSP varieties have been bred to mature quickly (3-5 months), while most participants reported that WFSP takes longer to mature. It is possible that some farmers begin harvesting WFSP before it is fully mature through the end of its life cycle, which could account for the longer periods of market availability for WFSP compared to OFSP. The shorter maturation period for OFSP is theoretically a great advantage, and many participants spoke positively of this attribute; it could, however, lead to shorter periods of availability if farmers are not willing or able to plant SP multiple times per year.

Land Use

While sweet potato was considered important for household consumption and sale by all participants, the majority reported that corn or cassava were the most important crops for their families. Many participants noted that the land they cultivate is not unified; rather they produce food on multiple small plots that are located at variable distances from one another. This tradition makes it difficult for many people to estimate the size of their farms. Interviewees often stated that they had an entire hectare of SP but that they only sold a very small amount. A hectare of SP can yield, on average, ten tons of roots. Unless the entire crop was lost due to adverse environmental conditions, it is unlikely that anyone selling only a few bags of SP cultivated an entire hectare, or even 0.25 hectare. To better understand this seeming confusion and in order to compare responses, the researcher often supplemented the question of farm size by asking how many bags of SP were sold in the past cycle. Farmers were able to recall the number of bags sold with relative ease; the majority had sold only a few bags of WFSP and/or OFSP. However, one farmer in Manhiça estimated that he would sell 50 sacks of 50 kilos each this year. In Macate, one farmer reported selling ten 50 kilo sacks of OFSP vines, while another stated that he had sold six tons of WFSP last year.

SP Growth

Although many participants agreed that WFSP varieties develop longer vines and more abundant leaves than OFSP varieties, there was no consensus on whether this is beneficial or detrimental. According to two subsistence farmers in Macate, WFSP is more

resistant because the vines grow farther and therefore are less susceptible to external factors (e.g. cows entering a farm) that could ruin them. However, according to one DVM, the OFSP varieties that develop shorter vines and fewer leaves are preferable because they are easier to manage. The priorities of these participants for their sweet potato production are very different: the subsistence farmers produce small amounts of food mainly for consumption, and therefore appreciate vines that they perceive as less vulnerable; the DVM is concerned with efficiency in vine multiplication, and therefore appreciates vines that are easily contained. Another subsistence farmer reported that because the WFSP vines grow longer, they need more water than OFSP. She also preferred the more modest vine development of OFSP vines because they require smaller seedbeds than WFSP and can produce a large amount of potato in a small area, and a DVM in Gurúè made a similar observation. He also noted a difference in root size between OFSP and WFSP, though he believed the difference was inherent as opposed to being the result of planting one vine per hole.

SP Preservation

The majority of interviewees indicated that access to planting material was a key constraint to beginning, continuing, and expanding production of OFSP. In some cases, interviewees have been able to preserve yellow and orange varieties for multiple years, but those that lose their planting material due to drought, flood, or lack of planning often report difficulty in finding vines for the next season.

Several participants reported that both OFSP and WFSP vines must be transferred to the moist lowlands during the dry season in order to preserve planting material for the following season as drought affects all flesh colors equally; others reported that vines may at times be preserved on-farm, depending on the extremity of temperature and dryness. However, multiple participants reported that OFSP must be transplanted to the humid lowlands during the dry season, while WFSP can survive in the higher elevation fields and does not require transfer to moist soils. In fact, several respondents reported that white vines they have ignored, or even actively tried to remove, have still independently germinated year after year. This is a key finding that highlights an important challenge associated with achieving critical mass of OFSP in Mozambique. Participants seeking to confirm OFSP as a useful technology may ultimately decide to discontinue use of the crop if it is perceived as less drought tolerant than WFSP.

A key perceived benefit to preserving vines is that it enables farmers to produce SP before those who did not preserve vines, and therefore must purchase planting material or depend on the distributions of others who will only consent to share once their own fields have been planted. Farmers who reported high levels of vine retention stated that those who lose their vines and must search for new planting material each season engage in this behavior for several reasons: 1) they do not have access to humid lowland zones, and therefore cannot transfer vines to preserve during the dry season; 2) they do not make the effort to maintain planting material because they know they can get it from a neighbor or organization the following season; 3) they are careless in their harvesting, perhaps pushing sand over the vines where they harvested the sweet potatoes in hopes

that some might survive for the coming season. This practice seems to result in a higher survival rate for WFSP, which many participants report is highly resistant to drought. Leaf consumption was discussed frequently in Gurúè interviews and focus group, and one interviewee in this district reported that some families consume the majority of the sweet potato leaves when other food is scarce, resulting in a low survival rate for vines. Still others may be overly generous in the sharing of vines or leaves with others, leaving them with little planting material for their own multiplication purposes.

Participants from Macate reported that storage of SP is less of a priority now than it was in the past, due to the fact that SP is now typically planted and harvested multiple times annually. Formerly, when communities relied on a single planting of white varieties each year, the sweet potatoes had to be taken out of the farm and stored in a cool, dry place in order to protect them from bugs and to extend their availability as a food source. The increasing commercialization of SP, especially as youth and men struggle to find employment, was also cited as a reason for infrequent storage. Those who produce SP often quickly sell the majority of their crop, leaving only a small portion for consumption at home. Multiple participants noted that, although they sell SP, they also practice storage for household consumption.

Various participants reported that OFSP could be preserved in the farm for a shorter period of time than WFSP due to a high susceptibility to bugs and poor resistance to sun. Others believe that WFSP lasts longer post-harvest than OFSP. The formation of such beliefs during the implementation phase could lead participants to reject OFSP in

the confirmation phase if the perceived advantages of taste, health, and profitability do not outweigh the agronomic challenges associated with OFSP.

Several participants reported that harvested SP can be stored longer when it is intended for home consumption rather than sale as vendors prefer fresh potatoes; vendors in Gurúè noted that after three days, SP is no longer good for sale. Multiple participants also mentioned that SP becomes sweeter the longer you store it. Storage methods mentioned include: 1) leaving SP in the farm and harvesting small amounts to eat or large amounts to sell; 2) curing SP in the sun for 1-2 days before storing indoors, either in a sack or spread on a cement floor; 3) digging a hole, burning the soil, and storing SP inside (after curing for 1-2 days) covered with grass; 4) storing SP on a raised platform, covered by grass. The reported length of time for which SP can be stored varied widely, from less than a week to 5 months.

Agricultural Practices

Informants reported that WFSP and OFSP must be cultivated in separate fields for a variety of reasons: 1) WFSP varieties take longer to reach maturity than OFSP; 2) WFSP varieties develop longer vines that would outcompete OFSP for space; 3) Planting separately facilitates the harvest and sale of different flesh colors. One participant even noted that measures must be taken to prevent cross pollination of SP varieties, although this is not a concern as SP is propagated vegetatively by farmers and not grown from seed.

While some interviewees, often DVMs or facilitators, believe that improved agricultural practices benefit any sweet potato regardless of flesh color, other participants believe that the methods they have learned from government extension workers or NGO staff are specifically for OFSP and not necessary for the production of WFSP. Multiple interviewees reported that OFSP requires precise measurement between plants and only one vine per hole while WFSP needs no measurement and benefits from multiple vines in each hole. Further, the need to remove all weeds prior to planting OFSP was cited by multiple interviewees in Macate and Gurúè and seems to be a deterrent for some producers. This perceived necessity for a "clean plot" and meticulous measurement can result in the belief that OFSP is more work than WFSP. However, some participants say OFSP is less work because the vines are smaller and the sweet potatoes mature faster, necessitating less frequent weeding. Multiple participants mentioned that OFSP can be harvested by hand while WFSP needs to be harvested with a hoe, as its roots go deeper into the soil.

Confirmation

SP Preference and Popularity

The majority of participants reported that OFSP is the preferred potato, resulting in high reliability of this response; however, the validity of this response is difficult to determine, since most participants understood that the researcher was interested in OFSP as an intervention food. The majority of farmers and vendors reported that when WFSP

and OFSP are both available at the market, OFSP would be bought more quickly than WFSP and at a higher price.

SP Economics

In Macate, participants reported a higher rate of buying and selling vines compared to the other two districts, where vines were more often shared for free by neighbors, especially WFSP. Several DVMs reported that community members buy vines if they have money, but that someone who does not have money will not be sent away empty-handed. Others reported that all vines are shared for free in order to maintain trust between neighbors, noting that anyone can lose vines and may need to request assistance in the future.

Two DVMs in Gurúè mentioned difficulties enforcing the CIP Viable Sweetpotato Technologies for Africa (VISTA) project policies on monetary contributions for vines. One reported that families complained that vines cost two meticais (USD $0.06) for 6 kilograms due to knowledge that families benefiting from former dissemination efforts received 8 kilograms for free. Another reported that he could not collect the two meticais contribution as community members are accustomed to receiving planting material for free; he therefore had to give away vines to community members in order to accomplish his dissemination goals. This resistance to monetary contributions even among those who have received information about VAD and the nutritional value of OFSP may suggest that the perceived relative advantage of OFSP is weaker than the conviction that vines should be shared for free, as is customary in many communities.

In markets in all districts, SP is often sold in piles measured by sight rather than by weight. In Manhiça and Gurúè, the researcher observed vendors selling piles of SP of mixed flesh colors, varying from light yellow to dark orange. Although a large majority of farmers reported planting, harvesting, and selling SP flesh colors separately, market vendors reported that the sacks they purchase from farmers often include a variety of flesh colors, especially during times of scarcity. In these cases, vendors may separate the flesh colors for resale in order to accommodate customer preferences. For many varieties, it is difficult to know the flesh color without breaking the potato, which is most likely a key factor in the mixing (intentional or unintentional) of flesh colors in the same sacks; however, market vendors report being able to tell the flesh color without breaking the potato.

Timing seems to be as important as flesh color, if not more so, in determining the price of SP. Various interviewees reported that the first potatoes of the year demand a higher price than the later season potatoes, regardless of the color.

Many interviewees reported a hesitation to expand their farms due to unstable markets, and voiced an interest in a processing facility that could purchase OFSP year round in order to ensure that they will be able to consistently garner a profit if they expand production. However, this concern seems to contradict the insistence by the majority of participants that OFSP is widely sought after and demands a higher price at markets.

Sharing

Hesitance to share information among some who have implemented OFSP indicates that they have focused on the individual advantage to be gained from using this crop rather than how OFSP could be distributed throughout their social system. Various participants described OFSP as a "novelty" and therefore something that farmers are less willing to share with one another when they first receive planting material. Their initial priority is to multiply enough vines for their own use, at which point they might share planting material with others, sometimes charging for this service. One DVM reported that those with vines might even misinform neighbors who seek planting material in order to capitalize on local markets by being one of the few producers of OFSP, apparently still perceived as a specialty crop.

Desire to Produce OFSP in the Future

Several participants expressed an interest in producing OFSP in the future, but sometimes qualified this response by noting that limited access to inputs (e.g. labor or fertilizers) would make expansion difficult. When asked how the project could improve in the future, various participants requested new varieties of OFSP, indicating a desire to experiment with the crop and continue producing it in the future.

STUDY LIMITATIONS

Most interviews and focus groups were conducted in remote areas where some participants did not speak Portuguese, necessitating a reliance on translators which has

the potential to influence research findings.[34] Further, as the researcher often traveled by motorcycle, bicycle, or even on foot, she was unable to work with a single translator to assist with local language, which varied between districts. The researcher would not have been able to meet participants in remote areas without the assistance of extension workers and NGO facilitators, and participant comfort levels as well as honest reporting were potentially increased due to familiarity with these individuals as translators. Conversely, it is possible that the presence of these individuals lead to misreporting in some cases. The researcher identified some participants independently, but in other cases the participants were identified by extension workers and project facilitators. This method of sampling substantially broadened the geographic area included in the research, but also could have created a bias in the characteristics of participants. Risks of this sampling strategy include bias during informant selection, as the researcher judges the informants' reliability, and the potential for informants to misreport due to favoring the socially desirable response. Self-reporting by participants could also have led to misreporting in some cases, especially in attempts to estimate plot sizes and recall the amount of SP sold in the past season. These risks were controlled by taking several entry points to initiate snowball sampling and crosschecking the responses through triangulation with other participants' responses and the researcher's detailed field log.[27,35] The original goal of the research was to interview 20 participants in each site, and this goal was surpassed in each site. However, the sample in Macate was larger than the other sites, which could potentially skew the results. Few in-person follow-up interviews were conducted due to

time and transportation constraints; however, many participants were accessible by phone and the researcher made multiple calls to ask follow-up questions.

CONCLUSION

Results from this research indicate that a wide variety of factors influence adoption and retention of OFSP across the Diffusion of Innovations model, including: perceptions of OFSP as different to WFSP in terms of nutrition, organoleptic qualities, and culinary properties; taste preferences for both roots and leaves; access to planting material; perceived difference in agronomic traits, including pest and drought resistance, time to root maturity, and vine development; dependence on NGOs or neighbors for planting material; perceptions of OFSP as the more competitive SP; inability to increase production due to lack of access to capital for inputs and labor; unstable markets, fluctuating prices, and relationships with traders, and; varying levels of sharing of information and planting material across farmer networks.

Access to planting material is a highly important factor as study participants demonstrated willingness to produce, consume, and sell OFSP. Dependence on government and NGOs for vine distributions may be diminished if the number of individuals multiplying vines, independently or as contracted DVMs, is increased. However, incentives for vine multipliers remain a challenge as it is clear that many Mozambicans are hesitant to pay for planting material. Understanding that some individuals prioritize vine preservation while others tend to seek assistance from neighbors or organizations is an important aspect of planning future interventions to

further the diffusion of OFSP in Mozambique. As OFSP becomes more available, perceptions of the crop as a 'novelty' may wane, which could have a positive effect on sharing of information and planting material. Agronomic traits that distinguish WFSP from OFSP, including drought tolerance and time to root maturity, have a key influence on the utility of OFSP, as do perceptions that OFSP requires improved agricultural practices that are not necessary for the production of WFSP.

One participant's quote summarized the importance of OFSP as a VAD prevention measure in Mozambique, indicating that the crop will continue to be produced in the future: "Yes she is thanking well the orange pulp. She says a long time ago, the people didn't have strength, the children, you are just seeing your child getting thin, but now after orange pulp appeared, the development, eh, it's different. It's different because, a person when they see that 'epa, these days I don't have strength' you have that way to prepare the orange pulp, eat it, they are well, they have small children, you, always in each house, prepare, and give it to the children, and the child grows very healthy. Yes yes. Then for this that until today, the orange pulp no, the people don't leave it, because it helps us well in the health."

In order to understand and improve adoption and retention rates of OFSP, future research should include a renewed emphasis on nutritional benefits and cooking methods for sweet potato roots, leaves, and derivatives, noting that OFSP can be prepared simply by roasting or boiling as is the tradition for WFSP. Further research should be conducted to understand the relative drought and pest tolerance for newer varieties of OFSP in regionally specific contexts, as many farmers continue to report that WFSP is more

resistant to sun. Understanding farmer preference for vine and leaf development could guide future breeding efforts, as some farmers prefer varieties with more abundant leaves and vines while others prefer varieties with smaller, more manageable vine systems. Researching how gender dynamics relate to sweet potato commercialization is key to improving markets and supporting female vendors. Finally, government and NGO sponsored training efforts to encourage the use of improved agricultural practices could highlight the agronomic similarities between OFSP and WFSP to avoid perceptions that OFSP production is more labor intensive.

The majority of the 95 participants in this study exhibited highly positive attitudes towards OFSP based on their experiences as producers, consumers, and vendors. Addressing the opportunities and challenges outlined in this study could lead to a significant increase in the adoption and retention of OFSP varieties in diverse geographic locations in Mozambique. Beta-carotene-rich OFSP is an important tool for preventing VAD and increasing food security in resource poor communities in various country contexts. Experiences from Mozambique offer a valuable reference point for other food-based approaches focusing on alleviating micronutrient deficiencies and improving the health of communities.

AUTHOR'S NOTE

Mica Jenkins is the lead author on this article and was responsible for research design and methodology, field research including interviews and focus groups, translation and transcription for all interviews, construction of the coding template, coding of

transcripts, structure and content of the manuscript, creation of tables, editing, and final submission. Dr. Carmen Byker Shanks provided guidance in research design and methodology driving field research. She also participated in coding template development, coding of transcripts, writing and multiple edits of the manuscript and tables. Dr. Roland Brouwer provided guidance in research design, in-country support for field research, and multiple edits of the manuscript and tables. Bailey Houghtaling provided coding of transcripts and a final edit of the manuscript and tables.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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CHAPTER FOUR

CONCLUSION

Sweet potato is an important staple crop for Mozambican producers and consumers, providing a critical source of dietary energy and income especially in times of food insecurity. Orange-fleshed varieties offer the added benefit of beta-carotene, a precursor to vitamin A in the human body, and can be easily incorporated into existing agricultural systems and diets. A significant amount of time and resources from government agencies and NGOs have been invested into the promotion of these nutritionally superior varieties and success has been measured in a variety of ways, including increased levels of vitamin A intake, reduced levels of VAD, and high levels of farmer and consumer acceptance of orange-fleshed sweet potato (OFSP).

Chapter two of this thesis collates a time line of events surrounding OFSP introduction to Mozambique, beginning with the introduction of planting material for field trials in Mozambique in 1997 and leading up to the Scaling Up Sweetpotato Through Agriculture and Nutrition (SUSTAIN) and Sweetpotato Action for Security and Health in Africa (SASHA) projects which are currently ongoing in Mozambique.

Chapter three details nine months of research in Mozambique to understand the socioeconomic, cultural, and agronomic factors affecting farmer willingness and ability to adopt OSFP varieties, with a specific interest in the retention of planting material over time. Results indicate that a wide variety of factors influence adoption and retention of OFSP, including: organoleptic qualities and taste preferences for both roots and leaves;

access to planting material; perceived difference in agronomic traits, especially drought tolerance; dependence on NGOs or neighbors for planting material; lack of capital to purchase farm inputs and labor; unstable markets and fluctuating prices; and varying levels of sharing of information and planting material across farmer networks.

Future research should focus on: mechanisms to increase year-round availability of planting material; improved drought and pest tolerance for OFSP; understanding farmer preference for vine and leaf development; renewed emphasis on nutritional benefits and cooking methods for sweet potato and its derivatives; gender dynamics of sweet potato commercialization; and farmer training on improved agricultural techniques that highlights the agronomic similarities between OFSP and WFSP to avoid perceptions that OFSP production is more labor intensive.

In the current research, agronomic challenges emerged as a key factor limiting adoption and retention of OFSP, a crop introduced to address chronic vitamin A deficiency and improve community nutrition. Addressing dietary deficiencies through interdisciplinary approaches emphasizing the linkages between agriculture and nutrition offers a promising mechanism for improving the health of communities in many cultural and geographical contexts. With proper attention to current challenges and consideration of farmer priorities, OFSP has the potential to increase food security, diversify diets, significantly reduce VAD, and provide a crucial source of income for Mozambican farmers and their families. The experience of OFSP in Mozambique can serve as a valuable reference point for other food-based approaches to alleviating micronutrient deficiencies in similar contexts.

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