Hermann Eiselen-Wissenschaftspreisträger 2024

Hermann Eiselen-Science Award Winner 2024

Custódio Efraim Matavel "Integrating more efficient renewable energy technologies into food systems in Central Mozambique: implications to food and nutrition security", Humboldt University Berlin, 2023

Summary

The global increase in food insecurity and undernourishment, driven by the multifaceted impacts of climate change, the COVID-19 pandemic, rapid population growth, economic barriers to nutritious diets, poverty, and inequality, presents an urgent challenge. Particularly in Africa, this crisis is magnified, with hunger rates more than doubling those of other regions. This dire situation calls for empowering smallholder farmers, who are instrumental in providing up to 80% of the global food supply, through the provision of advanced and efficient technologies to boost productivity and ensure energy access.

The role of energy-efficient technologies in enhancing food and nutrition security (FNS) is multifaceted and critical across all stages of the food system, including production, processing, preservation, and cooking. Despite their importance, many smallholder farmers in rural settings continue to depend on traditional energy methods, such as open-sun drying and three-stone fireplaces, leading to substantial post-harvest losses, compromised food quality, and unmet safety standards.

This dissertation investigates the impact of optimally designed energy processing technologies on the quality of food and its broader effects on FNS in rural Mozambique. By offering a detailed analysis of FNS determinants and the performance of new food processing and preparation technologies, this research fills a significant gap in the literature. It also examines the acceptability among users of these technologies and the effectiveness of dissemination strategies in ensuring their widespread adoption. Through this comprehensive study, we aim to shed light on scalable solutions to enhance food security.

The first fieldwork—that marked the initial phase in our comprehensive research design – aimed at rigorously assessing household food security through a multifaceted approach. Utilizing the Household Dietary Diversity Score (HDDS), we classified dietary diversity into low, medium, or high categories. Tue Household Food Consumption Score (HFCS) allowed us to measure the frequency of consumption across different food groups, categorizing households as poor, borderline, or acceptable. Furthermore, the Months of Adequate Household Food Provisioning (MAHFP) provided a longitudinal measure of food availability, distinguishing households by their consistency in securing adequate food supplies throughout the year. As the first step in our research sequence, this fieldwork established a foundational understanding of food security dynamics within the community.

This initial fieldwork revealed significant seasonal variations in household food security, with

notable deficiencies in dietary diversity and food consumption scores during the pre-harvest period, leading to heightened food insecurity. Conversely, improvements were observed during the harvest season. Through sophisticated analysis using the Generalized Ordered Logit Model with Partial Proportional Odds Model, key determinants of food security were identified, including geographic location, land quality, livestock diversity, and specific crop productions such as rice and cassava. These findings underscore the complex interplay of factors affecting food security and highlight areas for targeted interventions to bolster food security, especially in critical pre-harvest periods.

Following the initial fieldwork's insights into the community's food security challenges, we employed participatory action research, in which interventions were strategically implemented to address the identified gaps. These interventions involved the introduction of solar dryers (SD), improved cookstoves (ICS), and heat retention boxes (HRB). Each technology was carefully selected for its potential to enhance food preservation, improve cooking efficiency, and maintain food temperature, respectively. By integrating these technologies into the community, the aim was to directly tackle the root causes of food insecurity identified during the first phase of fieldwork, providing sustainable solutions to improve dietary diversity and reduce food insecurity.

Prior to the deployment of the SD, ICS and HRB in the community, thorough experiments were conducted to evaluate their effectiveness and efficiency. These preliminary tests aimed to ensure that the technologies were not only suitable for the specific environmental and social conditions of the targeted rural areas but also met the desired outcomes in terms of improving food preservation, cooking efficiency, and overall food security. This proactive approach helped in refining the technologies to better suit the needs of the community and maximize their potential benefits.

The SD was designed specifically for rural settings with scarce access to conventional energy sources. This eco-friendly appliance incorporates a wooden structure that includes a solar collector angled at 22° to maximize solar absorption, alongside a separate drying chamber equipped with five trays. lt features strategic venting to regulate temperature and promote efficient air flow, ensuring optimal drying conditions without the risk of overheating. The dimensions and design facilitate effective drying of agricultural produce, marking a significant advancement in sustainable food preservation techniques.

Tue experimental procedure to test the SD involved a methodical approach in Gurué district, Central Mozambique. Six solar dryers were used simultaneously to dry two types of produce: amaranth leaves and maize. The amaranth leaves underwent a blanching process before being placed in the dryer trays for seven days, using a semi-continuous method. In contrast, maize grains required five days of drying. The testing process meticulously recorded ambient conditions, solar radiation, and the weight of the products to assess the efficiency and effectiveness of the solar drying technology. We collected data on ambient and chamber conditions, alongside solar radiation and product weight, to analyze the solar dryer's performance. Through careful calculations and sensory analysis by evaluators, the study demonstrated significant improvements in drying efficiency for both amaranth leaves and maize compared to traditional methods. The solar dryer not only reduced drying times but also maintained high-quality product attributes, as indicated by evaluator feedback, underscoring its effectiveness and potential for broader application in rural agricultural practices.

Consumer preference testing for the dried products revealed a strong favorability towards

amaranth leaves and maize processed using the Passive Indirect Solar Dryer (PISD). A significant majority of participants rated these items as either "very good" or "good," showcasing a clear preference over products dried using traditional Open Sun Drying (OSD) methods, which received criticism for their texture, aroma, and color. Tue statistical analysis confirmed this preference for PISD-dried products, highlighting the solar dryer's ability to not only enhance drying efficiency but also to improve product quality and consumer satisfaction.

In addition to the solar dryer, the performance of ICS and HRS was also evaluated. The field tests for ICS demonstrated a significant enhancement in cooking efficiency when compared to traditional three-stone stoves. Conducted over six months in 2020, these tests involved twelve mud-based ICS units, designed after a model from Idifu village, Tanzania. The evaluation focused on the preparation of bean curry and maize flour porridge, measuring parameters such as fuelwood consumption, ingredient weight, and cooking time. Results confirmed that ICS units drastically reduced both fuelwood usage and cooking duration, underscoring their improved efficiency and potential impact on sustainable cooking practices.

The experiment on Heat Retention Systems (HRS) tested the efficacy of a HRB against traditional methods using leftovers (LO) and banana leaves (BL) for insulating cooked foods. Monitoring temperature changes over six hours for both beans and maize flour porridge, the HRB demonstrated superior performance in maintaining higher temperatures for longer periods compared to BL and LO. Specifically, the HRB slowed the temperature decline, taking 160 to 175 minutes to reach 60°C, showcasing its effectiveness compared to banana leaves and leftovers, which took less than 140 minutes to reach the same temperature. This evidence highlights the HRB's superior insulation capability, suggesting its potential to enhance food quality and safety by keeping meals warmer for longer durations.

The consumer preference tests for the ICS and HRS involved 122 participants evaluating food prepared with various combinations of stoves and HRS. The study used a 5-point Likert scale to rate taste, texture, aroma, color, and overall acceptability. Results showed a general preference for food prepared using any combination of stove or HRS, with no significant relationship between the type of stove or HRS and food preference, indicating broad acceptance of these technologies.

Following the testing of the solar dryers, the fieldwork extended to assess their impact on food security within selected communities. With a deliberate distribution strategy, solar dryers were allocated to half of the communities in each administrative post through a random selection process. This phase involved comprehensive surveys from December 2021 to January 2022, engaging 634 households to compare solar dryer users and non-users. This approach aimed to meticulously gauge the solar dryers' effectiveness in enhancing food security in the region.

The study also identified various socio-economic, demographic factors, individual perceptions, and training as key influences on the adoption of solar dryers. To evaluate the impact of solar dryers on food security, the research utilized several indicators: Food Availability Scores (FAS), Household Food Insecurity Access Scale (HFIAS), Women Dietary Diversity Score (WDDS), and MAHFP. These measures provided a comprehensive view of how solar dryer usage could affect different dimensions of food security within the communities.

The results revealed that solar dryer users exhibited higher FAS and WDDS, indicating positive effects on food availability and dietary diversity. Furthermore, there was a significant negative impact on the HFIAS, suggesting a reduction in household food insecurity among solar dryer

users. However, the study did not consistently observe an impact on the temporal dimension of food security, measured by MAHFP.

We further utilized probit regression to uncover the determinants of solar dryer usage, identifying key factors such as gender, age, family size, agricultural output, land size, training, information sources, and crop production. Results revealed that solar dryers were more likely to be adopted by female-headed households, older farmers, those with larger families, and individuals focused on specific types of crop production, indicating a nuanced understanding of the socio-economic and demographic influences on technology adoption in agricultural practices.

During the fieldwork, we also explored the link between the training approach and changes in energy-related behaviors. Conducted in Lioma and Mepuagiua, Gurué district, from June to December 2020, the study engaged 620 households across 40 communities, which were randomly selected to receive either group-based training, individual training, or a combination of both. These communities were chosen for their similar socio-economic characteristics and limited access to clean cooking fuels, with the training covering both the construction and usage of the stoves. The study demonstrated that individual and combined training methods significantly improved the adoption rates of ICS over group training alone. This was evidenced by a chi-square test showing a strong correlation between the adoption rates and the training methods used. Two rounds of face-to-face interviews further quantified the impact, revealing that individual training increased adoption likelihood by 20%, and a combined approach by nearly 14%, showcasing the effectiveness of tailored training approaches in promoting sustainable energy solutions.

The cost analysis showed that individual training was the most cost-effective method for implementing JCS, costing 625.0 MZN (l0 USD) per participant. Compared to group training, individual training not only resulted in higher adoption rates but also proved to be more economical, indicating its efficiency in promoting ICS adoption. This emphasizes the significant impact training methods have on the uptake of sustainable cooking solutions, with individual training offering a balance of effectiveness and cost-efficiency.

The findings of this work highlight the effectiveness of ICS and HRB in enhancing cooking efficiency and food storage, respectively. The solar drying technology have shown a positive impact on food security, improving food availability and dietary diversity, especially with targeted training. The dissemination of these technologies emphasizes the value of individual training over group sessions, promoting wider adoption and cost-efficiency.

In conclusion, the collective findings underscore the pivotal role of innovative interventions in addressing the multifaceted challenges of food security. From optimizing cooking practices to harnessing solar drying technologies, the research imparts invaluable insights into bolstering efficiency, accessibility, and diversity within food systems. Moreover, the emphasis on context driven training methodologies underscores the importance of tailored interventions in effectuating lasting change. As such, these findings not only advance our understanding of food security dynamics but also serve as a clarion call for concerted action towards realizing sustainable solutions to global hunger challenges.

List of thesis publications

Paper 1: Matavel, C., Hoffmann, H., Rybak, C. Steinke, J., Sieber, S., & Müller Klaus (2022). Understanding the drivers of food security among agriculture-based households in

Gurué District, Central Mozambique. Agriculture & Food Security https://doi.org/10.1186/s40066-021-00344-3

Paper 2: Matavel, C. E., Hoffmann, H., Rybak, C., Hafner, J. M., Salavessa, J., Eshetu, S. B., & Sieber, S. (2021) Experimental evaluation of a passive indirect solar dryer for agricultural products in Central Mozambique. Journal of Food Processing and Preservation, D01: https://doi.or/I0.11[1/jfpp. 15975

Paper 3: Matavel, C.E., Hafner, J. M., Hoffmann, H., Uckert, G., Massuque, J., Rybak, C., & Sieber, S. (2022) Toward energy saving and food safety in Central Mozambique: the role of improved cook stoves and heat retention boxes. Energy, Sustainability and Society 12, 26. https://doi.org/10.1186/sl 3705-022-00352-6

Paper 4: Matavel. C. E., Kächele, H., Steinke, J., Rybak, C., Hoffmann, H., Salavessa, J., Sieber, S. & Müller, Klaus. (2022) Efeet of passive solar drying on food security in rural Mozambique. Scientific Reports 12, 17154. https://doi.org/10.1038/s41598-022-22 129-9

Paper 5: Matavel, C. E., Kächele, H., Hafner, J. M., Rybak, C., Uckert, G., Hoffmann, H., Kipkulei, H., Massuque, J., Steinke, J., Sieber, S. (2023) How to increase cookstove adoption? Exploring cost-effective dissemination techniques in Central Mozambique. Energy Research & Social Science 100, Article 103082. https://doi.org/ 10.1016/j.erss.2023.103082