IMPLEMENTATION OF SOLAR DRYERS AND COOKERS FOR PROCESSING PRODUCE OF RURAL CROPS: EXPERIENCES OF TRANSDISCIPLINARY RESEARCH FOCUS

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ABSTRACT

It is estimated that approximately 2.4 billion people worldwide depend on biomass as their primary fuel source, mainly for cooking. One adverse effect of using biomass as fuel is the elevated incidence of respiratory diseases, especially among women and children, who often remain in homes where indoor cooking takes place. Solar cooking emerges as a sustainable alternative to address some of the challenges stemming from the widespread use of biomass as fuel. Solar cooking involves a clean and health-conscious approach to food preparation, where solar radiation is harnessed through passive or active devices. These devices transform the energy of solar radiation into thermal energy for cook. In solar cooking, the electromagnetic radiation energy from the sun is converted into heat energy for cooking food. Despite its numerous health and environmental benefits, the widespread adoption of solar stoves and cookers has encountered challenges in urban and rural settings. Research efforts are concentrated on enhancing the functionality and performance of solar stoves and cookers. However, implementation barriers hinder the widespread adoption of these technologies exist. These barriers include climatological factors related to solar resource availability and intermittency, technical considerations linked to the use and management of solar cooking devices, sociocultural factors associated with culinary traditions and beliefs specific to each region, and the types of available foods. In our current work, employing participatory methodologies and a transdisciplinary research approach, we have successfully implemented solar stoves and dryers in rural communities, fostering the establishment of small rural enterprises utilizing these technologies.

KEYWORDS

Solar Energy, Solar Dry, Solar Cooking, Rural Development, Transdisciplinary Research, Social Impact, Participatory Methodology.

INTRODUCTION

Mexico has an immense potential for harnessing renewable energy resources, especially solar energy. The average daily solar insolation of 5.5 kWh/m2 makes it feasible to implement solar energy technologies nationwide. However, Mexico faced the challenge of community resistance towards adopting renewable energy technologies. In response, the National Development Plan 2019-2024 emphasizes the importance of community involvement in decision-making for technological projects, fostering real solutions to socio-environmental challenges, and promoting shared responsibilities.

The conventional, top-down approach to the creation, advancement, and execution of Renewable Energy Technologies faces many obstacles and limitations worldwide [1]. Although certain policy responses to the global energy crisis appear likely to improve the outlook for renewables and energy efficiency, other necessary policy actions, as well as financial flows, continue to lag. This particularly concerns lacking universal access to electricity and clean cooking in developing economies, with projections indicating that SDG 7 will not be reached by 2030. The Energy Progress Report 2023 shows that about 2.3 billion people in the worldwide relied on solid fuels for household energy needs, including cooking. Despite efforts of the global community to promote access to clean energy and technologies for cooking and other household needs, overreliance on solid fuels (non-clean) sources of energy, specifically firewood and charcoal is still a big development challenge [7].

Nayarit state, located in western Mexico, boasts of its rich grain production and diverse tropical fruits. A notable annual farm production of tropical fruits reaching 500,000 tons, benefiting from the abundant solar energy resource exceeding 5.65 kWh/m^2 on a daily average across the entire state of Nayarit, along the Pacific coast, Mexico exists. With a growing number of companies involved in fruit dehydration, such as mango, banana, jackfruit, and pineapple, these semi-industrialized drying procedures can handle up to 20 tons of products daily using ovens ranging from 1 to 4 tons each. Agricultural producers deliver their fruits to packing companies for sale in local, national, and international markets. Any fruits that don't meet quality standards for packaging are transported to dehydration companies, where they are given a second chance to meet the requirements. Thus, the prospect of employing solar-powered drying methods directly at the rural farm sites, emerges as a promising for sustainable rural development.

Our previous work we proposed using solar technologies to achieve sustainable development initiatives in rural Mexico and worldwide [2] thorough implementation of solar dryers, with straightforward engineering designs that users can easily incorporate.

In present work, we implemented such solar driers in agricultural activities of small rural producers as a strategy for sustainable local development. By employing a transdisciplinary approach, the objective is to seamlessly integrate solar drying in rural activities within communities thereby diversifying productive endeavours and promoting sustainable development within the rural regions of Nayarit state in Mexico. This study presents a transdisciplinary methodology for boosting solar drying and cooking practices within the rural communities. In rural areas with limited knowledge, it's necessary to strive to make the technology to be implemented more user-friendly and understandable for people. Therefore, it's important to raise awareness about how the technology works and ensure that the local community can comprehend its functionality and utilizing it for their own benefit. This will promote the implementation, care, and use of new technology in rural areas [3].

The contemporary challenges within the energy sector demand extensive fieldwork to construct models rooted in ethical values and enriched by epistemic qualities across the realms of environmental, social, academic, business, and governmental dimensions [4]–[6].

The persistent issue of rural depopulation and the migration of people from rural to urban areas remains prevalent in various regions. Many of the rural areas predominantly depend on a single economy activity, often producing a specific agricultural product. Furthermore, rural regions in Mexico frequently lack essential infrastructure services, such as access to energy, which constrains the agricultural production, transportation, processing, preservation, and transformation of agricultural products. In this context, energy emerges as a pivotal factor for the successful development of agricultural production processes.

METHOD

For the development of this work, a social innovative transdisciplinary methodology was employed as described below:

1.Establishment of a stakeholders working group: focused in improve the productivity of agriculture produce trough solar drying. It is composed of scientists from the fields of social sciences, energy, physics, biology, agronomy as well as social leaders, agricultural producers, local entrepreneurs, community leaders and undergraduate and master's students, affiliated with the university, who interacting with the people of the community and local authorities.

2. Stakeholder dialogue and integration of knowledge: it was carried out through participatory methodologies by periodical meetings to discuss, provide feedback, and redirect each step toward goal achievement.

3. Social intervention of the core group with communities: to promote solar drying and cooking as sustainable development options for rural sites, aiming to generate collaborative synergies among stakeholders.

4. Training workshops on drying and solar cooking techniques: It was implemented strategically to encourage social participation and promote the development of productive rural projects based on renewable energies. Using posters, brochures, and stories was crucial in conveying scientific and technical information. The participatory dynamics, designed for each target audience with a transdisciplinary approach, aimed to achieve effective integration and encourage participation across different age groups.

5. Classification and Selection of the dryer user’s: Three type of users with different levels of leadership and knowledge were selected for the study; user with technical capabilities and expert leadership, user with average technical capabilities and empirical knowledge and user without technical capabilities and without leadership.

6. Implementation of solar dryers on the farm site for drying agricultural produce: In the engineering design of the dryers, models of easy construction were considered, with affordable materials available in the local market.

RESULTS AND DISCUSSION

1. **Formation of a Stakeholders Working Group:**

The core group has the responsibility of creating a common interest in integrating solar technologies to meet energy requirements that will add value to agricultural products. This will contribute to the collective identity, provide a guide for learning, and take appropriate actions.

2. Stakeholder Dialogue and Knowledge Integration:

Regular meetings were conducted using participatory methodologies to facilitate stakeholder dialogue, offer feedback, and redirect project steps toward goal achievement. Through the strategic use of open-ended questions and collaborative brainstorming to address pressing issues, with the aim to co-create a sense of belonging and foster shared values, paving the way for a profound and far-reaching social transformation. The research approach is driven by a commitment to heighten awareness regarding experiential learning in the realm of solar energy, with the overarching goal of making sustainable development a shared aspiration.

3. Social Intervention of the Core Group with Communities:

The core group engaged in social intervention with communities to advocate for solar drying and cooking as sustainable development options in rural areas. The primary objective was to foster collaborative synergies among stakeholders. Strategically employed the concept of solar drying and related processes to enhance productivity, reduce losses, and secure a consistent supply of nutritious food for families. Hence, in this work a transdisciplinary approach was employed to interact with the members of each community. Figure 1 shows images of the workshops on solar drying and cooking carried out as the first stage strategy to introduce the technology and its social appropriation and energy literacy [1]. Fieldwork was conducted, including surveys and workshops on solar drying, posters, brochures, and stories were designed to identify interest and adoption of solar technologies by community members.

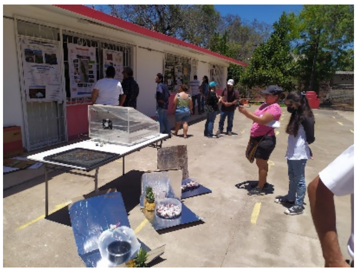
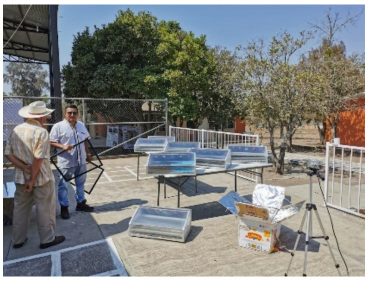
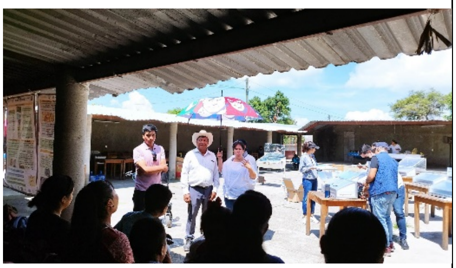
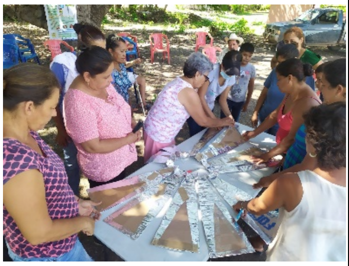
1) 	2) 	3) 
4) 	5) 	6) 

Figure 1. Social intervention field work in rural communities. 1) La Curva, Xalisco; 2) El Llano, San Blas; 3) Mesa del Nayar, Del Nayar; 4) Tequilita, San Pedro Lagunillas; 5) Los Aguajes, Jala, and 6) San José de Motaje, Acaponeta.

4. Training Workshops on Drying and Solar Cooking Techniques for rural entrepreneur:

The training workshops are designed to foster awareness, acceptance, and the assimilation of knowledge regarding drying processes and solar cooking, ultimately promoting the development of community-based productive projects. Through these workshops, we establish connections with each community, creating spaces for exchanging ideas. The construction of solar stoves in situ serves as a social participation strategy, allowing for the integration of new ideas generated collectively around the use of solar energy.

The efficient management of natural and social resources through integrating solar technologies is important for advancing in energy projects. Hence, the technical specifications of solar drying prototypes for its implementation are refined while collaboratively constructing innovative scientific and technological knowledge. On-site variable measurement systems to assess the energy performance of technologies and quantify the availability of solar resources in each locality, generate certainty through knowledge. When rural people associate the knowledge with their daily lives and comprehend it, knowledge exchange occurs, emphasizing the importance of science and technology in social development.

We placed a significant emphasis on solar cooking, recognizing its capacity to not only address the specific needs of these communities but also establish a meaningful connection and communication channel with them. During the waiting periods for cooking, we encourage dialogue and the exchange of knowledge, recipes, tastes, and culinary traditions. The leading group consistently discusses the science behind each process, ensuring that the community receives new knowledge in a relaxed and comfortable environment. This ease of interaction facilitates dialogues of expertise, fostering the acceptance and reinterpretation of this newfound knowledge. This epistemic process highlights other essential dimensions of using solar energy and its practical applications. We have assessed the widespread acceptance of the technologies based on exit surveys. Solar cooking has garnered greater approval in all cases and communities as it addresses a fundamental daily challenge, the meal preparation.

5. Classification and Selection of Dryer Users:

Three types of users with varying levels of leadership and knowledge were identified as users of solar dryers in the study.

i) Users with technical capabilities and expert leadership are defined in this work as formally constituted organizations with a well-established mission, vision, and values. They have final commercial products duly registered and positioned in the regional market. Therefore, they did not require technical support.

ii) Users with average technical capabilities and empirical knowledge need moderate support in leadership and refer to families of producers engaged in a family enterprise. They create products with the possibility of commercialization in the local market but lack formality in their venture. These producers know open-air drying methods and use the homemade production of jams.

iii) Users without technical capabilities and leadership, as addressed in this work, are social groups formed by rural people with past experiences in collaboration and ancestral knowledge about the use of land and plants. However, they lack technical capabilities, requiring close support and continuous monitoring.

6. **Implementation of Solar Dryers on the Farm Site**:

In the engineering design of the dryers, consideration was given to models that are easy to construct using affordable materials available in the local market. The manufactured dryer features 1.22 m x 2.44 m x 2.44 m, constructed with square aluminium profiles, brackets, and a 6mm transparent cellular polycarbonate roof. The drying area covers approximately 15 m^2, distributed across 36 trays in 6 levels, and can accommodate up to 70 kg of fruit pulp. Fruit loading and unloading are facilitated through two hinged side doors, and air circulation is ensured by four fans at the top and four at the bottom for air injection and extraction, respectively. Figure 2 shows the installation of such solar dryers at the farm site.

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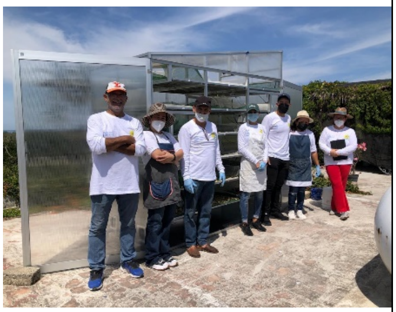

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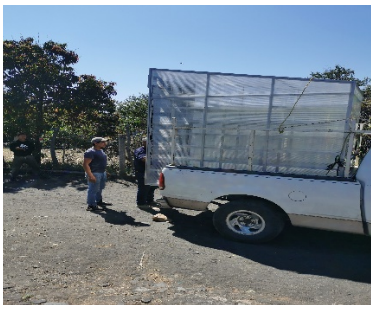

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Figure 2. Implementation of solar dryers in the rural sites for users without technical capabilities and leadership formed by rural people with past experiences in collaboration and knowledge about the use of land and plants: 1) El Llano, San Blas; Rancho Chiota, Compostela) La Curva, Xalisco; 3) Meseta de Juanacatlán Jala, 5) Coapan, Jala and 6) Tepic, capital of Nayarit State.

Following the installation of the solar drying prototypes, the core group provided user support based on their level of expertise and leadership. To facilitate technology adoption, core group members collaborated with each type of user to conduct initial drying runs, obtaining dehydrated products representative of each site, also delivered technical training on safety criteria, basic drying process parameters. Concurrently, to further promote energy use in the intervention sites, the core group conducted parallel workshops on constructing solar stoves. With each drying practice, operation manuals for the dryers were refined, prototype designs were improved for continuous enhancement, and collaborative proposals for improvement were implemented. User's practical experiences led to suggestions and actions for refining the dryer and data acquisition systems, ensuring user-friendly handling and operation.

CONCLUSION

We have successfully implemented solar dryers in rural communities near the farm site, which can effectively dry 70 kg of fruit pulp within just 2 solar days, employing a transdisciplinary research approach. This approach proves effective in promoting sustainable rural development, and installing simple, easily manufactured solar dryers is feasible in all rural regions of Mexico and worldwide, provided there are suitable agroclimatic conditions. By implementing small solar dryers near to the farm sites a sustainable rural development can be achieved.

Maintaining continuous support from academic members is crucial to attaining energy project goals. This fosters trust and commitment between the community and the core group. Ongoing feedback and monitoring have enabled the core group to fine-tune drying processes at each site and for each product. Insights from each community have been shared with others, fostering opportunities for exchanging experiences, products, collaborative efforts, and cooperation to strengthen collective endeavours.

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