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Impacts of Using Solar Dryers on Socio-Economic Conditions of Dried Fish Processors in Cambodia

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Abstract: Fish is a vital source of proteins and nutrients and can be eaten in many forms, one of which is dried fish. In Cambodia, fish is mostly dried in traditional ways and can be subject to dust, flies, rain, and weather events, resulting in low-quality products. These issues can be addressed by using solar dryers. Thus, this study was aimed to (1) compare the socio-economic conditions between dried fish processors practicing traditional drying and those using solar dryers, (2) to identify potentials and challenges to dried fish production between the two groups, and (3) to determine the factors affecting income. The study was conducted between May and August 2023, using purposive sampling to select two groups of dried fish processors in three provinces along the river systems in Cambodia. The selection criteria included (1) engagement in year-round dried fish production, (2) at least 100 kg of raw fish dried per month, and (2) willingness to participate in the interviews. Then, 35 dried fish processors that practiced traditional drying and 9 processors that utilized solar dryers were selected. *T*-tests, chi-square tests, analysis of variance (ANOVA), Likert scale analysis, and multiple linear regression model were used to compare the socio-economic conditions, perceptions, and the factors affecting the income. The results show that the solar dryer group used more labor, produced more dried fish, and had a higher selling price when compared to the traditional drying group. They had more opportunities to attend training and trusted the solar dryer technology. Meanwhile, the traditional drying group preferred direct sun-drying, but dried fish quality was better when solar dryers were used. Experience, total costs, and the use of solar dryers affect the income. In conclusion, using solar dryers tends to produce dried fish of better quality and a higher income, which is good for both health and improved livelihoods of fish producers and sellers.

Keywords: protein; fish production; traditional drying; solar dryers; economic analysis

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1. Introduction

Fish plays an important role in providing an excellent source of food and generating employment across the world. About 17% of global animal protein comes from fish or fishery-related products [1], while 10–12% of the world's population depends on fisheries and aquaculture for their livelihood [2,3]. Fish is also considered part of a healthy diet because it contains Omega-3 fatty acids, vitamins, proteins, and minerals that can promote body growth and immune systems while preventing high blood pressure and the risk of a heart attack [4–6]. The protein content of raw fish ranges from 15 to 20% of the body weight and it is low in fat [7]. Meanwhile, the main vitamins found in fish include vitamin D and B2, known as riboflavin, and it is also rich in calcium and phosphorous which are good for health [8]. Thus, fish is recommended to be eaten at least twice a week for balanced health [9].

In Cambodia, fish is the most important protein source because it provides 75% of all animal protein intake [10], and it is also the most consumed food after rice. More than 2 million people in Cambodia make their living in fisheries or related activities [11]. In the early 2010s, the average apparent fish consumption was 63 kg/person/year, of which 70% came from inland fish [12,13]. However, it was reduced to 42.7 kg/person/year in 2017 [11], while the average fish consumption per capita in Asia and in the world is 24.5 [14] and 17 kg/person/year, respectively [15]. Fish is also exported abroad, and the whole fishery sector contributed to 5.5% of the gross domestic product (GDP) of Cambodia in 2019, which was higher than that of livestock (2.2%) [16]. In the Tonle Sap River, an average household catches 263 kg of fish annually, 11% of which is processed, while the rest is sold fresh directly to wet markets [17]. Nevertheless, higher added value can be created with proper fish processing.

Fish possesses extreme perishable characteristics [18,19], so it is usually processed in various forms for longer use [20]; the final outcome can be in the form of paste or dried products. One of the most common practices in Cambodia is fish drying, which is part not only of food and economy but also of culture deeply adherent in the society. Cambodian people prefer direct sun-drying techniques [21], but open sun-drying is considered ineffective in terms of hygiene and nutrition, which can cause health-related issues [15,22]. Without proper covering, fish can be exposed to extreme ultraviolet radiation that can damage nutrient sources inside and darken the outer part of the drying fish [23]. In addition, there are more opportunities for contamination causing food safety issues.

Biologically, sun-dried fish are subject to variations in temperatures and humidity because the climate is not controllable, thereby affecting the chemical and physical properties that lead to low-quality products. The temperature obtained directly from the sunlight even during the hottest hours is normally less than 40 °C, which prolongs the drying process. This results in a waste of time and energy. That is why solar drying is recommended to shorten the drying process [24]. Open sun-drying also exposes fish to dust, rain, insects, or rodents, which is considered unhygienic for consumption [25,26].

To solve these issues, solar dryers are used because they are a closed drying system that produces heat inside the drying chambers to dry the intended products without letting them be contaminated by external factors [27]. This process leads to faster moisture removal from products being dried. The climate inside the dryers is more controllable with an average temperature of 30–60 °C [28], which almost doubles the temperature measured in the outside atmosphere. One study found that temperatures can be maintained at 50–52 °C in different trays [29] and some mentioned that during the peak hour the temperature can reach 62 °C, which is almost twice the ambient temperature [30], which can heat up the air inside faster and lead to faster fish drying. In short, there are many advantages that can be obtained from using solar dryers when compared to other drying processes, such as shortening the drying period, producing better quality of dried fish and reducing energy consumption [31].

For improved adoption of this technology by fish producers and processors it is important to understand its perceptions, challenges, and needs. The evaluation of the benefits and economics of solar dryers compared to traditional sun-drying is needed. Such information and data are limited in Cambodia. An improved understanding will allow development of strategies to enhance adoption and support of fish producers and processors through knowledge sharing and outreach activities. In addition, it will also help the engagement of the private sector and the government sector to provide solar drying systems to support fish producers and processors. The sustainability of fish-drying businesses in Cambodia depends largely upon proper techniques such as reliable solar dryers, which can both increase the household income and enhance human health.

The overall objective of this study was to identify the effect of the use of solar dryers on the household economies of dried fish processors in Cambodia. Thus, the specific objectives were to (1) compare the socio-economic conditions between dried fish processors that practice traditional drying and those that use solar dryers, (2) identify potentials and challenges to dried fish production between the two groups, and (3) determine the factors affecting income.

2. Materials and Methods

The study was conducted from May to August 2023 using a quantitative approach to understand the differences in dried fish processing in two main river regions where fisheries and fish processing are widespread in Cambodia [13]. These were Kampong Cham Province on Mekong River and the Kampong Thom and Siem Reap Provinces in Tonle Sap River (Table 1; Figure 1). The full process of obtaining the data started with initial desk reviews, consultation with relevant stakeholders, prior identification of interviewees, questionnaire formation, a preliminary survey along with phone communications, and a final survey after adjustment of the questionnaires based on preliminary survey results.

Table 1. Sample size selection for two kinds of dried-fish processors in three different provinces.

River	Province	Type of Processor		Total
		Traditional Drying Group (n = 35)	Solar Dryer Group (n = 9)	
Mekong	Kampong Cham	5	2	7
Tonle Sap	Kampong Thom	27	3	30
	Siem Reap	3	4	7
Total		35	9	44

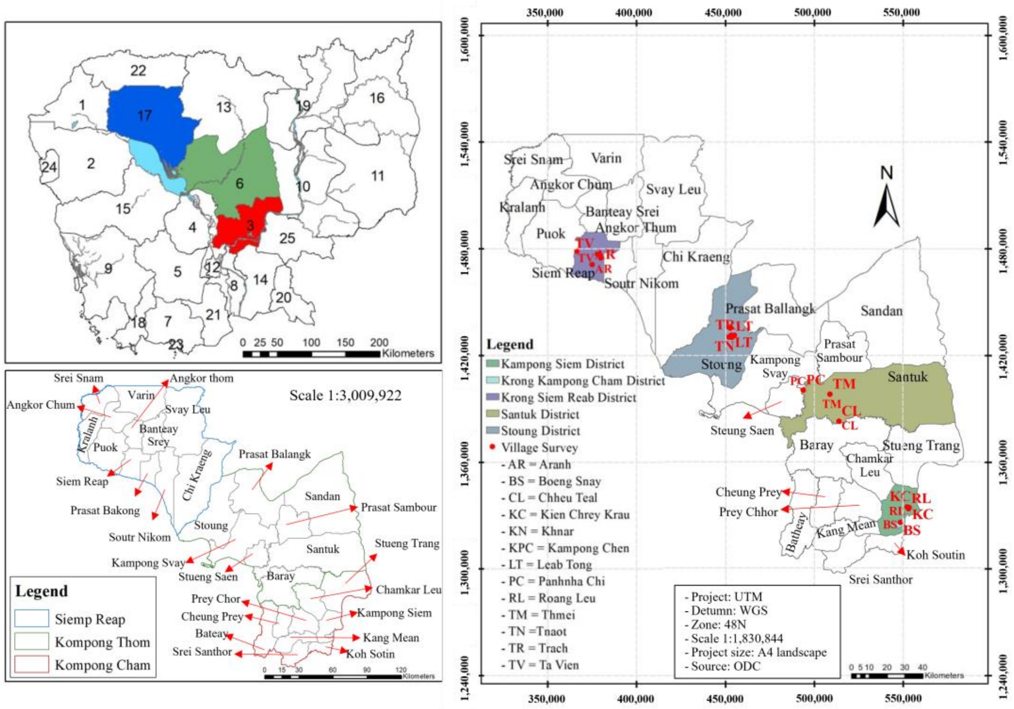

Figure 1. Map of the studied locations and location points of interviewed dried fish processors in three provinces: Kampong Cham, Kampong Thom, and Siem Reap, along the two main Cambodian river systems, namely Mekong River and Tonle Sap River.

2.1. Sampling Method

In this survey, purposive sampling was employed by categorizing the samples into two groups: fish processors who utilized solar dryers as the only means of producing dried fish and processors who practice direct sun-drying, also called traditional drying. A set of criteria was applied to select the samples: selected dried fish processors (1) had to run their business year-round; (2) had a minimal production of at least 100 kg of raw fish per month; and (3) were reachable and willing to participate in the face-to-face interviews along with phone calls in case of requiring additional information.

2.2. Sampling Size

In the studied locations, only a small percentage of people practiced fish drying as their business, and they were scattered. Despite that, sufficient sample sizes are important for statistical tests. Many scientific studies have suggested that a minimum sample size of 30 is enough to disregard non-normality, so that statistical analysis can be performed parametrically [32–34]. Therefore, to be more accurate, this study took an extra 17% for the traditional drying group, so the total sample size for this group was 35.

In Cambodia, so few dried fish producers utilize solar dryers because this technology is new [21]. Thus, the sample size that could be actually obtained for this second group was only 9, only 30% of the required minimum sample size. Many studies also mention that in cases when samples are hard to find or are already rare, the study is still possible and can be carried out to understand the situation of that small sample size [35,36].

The samples of each group were selected from three provinces. In the traditional drying group, 27 were chosen from Kampong Thom because this province has the most active fish-drying activities. Meanwhile, only 5 and 3 respondents were selected from Kampong Cham and Siem Reap Provinces, respectively. In the solar dryer group, 2 samples were selected from Kampong Cham, 3 from Kampong Thom, and 4 from Siem Reap (Table 1; Figure 1). A name list of the respondents was created before the survey started, and this was achievable through a preliminary survey, key informant interviews (KIIs), data from relevant provincial departments, and then prior contacts with potential respondents. The name list contains the respondents' names, contacts, locations, and types of fish-drying technology, so the survey was conducted smoothly and timely.

2.3. Data Collection, Analysis, and Interpretation

The data were collected using well-structured questionnaires specifically designed for the two different groups of dried fish processors: the traditional drying group and the solar dryer group. The questions contained six main sections that included household information, types of fish popularly purchased for producing dried fish, the economics of production, types of drying techniques, training, and perceptions with respect to current fish-drying practices.

2.3.1. Independent Two-Sample *T*-Test

The collected data were first entered and cleaned in MS Excel, while the analysis was performed using R Program (version 3.3.0^{+}) and RStudio (version 2023.06.1 + 524), which are available for free online. Independent two-sample *t*-tests were adopted to compare all quantitative data between the two processor groups at the error level of 5% (95% confidence level). Before performing the tests, assumptions of normality and homogeneity were checked and verified. However, as the sample sizes of the two groups were unequal and might be heterogenous, Welch's test was also performed to double-check the analysis results [37,38].

2.3.2. Chi-Square Test

In this study, two kinds of chi-square tests were used: a chi-square test for goodness of fit applied to measure how well a statistical model fits into a set of observations and a chi-square test of independence to check whether two categorical variables are related or not. Statistically significant differences were determined at the error level of 5% (95% confidence level) [39,40].

2.3.3. Two-Way Analysis of Variance

A two-way analysis of variance (ANOVA) was also used to compare numerical data such as the quantity of raw fish purchased, prices of raw fish, and prices of dried fish between two variables: the processor groups and the operational seasons. Because the sample sizes of the two groups were unequal, Welch's ANOVA was also performed to verify the analysis result. Only when significant differences were observed for any variables or their interaction at the error level of 5% (95% confidence level), post hoc tests were performed using the adjusted least significant difference (LSD) in Bonferroni's test.

2.3.4. Likert Scale Analysis

Likert scale analysis was used in this study to evaluate and compare a set of dried fish quality parameters between the two groups based on challenging issues related to dust, flies, rain, product color, product odor, and stiffness. A five-point score was applied to evaluate those issues: 1 (no issue), 2 (small issue), 3 (moderate issue), 4 (big issue), and 5 (very big issue) [41,42]. For the respondents from the traditional drying group, the questions were asked only once, while the solar dryer group was asked the same questions twice because they were evaluated before and after using the solar dryers. To understand and compare the issues properly for this case, the data were analyzed and compared between the traditional drying, the period before solar dryer use, and the period after solar dryer use. Likert scale analysis was also used to identify prioritized potentials and constraints to the fish-drying techniques implemented by the two processor groups. Unlike the assessment of dried fish quality, a five-point score applied to evaluate the perception is based on agreement: 1 (strongly disagree), 2 (disagree), 3 (moderately agree), 4 (agree), and 5 (strongly agree).

One-way ANOVA was adopted to compare mean scores rated for each issue suggested by the groups at the error level of 5% (95% confidence level) [43,44]. All assumptions were checked and verified before performing the test and, in case of statistically significant differences, means were separated using the adjusted LSD in compliance with Bonferroni's test [45,46].

2.3.5. Multiple Linear Regression

To further understand the economic conditions and to determine the factors affecting the income generated by the dried fish processors in the studied locations, the multiple linear regression model was applied, considering the income earned per ton of dried fish as a dependent variable [47,48]. Meanwhile, predictor variables that might influence the income were age; educational level; all available labor, including household and hired labor; years of fish-drying experience; a chance of attending training related to fish processing; current fish-drying technique adoption; traditional drying or solar dryer use; and total production cost (Table 2).

The multiple linear regression model is presented below [48]:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + \beta_n X_n + \varepsilon \quad (1)$$

Table 2. Description of all variables used for performing multiple linear regression.

No.	Variable	Description	Letters
	Dependent variable		
1	Income (USD/T dried fish)		Y
	Predictor variables		
1	Age (year)		X_1
2	Educational level (year)		X_2
3	Available labor (person)		X_3
4	Fish-drying experience (year)		X_4

Table 2. *Cont.*

No.	Variable	Description	Letters
5	Chance of attending training related to fish processing	0 = Never attend training 1 = Used to attend training	X_5
6	Current fish-drying technique adoption	0 = Traditional drying 1 = Solar dryer use	X_6
7	Total production costs (USD/T dried fish)		X_7
8	β_i	The slope of individual predictor variables	
9	ε	Error	

2.3.6. Economic Analysis

To compare the economic aspects of the two processor groups, dried fish production was evaluated based on total variable costs (TVCs), total fixed costs (TFCs), total costs (TCs), total revenues (TRs), total profits (TPs), and economic efficiency [49]. To simplify the comparison between the two processor groups, the same unit for all these parameters was used, which included USD (US Dollars)/kg of dried fish produced, also abbreviated as USD/kg dried fish; and USD/T dried fish, calculated by multiplying USD/kg dried with by 1000 [50].

Normally, TVC, TFC, and TC were calculated based on the purchase of raw fish, and the weight of raw fish was reduced after being dried as a final product. Thus, conversion was required by multiplying those values with the weight of dried fish produced from one kg of raw fish, while this coefficient was obtainable through the data collected from the questionnaire.

TFC is the sum of all depreciated costs (DCs) needed to operate dried fish production. DC was calculated from tools/equipment, solar dryer use, and truck use for transportation, depending on their lifespans [51]. In this study, it was assumed that the lifespans of a solar dryer and a second-hand truck are 5 years. A longer lifespan can be assumed according to the real quality of the products; however, the longer the lifespan, the smaller the DC. Because economic analysis in this study was based on USD/kg of dried fish, very small depreciation costs may be hard to visualize. The DCs of a solar dryer and a truck (USD/kg dried fish) are calculated by dividing the annual depreciation costs by lifespan and then by annual dried fish production.

TR was calculated based on the weight of sold dried fish multiplied by selling prices. There are two prices, either retail or wholesale, but in this study, wholesale prices were used to calculate TR because it is more common for the two processor groups.

The following are the formulas of DC, TC, TR, TP, and economic efficiency [49]:

$$\text{DC} = \frac{\text{PV} - \text{SV}}{\text{L}} \tag{2}$$

$$\text{TC} = \text{TVC} + \text{TFC} \tag{3}$$

$$\text{TR} = \text{P} \times \text{Q} \tag{4}$$

$$\text{TP} = \text{TR} - \text{TC} \tag{5}$$

$$\text{Economic efficiency} = \frac{\text{TR}}{\text{TC}} \tag{6}$$

3. Results

Characteristics of fish-drying practices and investment in the dried fish business were seen to differ between dried fish processors that practice traditional drying and those who utilize solar dryers. Fish species and fish amounts required for the production were also different between the two groups. Based on participant opinions, they preferred specific ways of fish drying due to their own knowledge and habits, affordability, and perspectives.

3.1. Household Status of Dried Fish Business

3.1.1. Gender

The ratios of the genders of the dried fish processors interviewed in the studied locations were compared between the processor groups in order to understand the demographic actively engaged in dried fish production (Table 3). The results show that women had the largest percentage in providing responses to the interviews, regardless of the groups. For the traditional drying group, 89% were female respondents, while there were 67% for the solar dryer group. The interviews were purposively conducted to obtain as accurate information as possible, and only women directly involved in fish-drying activities provided the needed responses. For the male respondents in this study, they were also constantly engaged in the business, so they also provided responses; that is the reason why male respondents were also selected for interviews.

Table 3. Comparison of the household status of dried fish processors with traditional drying and with solar dryers.

Parameter	**Drying Technique**		**Grand Mean**	**Pr (>t)**	**Pr (>χ^2)**
	Traditional Drying Group (n = 35)	**Solar Dryer Group (n = 9)**			
Gender					0.275^{ns}
Male	4 (11%)	3 (33%)			
Female	31 (89%)	6 (67%)			
Age (year)	43.6 ± 2.0	45.2 ± 3.0	44.4 ± 2.5	0.649^{ns}	
Education					0.223^{ns}
No education	3 (9%)	1 (11%)			
Primary	6 (17%)	0 (0%)			
Secondary	19 (54%)	5 (56%)			
High school	6 (17%)	1 (11%)			
University	1 (3%)	2 (22%)			
Household member	5.4 ± 0.35	4.8 ± 0.46	5.1 ± 0.41	0.277^{ns}	
Female member	2.7 ± 0.27	2.4 ± 0.34	2.6 ± 0.31	0.540^{ns}	
Dried fish processing as main job					0.895^{ns}
Yes	28 (80%)	8 (89%)			
No	7 (20%)	1 (11%)			
Years of fish-drying experience	8.3 ± 1.6	11.7 ± 3.0	10.0 ± 2.3	0.333^{ns}	
Members involved in fish-drying activities	2.5 ± 0.24	1.9 ± 0.26	2.2 ± 0.25	0.076^{ns}	
Hired labor					<0.001 ***
Yes	6 (17%)	8 (89%)			
No	29 (83%)	1 (11%)			
Number of hired laborers	1.5 ± 0.2	5.6 ± 1.1		0.007 *	
Monthly fees for hired laborers (USD/month)	248.0 ± 25.6	178.7 ± 27.3	213.4 ± 26.5	0.343^{ns}	

Note: Categorical data are presented with frequency and percentage and numerical data with mean values (mean ± SE). Pr (>t) and Pr (>χ^2) represent probability values for independent two-sample *t*-test and chi-square test of independence, respectively, while asterisks "*" and "***" denote statistical significances at $\alpha < 0.05$ and at $\alpha < 0.001$, respectively. Abbreviation "ns" means non-significance; then, a grand mean calculation between the two groups was applied.

3.1.2. Age and Education

The two processor groups were compared by age, regardless of gender, to detect the effects of age on particular fish-drying practices (Table 3). There was no difference in age between the two groups (p = 0.649), and the mean age of all the respondents was 44.2 ± 2.5 years. The education level of the two processor groups was also compared (Table 1). For the traditional drying group, 80% of the respondents could not reach high school, while 13% finished high school and 3% obtained a bachelor's degree. Similarly, more than half of the participants in the solar dryer group could not reach high school, but 22% attended university for their bachelor's degree.

3.1.3. Household Members and Female Members

The numbers of total household members and specifically females were compared between the two processor groups (Table 3), and significant differences were not observed in the two cases: number of household members $p = 0.277$ and number of female members $p = 0.540$. Regardless of the groups, each household had about 5 members, of whom 2–3 were females.

3.1.4. Fish-Drying Business and Experience

All the respondents interviewed in this study were dried fish processors, but not all of them took up this business as their first income-earning job; however, the vast majority of the two processor groups did (Table 3). The percentage of both groups with dried fish businesses as their first job was not significantly different ($p = 0.895$), and it was high (80–89%); the rest reported engaging in this business as a second job.

When asked about the experience of producing dried fish, all the respondents in the two processor groups reported having many years of experience, but there was no significant difference between them (Table 3; $p = 0.333$). Regardless of the groups, they all had around 10 years of fish-processing experience in producing dried fish for the market.

3.1.5. Labor in Dried Fish Production

Household labor, hired labor, and monthly wages were studied and compared between the two processor groups (Table 3). Active household labor required was similar among the two groups ($p = 0.076$). On average, two people within each household were engaged in producing dried fish. To fully support the business, almost all of the solar dryer group hired extra labor, while only 17% in the traditional drying group needed that ($p < 0.001$). The number of hired workers was also significantly different between the groups ($p = 0.007$). It was almost four times higher in the solar dryer group (5–6 persons) than in the traditional drying group (1–2 persons). On a monthly basis, each group had to pay a similar amount of money, 213.4 ± 26.5 USD/month ($p = 0.343$).

3.2. Fish, Fish Quantity, and Source of Supplies

3.2.1. Fish Quantity and Prices

The quantities of fish required as main inputs for processing and their prices were compared between the two processor groups, considering seasonal changes (Figure 2). In addition, the percentage of each processor group that changed the size of seasonal production and fish quantities were also compared to understand their differences (Table 4). The results show that the quantity of raw fish required for dried fish production differed by processor group ($P_T < 0.001$), but not by season within the same group ($P_S = 0.674$; Figure 2A). No interaction between processor group and seasonal production was observed ($P_{TxS} = 0.898$). Therefore, the result is presented by comparing the amount of required raw fish by processor group only. Regardless of seasons, the solar dryer group needed a much larger quantity of raw fish to fulfill its weekly dried fish production (785.0 ± 53.10 kg/week) when compared to the other group (169.5 ± 4.12 kg/week), which was almost five times lower.

Prices of raw fish purchased for producing dried fish were significantly different between the two processor groups ($P_T = 0.003$) but were not subject to seasonal changes ($P_S = 0.382$; Figure 2B). Besides that, the interaction between the processor groups and seasonal purchases was not detected ($P_{TxS} = 0.422$). Thus, the result of the study is presented by comparing raw fish prices between the two processor groups only. The traditional drying group had higher prices for raw fish than those who used solar dryers, 3.5 ± 0.02 and 2.9 ± 0.07 USD/kg, respectively. This is because the participants in the solar dryer group tend to buy in large quantities and have a more secure supplier and price, which may lead to price reduction when compared with the traditional drying group.

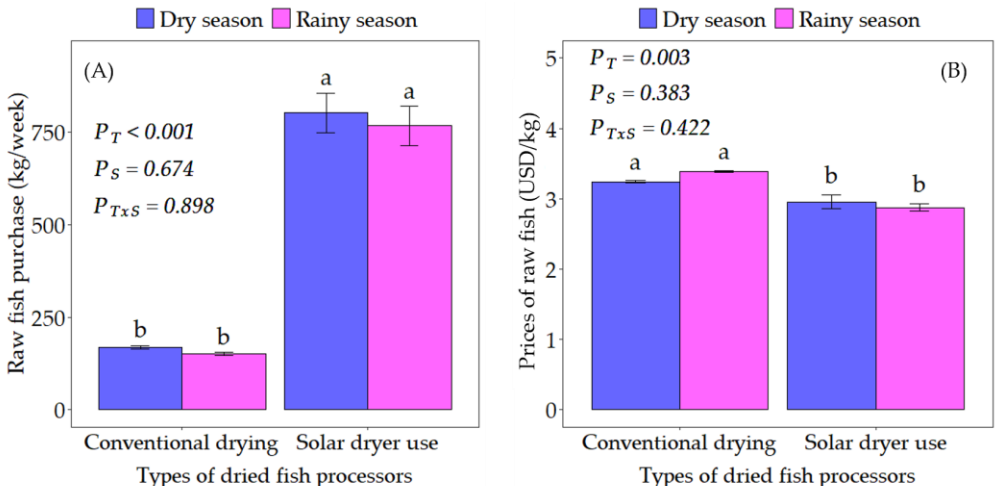

Figure 2. Seasonal changes in fish quantity (**A**) and prices of fish (**B**) among the two groups. Different alphabetical letters signify different means.

Table 4. Comparison of seasonal changes in fish quantity and supplies used by the two groups.

Parameter	Drying Technique		Pr (>t)	Pr (>χ^2)
	Traditional Drying (n = 35)	Solar Dryer Use (n = 9)		
Changing fish quantity for drying by season				<0.001 ***
Yes	12 (34%)	1 (11%)		
No	23 (66%)	8 (89%)		
Quantity changed between the seasons (kg)	29.6 ± 12.61	100 ± 0.0	N/A	
Interval for drying new fish (day)	2.5 ± 0.31	1.0 ± 0.01	<0.001 ***	
Dried fish yield (kg/kg raw fish)	0.5 ± 0.02	0.5 ± 0.04	0.722 ns	
Day spent for drying before sales (day)				
During dry season	1.9 ± 0.33	0.9 ± 0.14	0.009 **	
During rainy season	2.5 ± 0.33	0.8 ± 0.12	<0.001 ***	
Annual fish-drying period (month)	12	12		N/A
Fish supply sources in dry season				0.053 ns
Local	35 (100%)	7 (78%)		
Overseas	0 (0%)	2 (22%)		
Fish supply sources in rainy season				N/A
Local	35 (100%)	9 (100%)		
Overseas	0 (0%)	0 (0%)		

Note: Categorical data are presented with frequency and percentage, and numerical data with mean values (mean ± SE). Pr (>t) and Pr (>χ^2) represent probability values for independent two-sample *t*-test and chi-square test of independence, respectively. Asterisks "**" and "***" denote statistical significances at $\alpha < 0.01$ and at $\alpha < 0.001$, respectively. Abbreviation "ns" means non-significance. N/A, not available.

Seasonal changes in dried fish production were mostly observed with processors that practice traditional drying (Table 4; $p < 0.001$). About a third of the respondents from the traditional drying group reported changing fish quantities of approximately 30 kg/season, which is considered rather small, while one-ninth of the respondents from the solar dryer group reported changing dried fish production. However, the amount was rather high, around 100 kg of seasonal changes in required fish quantities.

3.2.2. Drying Interval and Fish Supply Source

After raw fish was purchased, it was prepared right away by the two processor groups to ensure its freshness for drying. Nevertheless, the time interval for replacing a new batch of dried fish was seen to differ among the two groups (Table 4; $p < 0.001$), and the respondents from the traditional drying group spent more time replacing new fish between each drying period when compared to those who had solar dryers. The time interval was 2.5 ± 0.31 and 1.0 ± 0.01 days, respectively. The results show that dried fish processors that practice traditional drying depend heavily on their own labor to prepare fish for drying, whereas the other group is more specialized, better equipped, and supported by hired labor to ensure timely work.

The average number of days required for drying fish until it is ready for sale and annual fish-drying activities were compared between the two processor groups (Table 4). Regardless of the seasons, the respondents from the traditional drying group spent more time drying fish, and they spent half a day more during the rainy season for the same purpose. Unlike this group, the respondents who utilized solar dryers could maintain a similar drying period of approximately one day in both seasons. These findings really show the advantages of using solar dryers to cope with the effects of weather and temperature. Although there was some change in the time required for drying fish according to the seasons, fish-drying activities were carried out the whole year by the two groups.

To understand the demands for raw fish by season, both groups were asked about sources of supplies, which are both domestic and from abroad (Table 4). In the rainy season, fish were abundant, so the whole source of supplies was available locally, and the two processor groups did not seek fish supplies from outside the country. Nevertheless, in the dry season, fish supplies were limited, but all still preferred local supplies rather than depending on the outside source, except for a small proportion of the solar dryer group that reported purchasing fish from the neighboring countries, specifically from Vietnam, to meet their production demand.

3.2.3. Popular Fish Species and Their Share in Production

There were several specific fish species popularly selected to produce dried fish, and more options were found with the respondents from the traditional drying group (Table 5). All the respondents in both processor groups used giant snakehead (*Channa micropeltes*) for their business, while only 60% of the traditional drying group and 78% of the solar dryer group reported using striped snakehead (*Channa striata*). For walking catfish, 44% of the respondents in the solar dryer group used that fish. Less than 10% of the respondents from the traditional drying preferred walking catfish (*Clarias batrachus*), but they opted to use pangasius (*Pangasius djambal*) and spotted-ear catfish (*Pangasius larnaudii*).

Table 5. Comparison of fish species commonly selected for making dried fish and their shares in the whole production between processors that practice traditional drying or use solar dryers.

Parameter	Drying Technique		Pr (>χ^2)
	Traditional Drying Group (n = 35)	**Solar Dryer Group (n = 9)**	
Giant snakehead (*Channa micropeltes*)			N/A
Yes	35 (100%)	9 (100%)	
No	0 (0%)	0 (0%)	
Striped snakehead (*Channa striata*)			0.615 ^{ns}
Yes	21 (60%)	7 (78%)	
No	14 (40%)	2 (22%)	
Walking catfish (*Clarias batrachus*)			0.013 *

Table 5. *Cont.*

Parameter	Drying Technique		Pr (>χ^2)
	Traditional Drying Group (n = 35)	Solar Dryer Group (n = 9)	
Yes	2 (6%)	4 (44%)	
No	33 (94%)	5 (56%)	
Pangasius (*Pangasius djambal*)			0.538 [ns]
Yes	5 (14%)	0 (0%)	
No	30 (86%)	9 (100%)	
Spotted-ear catfish (*Pangasius larnaudii*)			1
Yes	2 (14%)	0 (0%)	
No	33 (86%)	9 (100%)	
Others			0.538 [ns]
Yes	5 (6%)	0 (0%)	
No	30 (86%)	9 (100%)	
Share of fish species for overall dried fish production (%)			
Giant snakehead	81.0	70.0	
Striped snakehead	13.7	24.5	
Walking catfish	0.3	5.5	
Pangasius	2.1	0	
Spotted-ear catfish	0.3	0	
Others	2.7	0	
Total	100	100	

Note: Asterisk "*" denotes statistical significances at $\alpha < 0.05$. Abbreviation "ns" means non-significance. N/A, not available.

Of all the fish species purchased for fish drying, giant snakehead was the most popular, accounting for 81% and 70% for the traditional drying and solar dryer groups, respectively (Table 5). Striped snakehead ranked second in popularity, and its share was almost twofold in the solar dryer group. Other fish species were not so popular and had a very small share in the total dried fish production between the two groups.

3.3. Fish-Drying Technology and Support

3.3.1. Sources of Drying Technology

Fish was dried in different means between the two processor groups (Tables 6 and 7). The traditional drying group used fish-drying racks as a means of drying their fish. The racks were commonly made from bamboo sticks and raised one meter above the ground. This structure had no cover to prevent dust, flies, or rain. However, in case of rain, a plastic cover was spread over to avoid wetting. Additionally, about 17% of the respondents from this group resorted to using heat from cooking stoves to help remove fish moisture faster, so that fish could be sold regularly and timely.

Table 6. Drying structures and heat source used by dried fish processors that practice traditional drying (N = 35).

Description	Frequency	Pr (>χ^2)
Fish-drying racks		<0.001 ***
Yes	35 (100%)	
No	0 (0%)	
Stove heat		<0.001 ***
Yes	6 (17%)	
No	29 (83%)	

Note: Asterisks "***" denotes statistical significances at $\alpha < 0.001$.

Table 7. Characteristics of solar dryers and associated support for dried fish processors that use solar dryers (N = 9).

Description	Mean ± SE	Frequency	Pr (>χ^2)
Type of solar dryer			0.096 ^{ns}
Solar dryer dome (SDD)		7 (78%)	
Electricity-aided solar dryer		2 (22%)	
Source of fabrication support			0.019 *
NGOs		8 (89%)	
Own fabrication		1 (11%)	
Price of solar dryer (USD/set)			
Solar dryer dome	1733		
Typical solar dryer	1000		
Year of installation			0.019 *
2019		1 (11%)	
2023		8 (89%)	
Share of installation funding			
NGOs	60%		
Own spending	40%		
Seeking loan for spending			0.739 ^{ns}
Yes		5 (56%)	
No		4 (44%)	
Willingness to install one more solar dryer			0.739 ^{ns}
Yes		5 (56%)	
No		4 (44%)	

Note: Categorical data are presented with frequency and percentage, and numerical data with mean values (mean ± SE). Pr (>χ^2) represent probability values for chi-square test of independence. Asterisk "*" denotes statistical significances at $\alpha < 0.05$, while abbreviation "ns" means non-significance.

In contrast, the solar dryer group used two kinds of solar dryers: solar dryer dome (SDD) or solar dryer modified to run on electricity as a source of heating (Table 7). Among them, 78% of the respondents used SDD and only 22% used the latter. Almost all these solar dryers were installed by local suppliers through coordination and support from some NGOs, except for one solar dryer self-fabricated by the owner. In comparison, the prices of SDD were much higher than those of the modified solar dryers, 1733 and 1000 USD/set, respectively. All the solar dryers available in the studied locations were newly installed because eight out of nine were installed in 2023, and only one was installed in 2021. This result may show that the adoption of solar dryer technology remains new to the Cambodian context.

3.3.2. Technology-Related Funding Source

The respondents from the solar dryer group were asked whether they invested their own money in installing solar dryers, and all said yes, but with prior encouragement and partial financial support from some NGOs (Table 7). To set up one solar dryer in any form, the owners spent around 40%, and the rest of the cost relied on the funding. Although the respondents used their own money to set up the solar dryers, still, they needed to seek loans to support installation. In this regard, five of nine respondents reported taking out loans from various sources such as relatives and micro-finances. For those who wished to expand their business, they were willing to install a new solar dryer in the near future. According to Table 7, five of nine respondents were willing to do so.

3.4. Dried Fish Quality

Dried fish quality was evaluated based on a five-point Likert scale and compared in three conditions: traditional drying; the period before the solar dryer group started to use solar dryers; and the period after their use (Table 8). There were seven types of quality evaluated: dust, flies, color, rain, odor, mold, and stiffness. Issues with dust were significantly different ($p < 0.001$), and they were rated small when solar dryers were used.

Table 8. Comparison of fish drying-related problems between traditional drying and solar drying categorized into before and after solar dryer use.

Description	Dust	Flies	Color	Rain	Odor	Mold	Stiffness
Traditional drying	2.5 a	2.6 b	1.7 b	2.3 b	1.7 b	1.9 b	2.2
Before solar dryer use	2.6 a	3.2 a	3.0 a	3.2 a	2.6 a	2.9 a	2.7
After solar dryer use	1.3 b	1.9 c	1.9 b	1.3 c	1.7 b	1.8 b	2.4
Pr (>F)	<0.001 ***	0.002 **	0.004 **	<0.001 ***	0.012 *	0.021 *	0.365 ^{ns}

Note: Asterisks "*", "**", and "***" denote statistical significance at $\alpha < 0.05$, $\alpha < 0.01$, and at $\alpha < 0.001$, respectively, while "ns" means non-significance. Different alphabetical letters signify different means. The values shown in the table are mean values calculated from a 5-point Likert scale: not at all (1), small (2), moderate (3), big (4), and very big (5).

Problems with flies also differed among the three cases ($p = 0.002$). A low score was seen with the use of the solar dryer: 1.9. Meanwhile, traditional drying and the period before solar dryer use had higher scores and ranged from 2.6 to 3.2, which means moderate issues with flies.

The color of dried fish was also compared by asking the respondents' opinions, and the result was significantly different among the three conditions ($p = 0.004$). The solar dryer group expressed that the color problems were solved after using solar dryers. Similarly, the traditional drying group reported having small problems with color, but the result may show that they had nothing to compare because they practice only traditional drying and did not want to comment on their practices.

Rain problems were also significantly different among the three conditions ($p < 0.001$); using solar dryers could potentially prevent the drying fish from the rains. Without a solar dryer, problems with the rain ranged from little to moderate. According to their responses, the traditional drying group experienced occasional rain interruption, which was similar to those in the solar dryer before they had solar dryers. However, after using the solar dryers, they no longer had problems with rains.

Problems with bad odor that comes from dried fish were also evaluated and compared based on the respondents' opinions. Significant differences in odor rates were observed ($p = 0.012$). The solar dryer group reported that these problems decreased significantly after using solar dryers. This is because fish moisture and air moisture inside the drying chamber could be controlled with high heat. In contrast, the respondents from the conventional group reported having insignificant problems with bad odor.

Problems with mold were also evaluated and compared using the same method, and the results show that the problems were significantly different ($p = 0.021$). The solar dryer group had moderate problems with mold before using solar dryers, but the problems were solved after the use of solar dryers. Meanwhile, the traditional drying group also reported having occasional problems with mold. Despite that, after a series of discussions with this group, some participants reported having experience in removing or rinsing mold that grew on their dried fish so that it was still sellable. With this finding, the advantages of using solar dryers to maintain the quality of dried fish can be highlighted.

Stiffness that appeared in the fish after a certain period of drying was also evaluated and compared based on the respondents' opinions (Table 6). Significant differences in stiffness were not detected even after the use of solar dryers ($p = 0.365$). All the respondents felt that their dried fish became hardened, and those from the solar dryer group mentioned that fish became stiff faster when using the solar dryers, although the mean scores were not significantly different.

3.5. Dried Fish-Related Training and Capacity Building

Fish Quantity and Prices

The two groups of dried fish processors were asked whether they had ever joined training on fish processing and other related training: fish-drying technique, solar dryer use, hygienic processing, processing standards, packaging technique, marketing strategies, and business planning (Table 9). All the respondents from the solar dryer group had experience of joining training programs related to fish processing, while only 37% from the traditional drying group used to join the training.

Table 9. Comparison of fish-drying-related training programs attended by dried fish processors with traditional drying and with solar dryer use.

Parameter	Drying Technique		$Pr (>\chi^2)$
	Traditional Drying (n = 35)	Solar Dryer Use (n = 9)	
Attend training related to fish processing			0.003 **
Yes	13 (37%)	9 (100%)	
No	22 (63%)	0 (0%)	
Fish-drying technique			0.132 ns
Yes	8 (23%)	5 (56%)	
No	27 (77%)	4 (44%)	
Solar dryer use			0.685 ns
Yes	7 (20%)	3 (33%)	
No	28 (80%)	3 (67%)	
Hygienic processing			<0.001 ***
Yes	11 (31%)	9 (100%)	
No	24 (69%)	0 (0%)	
Processing standard			0.020 *
Yes	7 (20%)	9 (67%)	
No	28 (80%)	3 (33%)	
Packaging technique			<0.001 ***
Yes	0 (0%)	4 (44%)	
No	35 (100%)	5 (56%)	
Marketing strategies			<0.001 ***
Yes	0 (0%)	6 (67%)	
No	35 (100%)	3 (33%)	
Business planning			0.459 ns
Yes	0 (0%)	1 (11%)	
No	35 (100%)	8 (89%)	

Note: Asterisks "*", "**", and "***" denote statistical significance at $\alpha < 0.05$, $\alpha < 0.01$, and at $\alpha < 0.001$, respectively, while "ns" means non-significance.

Regarding fish-drying techniques, it is likely that those from the solar dryer group had more chance of attending training, accounting for more than 50% of the interviewees for that group. Meanwhile, only 23% of the traditional drying group received training in fish-drying techniques. In terms of solar dryer use training, there was no significant difference between the two processor groups, and only 20% from the traditional drying group and 33% from the solar dryer group reported having joined training.

There were significant differences between the two processor groups in terms of the percentage of those who join training on hygienic processing ($p < 0.001$), processing standard ($p = 0.020$), and packaging technique ($p < 0.001$). In all cases, the respondents from the solar dryer group seemed to have greater chance of participation in formal knowledge-sharing sessions, being 100%, 100%, and 44% with respect to the order of the mentioned training programs. In contrast, only 31% of the respondents from the conventional group reported participation in training on hygienic processing and 20% in processing standard training. However, none of them joined training on packaging techniques.

With respect to training on marketing strategies and business planning, none of the respondents from the traditional drying group had any experience of participation. Meanwhile, significant differences were found in the percentage of the respondents from the solar dryer group, accounting for 67%; however, a very small percentage of this group attended training on business planning.

Based on the findings, it could be suggested that dried fish processors who utilize solar dryers tend to participate more actively in fish-processing or related training when compared to the traditional drying group. Moreover, it is more likely that the respondents from the solar dryer group attend a wider variety of training that can strengthen their business capacity. This can be explained by the fact that they have large dried fish production and hire workers to support their enterprises, so they can spare time to attend any proposed training program and they are willing to learn more to support their business. On the contrary, dried fish processors who practice traditional drying work on their own to dry fish, so they are unlikely to attend any training provided.

3.6. Types of Sale and Dried Fish Taste

3.6.1. Types of Dried Fish Sale

The two groups of dried fish processors were asked whether they only engaged in retail, wholesale, or both types of sales (Figure 3A). Of all the respondents in the traditional drying group, 10% and 50% engaged only in wholesale and retail, respectively. Meanwhile, 40% engaged in both types of sales. In contrast, none of the respondents from the solar dryer group engaged in only retail, while 90% engaged in both types of sales and 10% only engaged in wholesale. Although retail sales were found in this group, such activities were considered minimal when compared to the wholesale activities because the solar dryer group focused on supplying products in bulk to their specific customers rather than engaging in small sales.

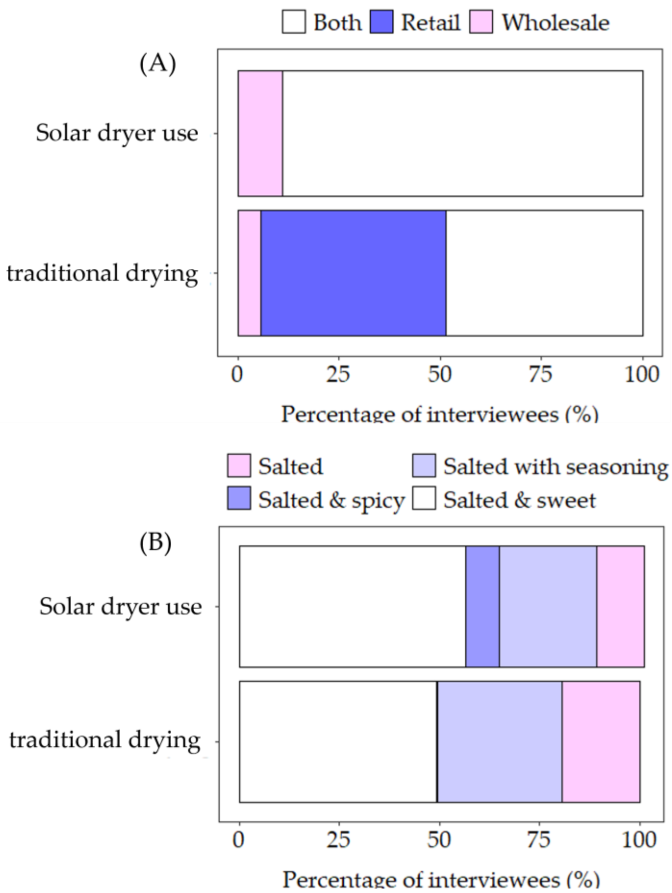

Figure 3. Type of dried fish sales (**A**) and preferential taste (**B**) between processors with and without solar dryers.

3.6.2. Types of Dried Fish Tastes

In the studied locations, there were some specific tastes of dried fish that are considered popular and tasty, thereby drawing customers' attention (Figure 3B). In terms of tastes, the traditional drying group provided only three taste options, while the solar dryer group had four taste options. The three most common tastes for all the groups were salted; salted with seasoning; and salted and sweet. Nevertheless, a salted and spicy taste was produced by the solar dryer group only. This specific product was also colored red by spicy chili. According to Figure 3B, regardless of processor groups, the highest percentage of preferred dried fish by customers was observed with the production of salted and sweet dried fish, followed by salted taste with seasoning, and then salted taste.

Of all the respondents in each group, at least 50% reported producing salted and sweet dried fish, followed by 20–30% of the respondents who produced salted taste with seasoning. Meanwhile, 10–20% in each group produced only salted taste. About 5% of the respondents from the solar dryer group produced salted and spicy dried fish.

3.7. Economic Analysis of Dried Fish Production

3.7.1. Costs of Raw and Dried Fish

The costs of raw fish purchased for dried fish production, along with those of dried fish, were plotted and compared by season between the two processor groups. Mean values for each price are presented with a straight line (Figure 4). Prices of raw fish fluctuated among the respondents from each group in both seasons, but the changes were minimal. That is why the mean values were similar in any season. Despite that, the mean raw fish costs were higher for the traditional drying group than for those utilizing solar dryers, 3.5 and 2.9 USD/kg, respectively, regardless of seasons.

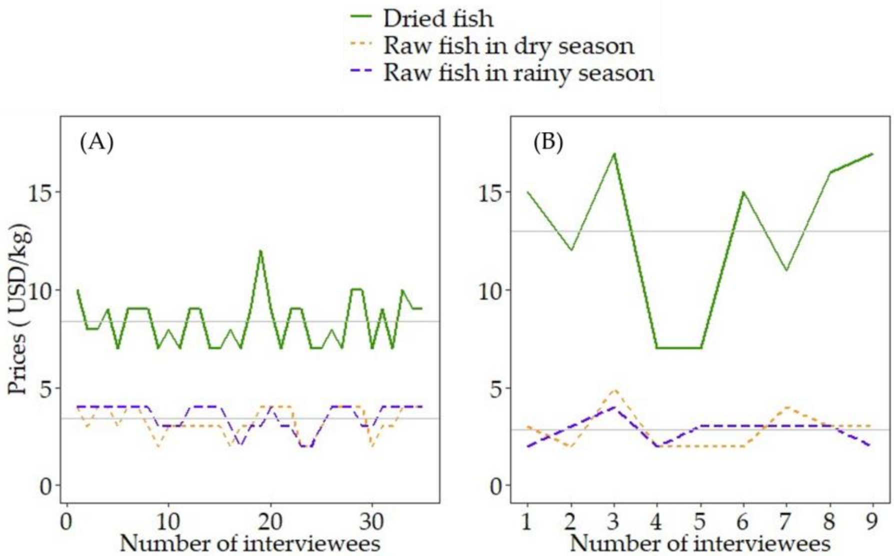

Figure 4. Prices of purchased raw fish and sold dried fish across the interviewed samples between professors without solar dryers (**A**) and processors with solar dryers (**B**).

The prices of dried fish sold by each processor group also fluctuated slightly among the respondents (Figure 4). The price of dried fish presented here was an average value, exclusive of the differences between retail and wholesale prices. Regarding the comparison between the two groups, the mean prices of dried fish were higher for the solar dryer group than for the traditional drying group, 12.9 and 7.7 USD/kg dried fish, respectively. This means that dried fish produced by the solar dryer group were more attractive to customers in terms of hygiene and appearance. Thus, the prices could be raised higher when compared to the traditional drying group.

To understand the differences in dried fish prices, retail and wholesale prices were compared within and between the two processor groups (Table 10). According to the interviews, both prices did not vary by season, so they are presented without focusing on seasonality. Regardless of the processor groups, retail prices were higher than wholesale prices, and the differences ranged from 8 to 10%. Significant differences in retail (p = 0.038) and wholesale prices (p = 0.006) were observed between the groups and, in both cases, the prices of dried fish produced by the solar dryer groups were higher. The differences were about 60%. The retail and wholesale prices were 8.2 and 7.6 USD/kg dried fish for the traditional drying group; and 13.5 and 12.3 USD/kg dried fish for the solar dryer group. It can be suggested that producing dried fish with solar dryer use may lead to higher prices, which can be economically beneficial for dried processors, and, at the same time, good quality products can also be distributed.

Table 10. Comparison of prices of dried fish sold in retail and wholesale between processors with traditional drying and with solar dryer use.

Type	Drying Technique		Difference [2] (%)	Pr (>t)
	Traditional Drying	Solar Dryer Use		
Prices (USD/kg)				
Retail	8.2 ± 0.04	13.5 ± 0.44	65%	0.038 *
Wholesale	7.6 ± 0.12	12.3 ± 0.07	62%	0.006 *
Difference [1] (%)	8%	10%		

Note: ([1]) denotes differences in percentage between retail and whole prices for each group, while ([2]) means the differences in the percentage of the same prices between the two processor groups. Pr (>t) is the probability of a two-sample *t*-test, while "*" denotes significant differences between the means at the error level of 5%.

3.7.2. Economic Analysis

To compare the economic conditions of the two processor groups, the costs, revenues, and profits were transformed and compared based on the same units (USD/kg and then USD/T dried fish; Table 11). All costs, incomes, and profits generated by the solar dryer group were higher than those in the traditional drying group, but the economic efficiency was slightly lower. For the traditional drying group, TVC, TFC, and TC for producing one kg of dried fish were 3.72, 0.74, and 4.46 USD, respectively. Meanwhile, they were 7.07, 1.60, and 8.74 USD/kg of dried fish for the solar dryer group. The revenues for the traditional drying and solar dryer groups were 7.60 and 12.30 USD/kg dried fish, respectively. These values were the same as the wholesale prices of dried fish when taking into consideration one kg comparison. TP was slightly higher for the solar dryer group (3.56 USD/kg dried fish), when compared to the traditional drying group (3.14 USD/kg dried fish). Economic efficiency values were slightly different between the traditional drying group (1.70) and the solar dryer group (1.41). When converted into USD/T dried fish, all the values were just multiplied by 1000.

Table 11. Economic analysis per kilogram of dried fish produced between processors without and with solar dryers.

Description	Type of Processor				Ratio [1]
	Traditional Drying		Solar Dryer Use		
	USD/kg Dried Fish	USD/T Dried Fish	USD/kg Dried Fish	USD/T Dried Fish	
Total variable cost (TVC)	3.72	3720.00	7.07	7070.00	1.90
Total fixed cost (TFC)	0.74	744.00	1.67	1670.00	2.26
Supporting material	0.74	744.00	1.41	1414.00	1.91
Solar dryer	-	-	0.16	160.00	N/A
Truck for transportation	-	-	0.10	100.00	N/A
Total cost (TC)	4.46	4464.00	8.74	8744.00	1.96
Total revenue (TR)	7.60	7600.00	12.30	12,300.00	1.62
Total profit (TP)	3.14	3136.00	3.56	3556.00	1.13
Economic efficiency (EE)	1.70		1.41		0.83

Note: ([1]) denotes ratios calculated by dividing each value from the solar dryer group by each value from the traditional drying group in the same rows. N/A, not available.

3.8. Perception of Dried Fish Processors

3.8.1. Traditional Drying Group

The respondents who practiced traditional drying were asked to score their perceptions from 1 (strongly disagree) to 5 (strongly agree) with respect to knowledge, skill, labor, tools/equipment, fish supplies, dried fish storage, capital investment, preferences to use a particular drying technique, and customers' preference (Figure 5). Adequacy of tools/equipment for processing, satisfaction with direct sun-drying, and the belief that customers like sun-dried fish—all were rated 4. Meanwhile, the continuity of practicing traditional drying was also rated 4. This means that the traditional drying group might not want to change their drying practices easily.

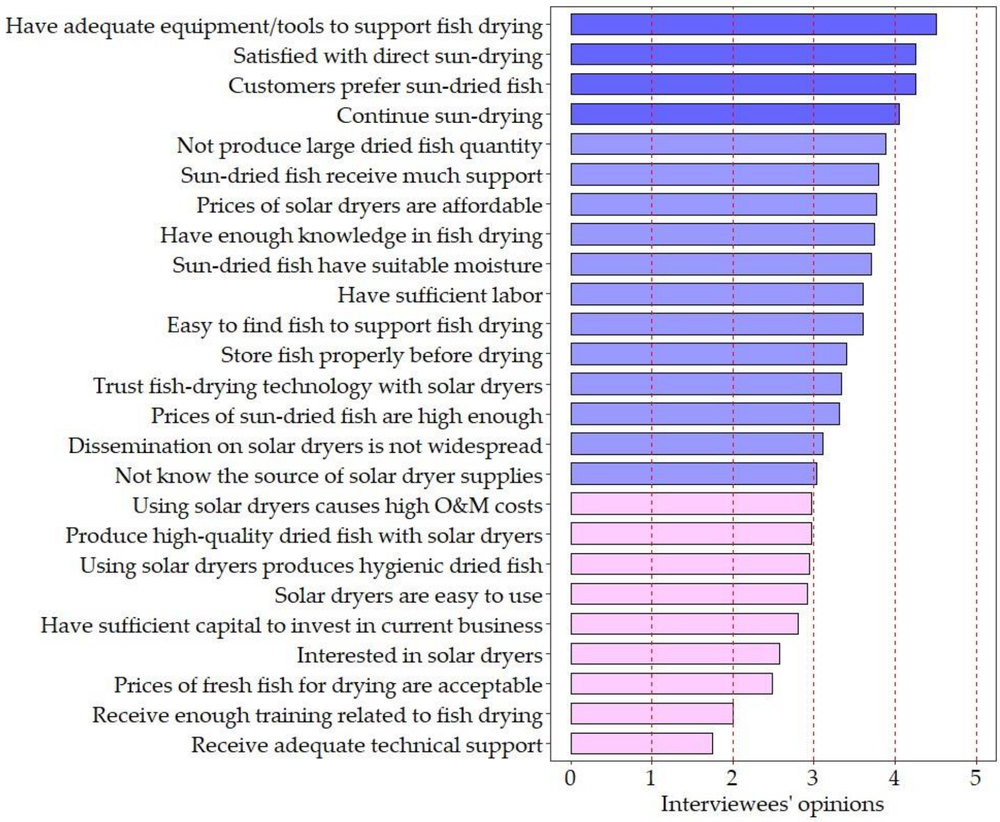

Figure 5. Evaluation of perceptions of dried fish processors that practice traditional drying over their knowledge, attitude, and practices based on a five-point Likert scale.

The respondents in this group also showed moderate agreement, equivalent to a score of 3, in response to questions about sufficient labor, adequate processing knowledge and skill, accessible raw fish supplies, sufficiently high prices of dried fish, and proper fish storage before drying. This finding may suggest that they need more labor, knowledge, rising prices, and processing techniques to boost their production. Besides that, respondents were also asked questions with respect to the use of solar dryers although they never had experience with that before. In this regard, they seem to feel that using a solar dryer is a good technology for drying fish, but they did not know the sources of supplies. That is why they were not persuaded to use this technique. Then, they assigned a score of 3 to the insufficient dissemination of solar dryer-related technology, also adding that they would use only if they could learn more about and observe the technology.

Scores of 2 were assigned to questions related to the operation and maintenance (O&M) costs of solar dryer use, hygienic and high-quality dried fish produced using solar dryers, easy operation of solar dryers, and sufficient capital investment in such technology. This means that the traditional drying group seems not to invest in installing a solar dryer because they feel that the fish quality and hygienic conditions generated by that technology are not different from what they are producing. Besides that, because they did not have experience in operation before, they did not think that solar dryers are easy to use. This is the reason why the respondents may not be interested in using that technology. Despite that, they said they also want to determine whether the price of a solar dryer is affordable or is partially financed. When asked about financial and technical support, the respondents assigned a score of 1 because they reported little support.

3.8.2. Solar Dryer Group

Similarly, the solar dryer group was also asked to share opinions by scoring the same questions from 1 (strongly disagree) to 5 (strongly agree). Many opposite answers were discovered in this case (Figure 6). Scores of at least 3.5, considered close to 4, were assigned to questions regarding hygienic processing, sufficient labor, trust in solar dryer technology, time-saving, high-quality dried fish, sufficient tools/equipment to support processing, and optimal moisture of dried fish. This finding may suggest that the solar dryer group feel more confident in using solar dryer technology. Thus, they must need enough labor through hiring rather than using only their own household labor.

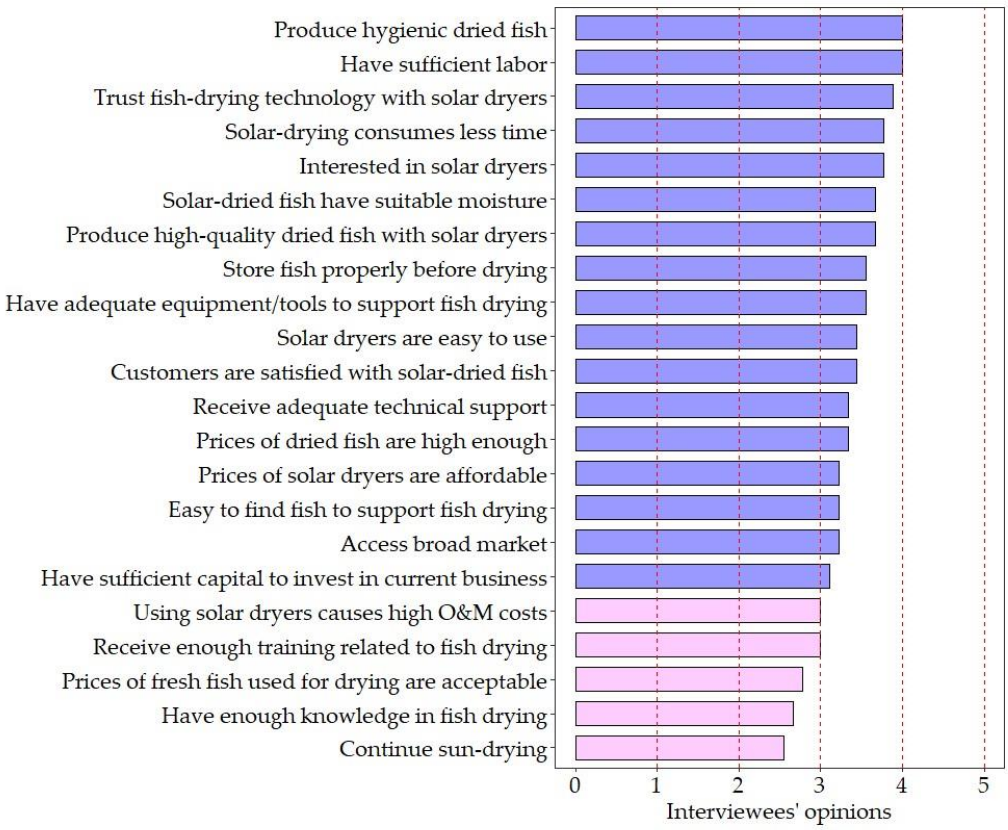

Figure 6. Evaluation of perceptions of dried fish processors that use solar dryers over their knowledge, attitude, and practices based on a five-point Likert scale.

Scores of around 3, which means moderate agreement, were assigned to questions about the easy operation of solar dryers, customer preferences for solar-dried fish, sufficiently high prices of dried fish, affordable prices of solar dryers, accessible raw fish supplies, and accessible markets. This finding may indicate that the feeling of solar dryer users is somehow moderate with respect to solar dryer-related technology. This may be true because more than 90% of the respondents in this group just installed their solar dryers, specifically SDD, in 2023. Their installation could happen only with the initiative and partial financial support from third parties rather than from their own willingness.

Scores of less than 3 were assigned to questions about training, knowledge, prices of raw fish needed for processing, and continuity to practice traditional drying. Although the solar dryer group had a higher chance to attend training or receive more training, they still felt that it was not enough. This may suggest that they are willing to attend more training to build up their capacity. When asked about continuation of traditional drying, this group reported the lowest score, meaning that they have a tendency to stop practicing the traditional technique because they already experienced many issues related with the quality and acceptability of the dried fish they produced before, and they are willing to change.

3.8.3. Factors Affecting Income

The income earned by dried fish processors was determined based on predictor variables, namely age, gender, educational level, available labor, processing training, drying technique, years of fish-drying experience, and total costs spent (Table 12). Among those variables, age, gender, educational level, available labor, and training did not affect the income earned. Meanwhile, the drying technique ($p < 0.001$), years of fish-drying experience ($p = 0.036$), and total costs ($p < 0.001$) positively affected income, which means that when the years of experience and total costs increase, so does the income. In terms of drying technique, solar dryer users tended to generate a higher income when compared to those that still practiced traditional drying.

Table 12. Determination of factors affecting the income earned from dried fish processing business in the studied locations.

Independent Variables	Estimate	Std. Error	t Value	Pr (>∣t∣)
Intercept	3121.9	2527.6	1.24	0.225
Age	−56.7	48.1	−1.18	0.247
Sex	−506.8	1284.7	−0.39	0.696
Educational level	−52.6	119.6	−0.44	0.663
labor	−86.2	266.3	−0.32	0.748
Training	28.3	1148.3	0.02	0.980
Drying technique	9534.4	1635.3	5.83	<0.001 ***
Years of experience	126.4	57.8	2.19	0.036 *
Total cost	6.0	1.1	5.55	<0.001 ***
Adj. R^2	0.85			
F-ratio	31.97 ***			

Note: asterisks "*" and "***" denote statistical significance at $\alpha < 0.05$ and at $\alpha < 0.001$.

4. Discussion

The study compared the socio-economic conditions of the two processor groups in Cambodia: the traditional drying group and the solar dryer group. The data used for comparison included household information, dried fish production, type of fish selected for business, prices of raw fish and dried fish, quality of dried fish, drying techniques, perception of current drying practices, economic analysis related to the business, and factors affecting income. The result shows that fish-drying businesses are mostly operated by females, regardless of the groups, while larger production was seen with the solar dryer group.

The results show that giant snakehead is the most popular fish species used for drying among the two processor groups, as reported by others [52,53]. The reason that this fish species is mostly preferred is because of its large and fleshy texture, which is good for consumption. In addition, the price of dried fish is also one of the main factors that affects the adoption of solar dryers in case customers still demand the same prices for fish dried using solar dryers. Unlike for the conventional drying group, fish volumes used for drying are large for the solar dryer group, and solar dryer users provide constant supplies to the market throughout the year. In our study, the period for drying fish using solar dryers was shorter when compared to traditional drying, as observed previously in Cambodia [54].

It was even shorter than that in a report released by Switch to Solar, which also focused on the use of SDD [55,56]. Many studies found that using solar dryers can reduce drying time substantially [24]. Mehta et al. [56] reported that using a mixed model tent solar dryer can halve the drying time when compared to traditional drying. Similarly, Al-Saadi et al. [57] found that using a greenhouse tunnel dryer reduced the drying time by 50%. UNIDIO [21] reported that a huge amount of time can be reduced using a solar dryer dome for freshwater fish in Cambodia.

Apart from time saving, solar drying can reduce contamination of dried fish, unlike traditional drying. Harmful microbial content was found to be low with the use of solar dryers. The presence of a coliform-forming unit (CFU) was 30% lesser in the greenhouse tunnel dryer than in traditional drying [57]. Similar results were also reported with the use of a solar cabinet dryer, which reduced bacteria colonies by 22.3% [58]. Moreover, our study showed that the use of solar dryers can prevent contamination from external factors such as dust and rain. This has been observed by other researchers [26,59,60] who mentioned that the use of solar dryers can also prevent the attacks of rodents and insects. Patterson et al. [24] also reported that commonly eaten fish in India was free of dust, sand, and air-borne diseases when it was dried in a solar dryer in comparison to traditional drying. Bala and Mondol [61] who studied fish dried in a solar tunnel dryer confirmed that this practice could protect the fish from dust, rain, or insects, ensuring good quality of dried fish.

Our study shows that profit is higher when solar dryers are used. However, it is different from studies conducted in other countries. For example, in Malawi, it was observed that the profit obtained from fish dried using solar drying was not different from that using traditional drying, but solar drying was faster and required less labor [62]. Meanwhile, the income obtained from fish drying was positively affected by production cost: income increased when production cost increased. These results were similar to the study by Madan et al. [63] who found that costs were the key factors that influenced the income of dried fish processors in India. Sumantri et al. [64] and Herawan et al. [65] also found that the cost of raw materials affected the income of the fish-drying business in Indonesia. Besides the prices of raw materials, experience is also considered as one of the key factors that positively influence income [65]. Chiwaula et al. [66] and Affognon et al. [67] mentioned that the use of a solar tent dryer might increase economic value through a reduction in quality losses often caused by dust, flies, and rodents.

5. Conclusions

Our results show the importance of using solar dryers to improve dried fish quality and increase added value in Cambodia by comparing the production, practices, and perceptions between two processor groups: the traditional drying group and the solar dryer group. The two groups had similar household characteristics in terms of educational background and age. However, the traditional group employed less labor to support the fish-drying business, while the solar dryer group required more labor and hired additional workers to support the businesses. Both groups processed fish year-round, but the solar dryer group had almost fivefold larger production and purchased raw fish at lower prices while selling dried fish at higher prices when compared to the traditional drying group. This means that using solar dryers tends to increase the added value of dried fish produced.

In terms of dried fish quality, it can be concluded that with the use of solar dryers, dried fish had better quality because dust, flies, rain and other external factors could be effectively prevented. Moreover, the drying period was also shorter when solar dryers were used. In terms of traditional drying, the drying period was 2–3 times longer in the rainy season than in the dry season, and this was because of climatic conditions and rains, whereas the drying period was not different regardless of the season when solar dryers were used. These findings highlight the benefits of using solar dryers in preserving dried fish quality and saving time when compared to traditional drying.

The income generated from dried fish businesses was affected by production costs. Another factor was experience, and when fish processors had more experience in fish drying, they tended to earn more income. This means that experience tends to make production cheaper, and it also results in high fish quality and taste, which attract more customers and warrant better price. The last factor that affected the income was the use of solar dryers. The results of multiple linear regression show that practicing traditional drying tends to earn less income, while higher income is obtained with the use of solar dryers.

Future studies should focus on the assessment of dried fish quality between the use of solar dryers and traditional drying practices on the site. The operation and functionality of SDD in Cambodia should be further evaluated to identify their potential and constraints to ensure that the technology can help fish processors in different locations. Studies should also be conducted to fabricate any low-cost solar dryer to meet the demands of fish processors and make it a more economical and viable option. In addition, emphasis on the benefits of using solar dryers should be placed on demonstrations, knowledge sharing, and training to both traditional drying and solar user groups in different communities, so that the quality, hygiene, and value-added of dried fish be improved more.

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