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# Participatory Evaluation of *'Irorunde'*, A Prototype Drum Oven for Traditional Fish Smoking in Nigeria: A Case Study of Knowledge Co-Production and Inclusive Innovation

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## Abstract

In Nigeria, traditional fish smoking methods predominantly utilize firewood as an energy source, which presents sustainability challenges. Improved fish smoking techniques face low popularity owing to considerable obstacles hindering adoption by fishers involved in fish smoking and development by inventors. This study explored the benefits, challenges and social acceptance of a modern drum oven prototype by fishers engaged in fish smoking. Against this backdrop, Participatory Action Research (PAR) was conducted using a prototype kiln using carbonized biomass briquettes (CBB) in traditional fish smoking drum ovens. Fishers involved in fish smoking performed evaluations of the prototype, and their perceptions regarding the characteristics of innovation were utilized to assess their willingness to adopt the prototype.

The WhatsApp platform was used to share information and promote peer-to-peer learning. The PAR and evaluations by the fishers led to improvements in the design, construction and performance outputs of the prototype. The fishers agreed that CBB was economical and was a cleaner energy source, facilitating social acceptance and the adoption of the prototype as a substitute for the local drum. The portable size, quality and aesthetic structure also contributed to the adoption of the prototype. In conclusion, the prototype became a socio-economic tool that has encouraged the use of CBB in fish smoking with improved financial and health benefits of the fishers engaged in fish smoking. Local technologies must incorporate inclusive innovation and gender-responsive approaches to facilitate implementation and adoption, thereby improving benefits and well-being of the fishers.

**Keywords**: Prototype, traditional drum oven, willingness to adopt, perceived characteristics of innovation, participatory action research.

## Introduction

In West African countries, including Nigeria, fish smoking is a major fish processing industry which provides essential protein to the population. The industry is predominantly led by women, who also constitute most of the labour force. To make industry and its products safe for consumers and producers, improved technologies that are effectively diffused to fishers engaged in smoking fish are required. Despite significant technological advances, the diffusion of new types of smoking ovens has been limited and users of such technology have had minimal involvement in the development of these new designs.

Fishers primarily use traditional fish smoking methods distinguished by various local methods referred to as ovens, dryers, or kilns. These methods are marked by high firewood consumption, inefficiency, and inconsistency, leading to suboptimal product quality and significant environment costs.

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Reliance on these techniques is one of the principal causes of degradation and deterioration of processed fish quality in developing nations (Kruijssen et al., 2020). The techniques are characterized by immense heat loss due to lack of insulation and control over the drying process. Smoking fish with local techniques requires constant attention to monitor and turn the fish to prevent charring (Nti, Quaye, & Sakyi-Dawson, 2002). The process is therefore laborious, time-consuming and does not meet the national and international sanitary and technical standards. The heat and smoke generated cause occupational hazards to women and their families, during the smoking process.

Nigeria consumes 3.6 million tonnes of fish annually but has a recorded deficit of 2.5 million tonnes which is compensated through fish imports (Ogunji & Wuertz, 2023). Further, post-harvest losses in the small-scale fisheries could be in excess of 30% of the catch (Akintola & Fakoya, 2017). Technological improvement is crucial in increasing the output of smoked fish, reducing post-harvest losses and thereby reducing fish import, while also ensuring the welfare of fishers engaged in smoking fish (Isaacs, Comfort, Igbekele, & Timothy, 2020). Improved fish-smoking techniques have been developed over the years to increase the quality of fish, and hence the quality of life of fishing communities (Nti et al., 2002). The techniques include the drum oven, the *Chorkor* oven and the *Banda* oven, and more complex designs such as the *Altona* Oven and the Nigerian Institute for Oceanography and Marine Research (NIOMR) Oven (Bolade, 1988). A more recent technique is the FAO-Thiaroye processing technique (FTT-Thiaroye) introduced to Africa and Asia (Akintola, Fakoya, Elegbede, Odunayo, & Lekan, 2022).

The limited adoption of improved techniques in Nigeria and sub-Saharan Africa suggests that prior efforts have largely failed due to numerous unresolved barriers. In Ghana, a hub of fish smoking technology research, less than one percent of the roughly 120,000 processing ovens are classified as 'improved' smoking technology (Adjei, 2023). Due to inadequate infrastructure, including cold storage, processing facilities, access roads, and reliable electricity, conventional post-harvest technologies continue to prevail in tropical countries such as Nigeria (Akintola & Fakoya, 2017). Individual limitations and societal and political issues contribute to systemic barriers to technological adoption (Mobarak & Saldanha, 2022).

Women engaged in fish smoking are frequently seen as consumers of oven technology related to fish smoking rather than co-producers. Since the 1960s, improved fish smoking ovens have been designed with little evidence of engaging women fisherfolk in research (Williams & Sydall, 2022). Adoption and replication of improved fish-smoking techniques face several challenges, including high costs, low awareness of benefits, insufficient technical knowledge sharing, and lack of monitoring, evaluation, and learning beyond pilot stages. Incompatibility with traditional processing systems, socio-cultural practices, and failure of developed technology to address real problems of women engaged in fish smoking are some other challenges (Nti et al., 2002; Alabi et al., 2020; Anane, 2020; Adeyelu, Johnson, Adeyelu, & Adedokun, 2022; Feka, Massaquoi, Lamptey, & Osei-Owusu, 2022). In addition, the innovations have created controversy within development circles because the focus has been on national economic growth at the expense of individual improvement of the farmer or fisher and has thus contributed to widening socio-economic inequity (Bolade, 1988). In response to these issues, new forms of innovation relevant to the needs of end-users and supporting individual growth are emerging (Heeks, Amalia, Kintu, & Shah, 2013), and invariably, these models depend on closer interaction between technology developers and end-users.

Innovation is defined in various ways, with ISDC (2022) describing agricultural innovation as "the process of creating and applying agricultural practices new to a specific environment." Inclusive innovation, on the other hand, emphasizes a collaborative process that engages local actors and integrates intersectional factors such as age, gender, and ethnicity. Mbabu and Hall (2012) highlight innovation as the application of new or existing ideas with social or economic value, assessed only after implementation. Adoption of innovation is influenced by individual decision-making, shaped by factors like information sources, user attitudes, perceived benefits of the technology, and external influences. Key characteristics for successful adoption include advantage, compatibility, complexity, trialability, and observability (Blythe et al., 2017; Dedehayir et al., 2017), and these elements collectively determine the acceptance and impact of new technologies.

Principally we investigate the reasons for women (and men) in adopting innovations. It is critical to understand how they see technologies to understand what drives their decision to embrace it or not to uptake it, and effects on replication and scaling up. In light of this, a Gendered Design in Science, Technology, Engineering, Arts, and Mathematics (GDS) project, assessed the factors that women engaged in fish smoking perceived to be important in the adoption of a prototype fish drum oven. The project specifically identified socio-economic characteristics of a small pool of fishers engaged in fish smoking and explored perceived characteristics of the innovations which are paramount in influencing their adoption decision.

This study introduces a prototype fish smoking oven designed to address the needs of local fishers, marking an incremental improvement to traditional fish smoking technology. The objective of the study was to specifically identify socio-economic characteristics of fishers engaged in fish smoking and explore perceived characteristics of the innovations which are paramount in influencing their adoption, replication and scaling up decisions.

## Materials and Methods

A training workshop was conducted to pilot the use of carbonized biomass briquettes (CBB) as an alternative smokeless energy source to charcoal and firewood-based fish smoking technologies that was previously conducted with some stakeholders across Lagos State. Post-workshop, the stakeholders experimented with fish smoking with CBB in their homes and shared their experiences on a WhatsApp Discussion Platform created purposefully to encourage peer-to-peer learning. The decision to produce a prototype modern drum oven in this study was prompted by one of the stakeholders located in Badagry, the coastal region located west of Lagos, experimenting with CBB in a traditional, open half-drum oven. Participatory Action Research (PAR) was used in the present study to ensure the active involvement of local fishers engaged in fish smoking activities throughout the research process. PAR ensured that the evaluation was bottom-up driven and addressed challenges with respect to the fabrication of a modernized drum oven. Participatory evaluations involved selected fishers, who were randomly drawn from the GDS workshop participants list, which had three project team members, three research assistants, and the technology producer. A total of three evaluations were conducted in three phases at the premises of the technology producer located at Kalos Agro Homes in metropolitan Lagos, Nigeria during September 2022. The technology provider who was involved was a small-scale producer of CBB, who also fabricated local grills and dryers.

The fishers were selected from four divisions consisting of Ikorodu, Badagry, Lagos Mainland and Epe. The only exception was Ikeja where there were no representatives due to lack of activities in small-scale fisheries. Selected fishers were prominent members of their associations with small-scale enterprises dealing predominantly in purchase and smoking of fresh fish and shellfish.

Fig. 1. Fish smoked with CBB in a traditional drum oven.

The prototype was designed and constructed with an understanding of the specific needs and preferences of the fishing community. The idea was to develop a decent and affordable smoking oven that promotes occupational safety, health and wellbeing of people handling the oven. One specific requirement was to improve safety, since after several years in the profession, many suffered occupational

hazards from exposure to intense heat and smoke affecting eyes and respiratory system when using traditional ovens. The other need was an oven that can utilize safe and more cost-effective fuel sources like charcoal, at a time when the Government had been campaigning for change from firewood to charcoal. Besides, it was also intended that the innovation should be able to create employment, and should positively impact the fisher lives socially, financially and economically. The familiarity of the research team and the fishers with traditional drum oven technology and availability of construction materials were major factors driving the prototype construction. The prototype was constructed from locally sourced materials and was fabricated using two recycled food-grade metal drums of 200 liters capacity. The two drums were arranged to form a double wall with insulating or lagging material such as mud or fibre-wool, between the two walls. The prototype had three main parts: a chimney, the drying chamber and the firebox. Within the drying chamber were four layers of trays; each was split into two to conform to the two-door design which are also detachable. Each tray had a capacity of 5 kg to 6 kg. A cover plate was placed over a perforated firebox and a lid or roof bearing the chimney.

The fish used for experimental smoking were wild-caught croakers (*Pseudotolitus senegalensis)* which were processed following standard procedures. The prototype drum oven efficiency was evaluated based on the smoking duration and percentage weight loss in the final product. Temperatures were recorded at the onset of smoking and monitored till drying was deemed as sufficient. Three participatory performance evaluations of the prototype fish smoking oven with CBB as energy source were conducted. A qualitative case study approach was employed to collect primary data through dialogues guided by semi-structured interviews, observations, summary notes, and video clips shared on social media platform. Video clips and photos of the fabrication process were posted on a social media platform regularly to communicate the various stages of the project. Dialogues aided with interview helped gather opinions on perceived benefits, limitations and likelihood of adopting the prototype drum oven.

Following the method of Akande and Adeyemi (2016), the opinion of fishers was sought in three iterative tests to identify limitations in the prototype design and construction, and propose modifications for improvement. The main themes that emerged during the trials were related to criteria within the domains of product quality, drying time, batch capacity, drudgery, occupational hazards, complexity, maintenance and environmental impact.

Study on the adoption of innovation was based on the stages, from awareness to interest, evaluation, trials, and confirmation. Communication channels were used as strategies to monitor and sustain the progress of the project through dissemination of information. These channels included the training where the CBB was introduced to fishers, a WhatsApp Discussion Platform to respond to the questions, clarifications and interests of the participants; and video clips to promote the use of CBB after the training.

Qualitative data were transcribed and analyzed using inductive approach. Themes were derived using the perceptions of fishers on characteristics of innovation in a conceptual model for the adoption decision process and the influence of various factors adapted from Blythe et al. (2017) & Kumar, Engle, and Tucker, (2018) as shown in Fig 2. Data from all sources were triangulated to present the findings.

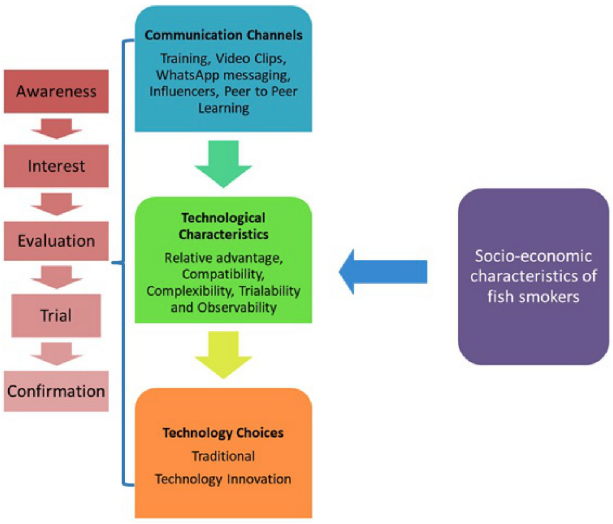


Fig. 2. A conceptual model for the adoption decision process and the influence of various factors adapted from Blythe et al. (2017) & Kumar et al. (2018).

## Results and Discussion

Participants consisted of six fishers, five women and one man, aged between 40 and 58 years. Four of the

participants were above 50 years while two were between 40 - 45 years. Two of the participants had formal education up to primary school level while the remaining had formal education up to post-secondary and graduate levels. Only one had acquired vocational training in fish processing, while the remaining five inherited fish smoking skills and knowledge from family members. The two oldest fishers, a woman and the only man, exclusively operated traditional drum ovens. In addition, two other women fishers managed both modern charcoal and traditional ovens. The other two women used modern charcoal ovens. Firewood was used more frequently than charcoal as a source of energy. The participatory action research enabled fishers to share experiences and challenges of their profession and their knowledge of various types of fish smoking interventions. This information gave insights into their expectations of the impact of the prototype in their occupation which was perceived as a modern version of the traditional drum oven technology they were accustomed to.

The six participants attended the first participatory performance evaluation held in September 2022 to identify specific needs and new areas for improvement of the prototype smoking oven. Based on individual experiences, fishers highlighted shortfalls in the construction requirements of the prototype and suggested modifications for improved performance. The fish drying process was identified as very slow at 4 hours and 40 minutes. The fish (croaker samples weighing 7.42 kg) was observed to retain considerable moisture and was consequently transferred to a charcoal oven for further cooking and drying. The final weight and percentage weight loss were not recorded because of the inconclusive performance of the prototype.

Table 1 presents a list of the shortfalls and major modifications of the mud-insulated fish smoking oven. Major shortfalls included its heavy weight, small size, lack of in–built thermometer and fish oil collector, lack of non-conducting materials for handles, spilt trays, lack of wheels for mobility, and of security locks to prevent theft of processed fish. Other problems were heat loss through gaps between the doors and from the chimney, and inadequate perforations of the firebox.

The second and third evaluations were conducted in mid and late September 2022. Recommendations to overcome technical problems identified in the mud-insulated prototype were addressed and implemented except for the small-size. The mud insulator was replaced with fiber-wool to become a fiber-insulated model that was evaluated for its performance (Fig. 3a – 3b).

The second and third participatory evaluations involved three fishers and two research members in their attendance. The mean weight loss for the test fish was 56.26%, occurring over an average duration

Fig. 3a. The prototype with detached components

Fig. 3b. The prototype with opened doors

of 4 hours and 40 minutes, with temperatures ranging from 100°C to 150°C. (Table 2).

Evenly smoked fish that did not require an interchange of tray/fish position were observed with CBB smoking in the prototype. Fishers testified to the improved efficiency of the prototype. Modifications to the prototype improved the outcome of CBB-smoked fish concerning taste, texture, aroma and appearance, and were judged to be better than charcoal and firewood smoked fish, respectively. CBB-smoked fish appeared golden and produced a dried texture that could preserve the fish for 1-2 weeks (Fig. 4).

The third evaluation was based on the detailed examination of the fisher requirements. A summary of the need-based criteria for the prototype after the evaluation was compared to the traditional drum oven (Table 3).

Fig. 4. Photograph of samples of golden coloured Croakers smoked with CBB from the 2nd evaluation

## Perceived Characteristics of Innovations by Fishers engaged in fish smoking

### *Relative Advantages*

The most common advantage of the prototype cited by participants was the positive environmental impact promoting the use of CBB and eliminating the use of firewood. The detrimental impact of firewood was highlighted *"Firewood is likely to cause death, and it causes blindness and darkening of the hands if it gets too much"* (Participant A, oldest woman, 56 years, operated traditional drum oven). As opined by another fisher, if firewood consumption could be reduced *"a lot of fishers smoking fish will use the prototype fish smoking oven to smoke fish thereby reducing consumption of contaminated fish that are harmful to our health"* (Participant L, woman, 54 years, operated both traditional and modern ovens). According to the only male fisher, *"It will reduce stress and hazard of smoke to producers and consumers"* (Participant E, 53 years, operated traditional drum oven).

Table 1. Fishers' perception of limitations of the prototype and recommendations

| Shortfalls | Distribution of respondents | Recommendation | Purpose for modification or changes |
|---|---|---|---|
| Heaviness of the prototype | 6 | Replace or substitute mud with fibre-wool | Weight reduction and enhance portability. |
| Small-size | 2 | Addition of more trays | Increase batch capacity |
| Lack of fish oil collector | 2 | Addition of fish oil collector tray | To avoid oil from fish dripping on the flame and causing possible explosion. |
| Lack of in-built thermometer | 2 | Add in-built thermometer | To measure temperature in drying chamber and make adjustments. |
| Split, circular trays | 4 | Replace with whole, circular trays. | To facilitate easy removal for cleaning and to prevent fish from falling off when the doors of the prototype are opened. It was opined that whole; circular trays would allow more fish to be added |
| Slow combustion of briquettes | 4 | Drill more holes at the base of the firebox and prototype. | For quicker and complete combustion of biomass briquettes, and prevent build-up of ash |
| | 1 | | Elevate or raise prototype about 4 inches from ground level. |
| Heat loss | 5 | Reduction of the diameter of the chimney and closing gaps between the doors when closed. | To eliminate heat loss during smoking and drying processes. |
| Lack of security | 6 | Add padlock hinges on doors | To prevent poaching from prototype |
| Lack of mobility | 4 | Add wheels at base of the prototype | To enhance mobility |
| Hot door handles | 2 | Add non-conductor materials | To prevent scorching of hands |

The second most commonly mentioned advantage was that the prototype saves time, allowing the fishers to engage in other activities, and also eliminates drudgery. Another fisher stated: *"When we smoke fish with the prototype, we can do other things as well"* (Participant A, oldest woman, 56 years, operated traditional drum oven). "*Irorunde*", the name in Yoruba Language proposed for the prototype by the fishers is a testimony. The meaning is literally akin to 'comfort' or 'relief' which implies that it is time–saving and eliminates drudgery. Other advantages of the prototype, particularly when used with CBB, were attributes of aesthetics and cleanliness that enhance fish smoking as attractive and decent work. A fish smoker commented: *"When smoking with CBB, we can use our hands to rub our body, we can wear our clean clothes while smoking"* (Participant A, oldest woman, 56 years, operated traditional drum oven).

Product quality was another positive attribute associated with smoking fish using CBB. Practical demonstrations and comparative evaluations of different fuel-type based fish smoking processes at the workshop pointed to the attractive quality of the CBB- smoked fish relative to those smoked by charcoal and firewood. A fisher described the fish smoked in the prototype as *"Tasty, possessing a glossy appearance and looking like fried as if an air dryer was used, hardy and dry without dark smudges and crumbs"*(Participant J, woman, 46 years, operated both traditional and modern oven). Furthermore,

another fisher stated that if the prototype passes the smoking fish testing, it is a useful and viable product.

## Compatibility

The fishers perceived the prototype and its operation as identical and compatible in comparison with their traditional fish smoking method. It was judged as an improvement and useful in discouraging the use of firewood. One fisher pointed out that, *"There might be other ones elsewhere but this is the first we are seeing in Lagos and we appreciate them for striving to help us out of the old methods"* (Participant L, woman, 54 years, operated both traditional and modern ovens). Other fishers were also delighted with the prototype fish smoking oven and training to educate them on alternative energy sources to firewood.

There were mixed reactions, however, to the small size of the fibre-insulated prototype. Although the size is portable and admired for mobility, limitations on smoking production and holding capacity are incompatible with fishers ' commercial scale of production. However, a fisher lauded the portable size because it did not require space and thought it an advantage for small-scale fishers who process small quantities, instead of using the large-sized oven for the same quantity of fish. But she too requested a larger-size oven for larger quantities of fish. Another fisher also highlighted that the prototype was presentable to fishers that still use the old drum but, referring to the size, she added, *"This size could discourage some fishers who are adamant and still use old trays and drum that can take more fishes."* Furthermore, she advised more trays to be added (Participant H, woman, 45 years operated only modern charcoal oven). Fishers also were satisfied with the time spent in smoking fish. The oldest womam fisher actually commended the time as convenient for her at the third evaluation.

## Complexity

The fishers experienced practical application of the prototype during performance evaluations, and

Table 2. Performance evaluations of the prototype drum oven

| Replicates | Weight before smoking (gms) | Weight after smoking (gms) | Body Weight Loss (%) | Drying Time (hours and minutes) | Average Temperature (°C) in drying chamber |
|---|---|---|---|---|---|
| 2nd Evaluation | 2094 | 1424 | 31.91 % | 4 hours and 44 minutes | 116.7 (100 -130) |
| 3rd Evaluation | 3080 | 600 | 80.52 % | 4 hours 35 minutes | 123.33 (100- 150) |

Table 3. Criteria for analyzing the perceptions of fishers on the advantages of the prototype drum oven compared to the traditional drum oven

| Comparative Parameters | Types of Smoking Ovens<br>Prototype Drum Oven | Traditional Drum oven |
|---|---|---|
| Locally sourced materials | This may be limited in the use of local materials e.g. lagging materials, etc. and good –grade drums. | Only locally sourced materials are used, though with several limitations. |
| Design | The design is more thoughtful working to fill the limitations of the traditional ovens. | Nothing much is done in the design of this type of kiln. |
| Processing time | This can potentially reduce processing time by more than 50% at least. | Too long processing time as fishers still transfer the products to other dryers after processing for several hours in the ovens. |
| Size or batch capacity | This is limited as the kiln has a maximum capacity per batch. | This is somewhat unlimited as more trays can be added on top of one another though the processing will take a long time but at least it can temporarily extend the shelf life longer especially when they have too many catches. |

| | | |
|---|---|---|
| Prevention of energy loss or insulation | Energy loss is reduced up to 80 to 90% due to lagging materials. | Energy is being lost to the environment. |
| Uniform drying | This is largely ensured although some monitoring may be necessary for very good quality processing. | Laborious monitoring is required. Uniform drying cannot be ensured. |
| Fish oil collection capacity | There is provision for an oil collector in the design of this kiln but this can be further improved for easy collection of oil. A gradual descent tray will be more appropriate than the flat surface design. | No provision for oil collection with this design. |
| Ergonomics | The design was put together considering the human systems and other factors alike. | No sense of ergonomics is considered here. |
| Drudgery, free up time | Drudgery is reduced to the barest minimum with this design. | The method has many processes inducing drudgery. |
| Easy to use | Easy to use. The positions of trays remain the same from the onset to the end of fish processing. | Easy to use though more laborious and close monitoring is needed when in use. |
| Easy to maintain | Easy to maintain though more demanding than the traditional one. | Easy to maintain though with very low durability. |
| Occupational hazards | Eradicated almost all occupational hazards. | Too many hazards associated with the use of this oven. |
| Smoking process | Neat and well done. | Not well done with a lot of drudgery. |
| Smoking technique | A bit technical giving rise to a better quality of product. Control of the drying process is attainable. Good for smoking, cooking, and complete drying of fish products. | There is little or no technology or technique infused here. Complete drying is difficult to achieve because of a lack of control over heat. |
| Environmental impact | This doesn't impact negatively on the environment. Smoke invasion is reduced to the barest minimum. | This impacts negatively on the environment. |
| Renewable and environmentally friendly energy sources | It encourages the use of environmentally friendly material such as the briquette. The design reduces release of obnoxious gases to the environment. | This promotes the use of firewood which degrades the environment. |
| Life span | Lasts longer than the traditional oven. | This lasts for less than 6 months if used constantly. |
| Holding capacity | The holding capacity though low is better than the traditional ones and this can still protect the products from rodents and pests. | This necessitates the transfer of most finished products to the dryer after being processed in the oven. |
| Portability | This is very portable. It can be wheeled from place to place. | Not portable. |
| Mobility | Easy to move from one place to another due to its detachability. | Difficult to move around. |
| Aesthetic | This has better aesthetics; it is beautiful to behold. It doesn't have the look of a dryer from far. | The aesthetic is poor. |
| Product quality (colour, texture, taste, smell) | The product quality is neat, light brown appearance, better texture, pleasant taste due to uniform drying, with good flavour. | Poor quality, very dark brown appearance with not-so-pleasant taste due to reduced uniformity in drying. |
| Usage relative to weather conditions | Can be used even when it is raining. Compact and enclosed from the weather elements. It can be moved into the home. | Exposed to weather elements and cannot be used when it is raining. It is can be used only outside especially when firewood is used. |

these contextualized the prototype as easy to operate and use, respectively. For example, at the first evaluation, one fisher expressed her excitement as follows: "*Learned or unlearned, skilled and unskilled laborers can use the prototype and CBB."* At the second performance evaluation, another fisher observed: *"We didn't have to turn or interchange trays during smoking"* (Participant J, woman, 46 years, operated both traditional and modern oven).

## Trialability and Observability

Performance evaluations and discussions on a WhatsApp platform provided opportunities for continuous learning on the use of the prototype. Both fishers engaged in fish smoking and researchers observed the smoking process in the prototype to assess its usability, efficiency, and safety during and after the project. Visible results of the utilization of the prototype created greater interest and knowledge sharing. The prototype was described as a user-friendly oven, which conserved heat, was safe to operate and showed effective performance within a timed process.

The research strategy was gender-responsive and inclusive, based on local knowledge and technology. The women fishers connected with the prototype based on its design and fabrication from the traditional drum oven to which they were accustomed and operated, potentially lowering the risks of rejecting the prototype innovation. They concluded the prototype had the required utility in terms of product quality, ergonomics, decent working conditions, reduced occupational hazards, time wastage, and tedium. The fishers positively demonstrated the adoption of the prototype due to the use of smokeless CBB as an energy source of the prototype. Including end-users in the evaluation phase and increased communication by information technologies were critical for closing learning and knowledge gaps. Effective communication between researchers and fishers significantly enhanced the understanding of the essential technological features required in the prototype oven. Furthermore, the efficacy of information distribution improved with smaller and socioeconomically comparable homogeneous groups of end-users as demonstrated in this research (Kumar et al., 2018).

The decisions on methodologies were not set at the beginning of the research process. Instead of controlling the innovation development process, our reactions to findings and unforeseen events constantly moulded the methodological decisions that were adaptive (Olmos-Vega, Stalmeijer, Varpio, & Kahlke, 2023). Therefore, women fishers were empowered as individuals whose perspectives were sought and adopted to improve the prototype during evaluations. The participation of women fishers enabled them to make decisions on the prototype thereby modifying the prototype to suit the requirements of small to medium-scale processors. Therefore, our research demonstrated an entry point for empowerment, a cardinal objective of a gender-transformative approach. It addressed asymmetry in power relations between the technology producer, the research team, and the women fishers (Beuchelt, 2016), leading to co-production in innovation and willingness to adopt the innovation. The research process was based on mixed data and an inductive approach rooted in and responsive to diverse settings.

This research provides a springboard to participate in national and global discourse on energy use in small–scale fisheries, decent working conditions and gender issues in post-harvest fisheries. It aligns with recommendations arising from a national multi-stakeholders and awareness-raising workshop for the Implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (SSF Guidelines) held in Nigeria in 2022 (Akintola & Fakoya, 2023).

The development of a prototype drum oven holds significant potential for improving the efficiency, consistency, and safety of fish smoking practices for local fishers engaged in fish smoking. The research was gender-responsive and inclusive to contextualize the adoption process and the characteristics of the innovations and factors influencing the innovation. Building on local knowledge, peer-to-peer learning and perceived benefits of the prototype on health largely contributed to the breakdown of cultural barriers between technology experts and fishers engaged in fish smoking, and increased willingness to adopt the innovations.

Further research, field trials, and stakeholder engagement are necessary to assess the viability and scalability of this prototype oven in different local contexts. Anticipated outcomes include scaling up the prototype, employment generation especially for youth in fish smoking, and oven fabrication.

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## References

Adeyelu, A. A., Johnson, S. B., Adeyelu, A. T., & Adedokun, B. C. (2022). Analysis of factors influencing the adoption of charcoal powered processing oven by fish farmers: evidence from Nigeria. *International Journal of Environmental & Agriculture Research, 8* (3), 49-58.

Adjei, P. L. (2023). *Social development and sustainable fisheries: Ghana*. International Collective in Support of Fishworkers, India.

Akande, G. R., & Adeyemi, R. S. (2016). Performance of a biofuelled detachable fish smoking kiln. *CIGR Journal, 18*(3), 233-244.

Akintola, S. L., & Fakoya, K. A. (2017). Small-scale fisheries in the context of traditional post- harvest practice and the quest for food and nutritional security in Nigeria. *Agriculture and Food Security, 6*, Article 34. https://doi.org/10.1186/s40066-017-0110-z.

Akintola, S., & Fakoya, K. (2023). *Report on the National workshop on media and advocacy capacity building for the implementation of the voluntary guidelines for securing sustainable small-scale fisheries (SSF guidelines) in Nigeria*. ICSF, Lagos.

Akintola, S. L., Fakoya, K. A., Elegbede, I. O., Odunayo, E. O., & Lekan, T. J. (2022). Postharvest practices in small-scale fisheries. In C. M. Galanakis (Eds.), *Sustainable Fish Production and Processing* (pp. 79-110). Academic Press, Cambridge, US.

Alabi, O. T., Olaoye, O. J., George, F. O. A., Adeola, A. A., Alabi, J. O., & Ojebiyi, W. G. (2020). Awareness and adoption levels of improved smoking oven among fish smokers in Lagos Lagoon, Nigeria. *Ghana Journal of Agricultural Science, 55*(2), 39–58. https://doi.org/10.4314/gjas.v55i2.1.

Anane, E. (2020) Adoption and diffusion of improved fish processing technology on household income: A case of Elmina community in Ghana using system dynamics thinking (MSc. Thesis). Department of Geography, University of Bergen.

Blythe, J., Sulu, R., Harohau, D., Weeks, R., Schwarz, A. M., Mills, D., & Phillips, M. (2017). *Social dynamics shaping the diffusion of sustainable aquaculture innovations in the Solomon Islands. Sustainability, 9*(1), Article 126. https://doi.org/10.3390/su9010126.

Bolade, E. O. (1988). Technological innovations for fisheries development: issues and analysis. *Agricultural Administration and Extension, 28*, 191-205. https://doi.org/10.1016/0269-7475(88)90035-9.

Beuchelt, T. D. (2016). Gender, social equity and innovations in smallholder farming systems: pitfalls and pathways. In F. W. Gatzweiler, & J. von Braun (Eds.), *Technological and institutional innovations for marginalized smallholders in agricultural development* (pp. 181–198). Springer International Publishing, Cham, Switzerland.

Dedehayir, O., Ortt, R. J., Riverola, C., & Miralles, F. (2017). Innovators and early adopters in the diffusion of innovations: A literature review. *International Journal of Innovation Management, 21*(9), 85-115. https://doi.org/10.1142/S1363919617400102.

Feka, Z. N., Massaquoi, A., Lamptey, E., & Osei-Owusu, P. K. (2022). Upscaling improved fish smoking ovens: A management perspective for nature-based solutions in Western Africa? *International Journal of Resources and Environmental Study, 9*, 1-11.

Heeks, R., Amalia, M. Kintu, R., & Shah, N. (2013). Inclusive innovation: definition, conceptualisation and future research priorities. *Development Informatics Working Paper,* Article 53.

Isaacs, O. A., Comfort, A. I., Igbekele, A. A., & Timothy, A. T. (2020). Adoption of improved technologies and profitability of the catfish processors in Ondo State, Nigeria: A Cragg's double-hurdle model approach, *Scientific African, 10*, Article e00576. https://doi.org/10.1016/j.sciaf.2020.e00576.

Independent Science for Development Council (ISDC). (2022). *Transformation through inclusive innovation*. CGIAR Independent Advisory and Evaluation Service, Rome.

Kruijssen, F., Tedesco, I., Ward, A., Pincus, L., Love, D., & Thorne-Lyman, A. L. (2020). Loss and waste in fish value chains: A review of the evidence from low and middle-income countries. *Global Food Security, 26*, Article 100434. https://doi.org/10.1016/j.gfs.2020.100434.

Kumar, G., Engle, C., & Tucker, C. (2018). Factors driving aquaculture technology adoption. *Journal of the World Aquaculture Society, 49*(3), 447-476. https://doi.org/10.1111/jwas.12514.

Mbabu, A. N., & Hall, A. (2012). *Capacity building for agricultural research for development: Lessons from practice in Papua New Guinea*. United Nations University-Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT), Netherlands.

Mobarak, A. M., & Saldanha, N. A. (2022). Remove barriers to technology adoption for people in poverty. *Nature Human Behaviour, 6*, 480–482. https://doi.org/10.1038/s41562-022-01323-9.

Nti, C. A., Quaye, W., & Sakyi-Dawson, O. (2002). Evaluation determinants for effective adoption of an improved fish-processing technology in Ghana. *Ghana Journal of Agricultural Science, 35*(1), 177-184.

Ogunji, J., & Wuertz, S. (2023). Aquaculture development in Nigeria: The second biggest aquaculture producer in Africa. *Water*, *15*(24), Article 4224. https://doi.org/10.3390/w15244224.

Olmos-Vega, F. M., Stalmeijer, R. E., Varpio, L., & Kahlke, R. (2023). A practical guide to reflexivity in qualitative research: AMEE Guide No. 149. *Medical Teacher, 45*(3), 241-251. https://doi.org/10.1080/0142159X.2022.2057287.

Williams, M. J., & Syddall, V. (2022). Women, fisheries technology and development: toward new research approaches, *Gender, Technology and Development*, *26*(3), 357-384. https://doi.org/10.1080/09718524.2022.2125456.