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Effectiveness of Modified Solar Dryer's Facility and Sensory Properties of brined Split Mullet Fish (Mugil cephalus)

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Abstract— The University of the Philippines Visaya has developed a Modified Solar Dryer (MSD) facility for improving the quality of dried fishes and the technology was extended and transferred to Partido State University. The effectiveness of the dryer was compared to Open Air Dry (OAD) , a traditional method of drying. Drying characteristics studies on Split Mullet Fish (Mugil cephalus) brine and different concentrations were conducted using MSD and OAD. The Split fish were dried for 2 days or 16 hours or until the required recommended moisture content of dried fish is reached. The temperature obtained inside and outside the MSD during drying ranges from 31.4 -41.60C and29.7-35.50C respectively. Dryers and brining methods had significant ($p<0.05$) on moisture loss and sensory attributes. Brines fish at 10% concentration dried in MSD showed moisture loss (59.23%) It was found that only 12 h of drying is required to bring down to the recommended moisture content of 18-20% for the dried split fish at 10% brine concentration and received highest overall acceptability in sensory evaluation study.

Keywords— Modified, Solar, Dryer's, Facility.

I. INTRODUCTION

Low-cost fish preservation, such as sun drying, is a popular technique not only used in the Philippines but also all over the world. Drying the fish is one of the traditional methods used in the Philippines particularly in the coastal part of Bicol Region and during glut seasons of low cost fish. During the seasons of fish mullet, fisher folks usually dried the fish along the bay side area using bamboo trays or fish net after splitting and salting. Drying of fish mullet in one the particular areas of Tinambac and Siruma Camarines Sur Philippines is one of the sources of income however there are sometimes loss of production especially during the rainy season and the products produced have limited shelf life. Hence this study was conducted to introduce the technology to help themselves in improving their drying process so that fish caught will not be lost thus increasing their income. Although this technology or methods thus does guarantee that the product will not be contaminated by microorganism.

Sun drying in an open air is the simplest way of processing fish in the Philippines but Espejo-Hermes, 2004 and Zakhia, 2000[1-2] and cited by cited by Gabriel, A and Buiao, A, 2015[3] stated that one of one of the major disadvantages of this traditional method is the susceptibility of the raw materials and products to microbiological contaminants that compromises product quality and safety. In this project, the Solar Fish

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Dryer developed by University of the Philippines was used to evaluate its effect in drying sea mullet. Flathead grey sea mullet (Mugil cephalus L.) locally known as "Balanak or Banak '' . Mullet species which is a coastal migratory fish and important for food. Flathead grey mullets usually live in the sea and are very durable to ecological factors (such as salinity, oxygen, etc.) (Sengor et al., 2004) [4]. During the summer, flathead grey mullet migrates to the coast of San Miguel Bay of Bicol Region from February to October. This period is suitable for processing dried mullet (Lanzuela N, Gallego E, Baltar JE (2020) [5]. The sea mullet are abundantly available from January to June but this fish is more valuable if it is dried because it is not more palatable when fresh. Hence, the study aimed to compare the effectiveness of the drying using the Modified Solar Dryer's Facility and an open-air sun drying.

III. MATERIALS AND METHODS

3.1. Construction of upgraded solar dryers.

This was prepared with a size of 36 square meter width and 4 heights and built with frame wooden poles completely covered with metal screen mesh, aluminum door and roof with UV plastic roof corrugated sheet to protect from direct sunlight, dusts, and flies and to quickly dry the products. The drying rack is made using a stainless wire mesh (Figure 1).

This Modified Solar Dryer's Facility produces better quality dried products, cannot be affected during rains, cannot be contaminated by dust, flies, rodents, etc. This facility is practical to use and any products like vegetables and fruit can also be dried in this facility.

Figure 1: The upgraded fish solar dryer

3. 2. Drying Procedure.

The 120 kilogram "balanak" were split and washed thoroughly and divided into six (6) parts, were soaked for one hour and in 10%, 15 % and other 20% brine solutions for 1 hour and dried to a modified sola dryer and open air dryer. After one hour the brined fish were washed and drained for 30 minutes and spread in the dryer rack in 4 cm spacing between split fish to minimize load and enhance drying days and turned

over every 2 h hygienically in each dryer to ensure uniform drying. The fish were dried from 9:00 AM and 4:00PM. Every after an hour the fish were weighed to determine the moisture loss. The fish were dried for two days in the upgraded solar dyer. The dried fish were collected at 4:00 PM, cool overnight and packed in polyethylene to protect moisture absorption.

3.3. Experimental design and treatments.

A 3^2 -factorial design with two independent variables at three treatments was applied. The dependent variables were: brining methods (10%, 15% and 20% brine) and drying methods.

3.4. Moisture loss determination.

The initial and continuous weight of fillets was weighed in each hour drying day and the final weight of fillets was recorded after two days. Time, temperature and humidity was recorded every hour from 9:00 AM to 4:00 PM and Moisture loss of fish fillets during drying days were calculated by using the following:

$$MC = \left(\frac{IW - FW}{IW} \right)$$

Where, MC = Moisture loss of the sample (%); IW = Initial weight (g); FW = Final weight (g)

3.5. Sensory evaluation. Sensory evaluations of dry salted fish fillets products were carried out by 30 panellists from. trainees who participated in the production of dried fish. The products were evaluated using acceptability tests (David and Francis, 1957) [6]. The acceptability test (color, flavor, odor, texture and overall acceptability) were evaluated using a 9-point hedonic scale rated from 1 (extremely disliked) to 9 (extremely like). The more widely used practice of three-digit code was used for identification of samples. Product samples were arranged in random order on white plates and served to the sensory judges. Orientation was given to the judges on the procedure of sensory evaluation before the test session.

3.6. Statistical analysis. The analysis of variance (ANOVA) was used to determine for significant difference between means of salting methods and drying technologies using appropriate software (SAS institute and Cary, NC) version 9.0. Duncan's multiple range tests were used to identify significant differences. Significance was accepted at $p < 0.05$.

IV. RESULTS AND FINDINGS

4.1 Drying Process and Rate of Drying Sea Mullet

Zebib, H. , et. Al. (2017) [6] cited the importance of fish drying. Drying or dehydration is used to describe any process involving the removal of water from fish or fish products by evaporation (Eyo, 2001) [7]. Sun drying is fraught with problems such as contamination by dust and insect infestation because the fishes are dried on mats spread on bare ground that leads to spoilage (BOSTID, 1988) [8]. The characteristic of dried fish that makes them shelf stable is their low water activity (aw) and thus prevention of growth of many

spoilage microorganisms (Antonios et al., 2005; Rorvik 2000) [9]. Fish with moisture loss of between 66 and 75% may not be infected by microbes and the shelf-life of the fish could be increased in solar dryers (Clucas, 1982; Frazier and Westhoff, 1998) [10].

In this study, Average atmospheric conditions during the experiments were measured using the Atmospheric Thermometer since it has a great influence on the drying of fish, the parameters were monitored on an hourly basis and reported (Table 1).

Table 1. Average Observations of atmospheric conditions during drying

No	Time	Modified Solar Dryer				Open Air Dryer			
		Day 1		Day 2		Day 1		Day 2	
		Temp. (⁰C)	RH (%)	Temp. (⁰C)	RH (%)	Temp. (⁰C)	RH (%)	Temp. (⁰C)	RH (%)
0	9:00AM	33.2	79	33.97	77	28.3	80	31.3	80
1	10:00AM	34.4	79	35.6	65	30.4	80	31.4	70
2	11:00AM	34.2	70.5	37.07	60.3	30.4	75	32.0	70
3	12:00AM	40.1	79.3	41.6	60.2	32.6	75	35.5	68.5
4	1:00AM	33	80.3	35.5	67.0	30.3	75	33.0	68.5
5	2:00AM	32.5	66.0	33.2	60.0	29.8	70	29.0	67
6	3:00AM	31.4	60.0	32	60.5	29.7	70	29.0	67
7	4:00AM	31.4	63.2	32	60.2	29.7	70	29.0	67

The drying depends on the speed of air at which moisture can be carried away from the surface of the fish. The important factors are Relative humidity (RH) of the air: if the air is fully saturated with water vapor (relative humidity 100 percent), it cannot carry any more water and no drying of the fish will occur.

As shown in Table 1 there was a temperature and relative humidity variation in both experimental dryers recorded from 9:00AM to 4:00 PM. The temperature was low from 9:00-10:00 AM and from 2:00 to 4:00 PM and high from 11:00AM-1:00PM for both dryers but the recorded phenomena of changes in temperature and humidity are higher to MSD.

The present study uses the modified solar drying facility with UV plastic roofing corrugated sheet which increases the air temperature. Hence, the drying process of split mullet fish is efficient. In this experiment the 20 kilos mullet fish were split and brined at the different concentrations such as, 10%, 15% and 20%. To determine the effectiveness of the modified solar dyer developed by UPV the experiment was conducted to the open air dryer where fish are arranged in a drying tray and exposed directly to sunlight and open air. Both products are dry for two days. During the drying it was observed that the atmospheric temperature and relative humidity varies from day one and day two. The differences of the temperature and relative humidity has a great effect in the drying process; the results are shown in Table 1 and Figure 2, 3 and 4.

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The highest temperature (41.60C) was recorded on the second day at 12 noon and the lowest RH (60%) at 3:00PM and 2:00PM on day one and day two respectively. The range of temperature in MSD is 31.4-40.1 on day one and on the second day 32 to 41.6 while in OAD 29.7-32.6 and 29.0- 35.5 respectively.

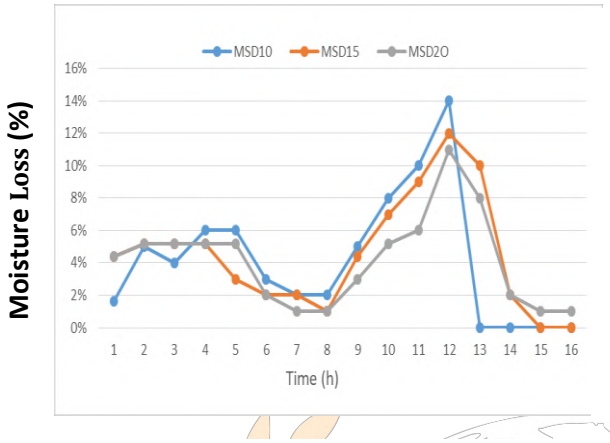

Figure 2: Drying Curve for Split Mullet fish in Modified Solar Dryer

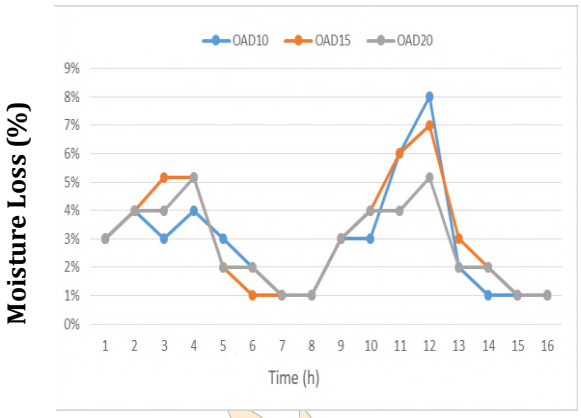

Figure 3. Drying Curve for Split Mullet fish in Open Air Dryer

The Figure above shows the drying curve for split mullet fish soak in different brine concentration for 1 hour and dried to the modified solar dryer and to the open air. Result shows that drying is slow due to lower temperature and higher RH (Table 1.) resulted in a minimal moisture loss. It was also observed that moisture was higher from 11 AM to 2 PM for both drying methods. However, the fish that are brined in 10% brine concentration the loss of moisture was faster than those brined in 15% and 20% solution.

4.2 Drying Process and Rate of Drying Sea Mullet

In Figure 2, it is seen that 12 h drying time was required for obtaining optimum moisture content in the brined mullet fish at 10% concentration whereas the fish brined in 15% to 20% concentration require 15 to 16 h. The fish dried in an open air dryer takes more than 16 h to obtain optimum moisture content. Sengar, S. H. et al. (2009) [11], reported that salts dried in the open air take 13 h or more to reach the required optimum moisture of dried fish.

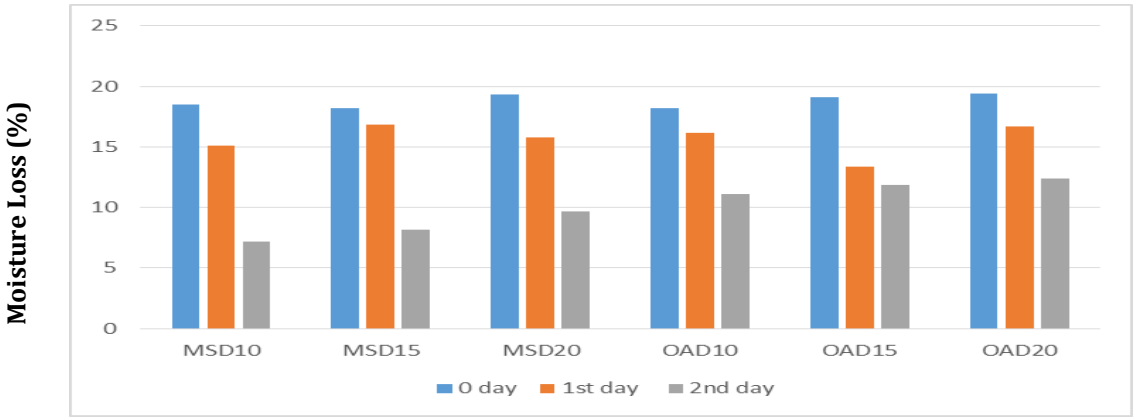

Figure 4: Moisture loss variation with dryers and brining methods during drying days

Figure 4 shows moisture loss of the dried split mullet fish brine at different concentrations. As the drying days increased, moisture loss increased. After 2 days of drying the highest moisture loss was observed in fish brine in 10% solution dried Modified Solar Dryer (MSD). Generally, the fish dried in MSD takes a shorter time to dry as compared in an Open Air Dryer (OAD) due to the UV plastic roofing corrugated sheet that is used in MSD. Using plastic in an enclosed dryer the air temperature increases (TNAU Agritech Portal, 2009) [12].

Table 2: Moisture Loss and the Final Weight of Dried Split Mullet

Product	IW (kg)	FW (kg)	MOISTURE LOSS
MSD10	18.5	7.02	59.23%[a]
MSD15	18.2	8.19	55.00% [a]
MSD20	19.3	9.67	49.88% [a]
OAD10	18.2	11.11	38.93% [b]
OAD15	19.1	11.88	37.78% [b]
OAD20	19.4	12.41	36.04% [b]

MC values are mean ± SD of duplicate analyses. Mean ± SD in a column with the same letter are not significantly different (p<0.05). IW= initial weight; FW= final weight; MSD=Modified Solar dyer; OAD= Open Air Dyer.

Table 2 shows the Moisture Loss and the Final Weight of Dried Split Mullet. As shown in the table there were no significant (p>0.05) differences between the products dried in MSD and OAD, Hence split mullet can be processed or dry applying any brine concentration (10%., 15% and 20%). Drying fish using MSD is significantly (p>0.05) different from OAD. Drying is faster in MSD thus preventing the growth of microorganisms and less likely to be contaminated by dust and flies. Similarly, Sulieman and Sidahmed (2012) [13] reported lower moisture loss values of dried fish in an open air dryer.

Table 3: Sensory evaluation of fish samples dried under modified solar and open air dryers

Parameters	MSD10	MSD15	MSD20	OAD10	OAD15	OAD20
Color	6.3±0.44 a	6.1±0.49a	5.6±0.48 a	5.0±0.66 a	5.1±0.49a	4.6±0.48 a
Appearance	7.8±0.15 b	5.2±0.48 a	4.0±0.71 b	5.9±0.19 a	5.2±0.48 a	4.0±0.71 b
Odor	6.0±0.74 a	5.4±0.74 a	4.5±0.37 a	5.0±0.87 a	5.4±0.74 a	3.8±0.37 a
Flavor	7.0±0.82 a	4.4±0.78 a	5.0±0.55 b	5.0±0.97 a	4.4±0.78 a	3.1±0.55 b
Texture	8.0±0.69 a	7.2±0.35 a	4.1±0.22 b	6.1±0.32 b	5.2±0.35 a	5.1±0.22 b
General Acceptability	8.7±0.76 b	6.0±0.25 a	4.1±0.65 a	5.3±0.15 a	5.0±0.25 a	3.1±0.65 a

All values are given as mean ± standard deviation; Different letters (a-b) in same row indicate significant differences within the sensory values (p<0.05).

Table 3 showed that for all the sensory quality examined by the panelists preferred the fish dried under MSD with the highest general acceptability score of 8.7±0.76. This confirms that the highly acceptable dried fish products can be obtained only if the samples are dried in an enclosed dryer that cannot be

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contaminated by flies and dust. Further, panelists like very much dried split mullet with low salt taste. It was observed that fishes dried under an open air dryer received a very low score in all the sensory qualities (Table 3). This may be due to visible growth maggots due to the contamination of flies and discoloration that occurred during prolonged drying. The results show significant differences in most of the sensory qualities of samples dried in MSD and OAD. However, significant differences were recorded in flavor and texture of fish products dried in both dyers with the high concentration of salt, the fish brined in 20% concentration (Table 3). From the studies it is concluded that drying time depends on brine concentrations applied in the fish and drying condition, though salt is a preservative in nature but can also affect the flavor or taste of the product. Quality evaluation indicated that fish dried under a modified solar dryer is superior and received highest overall acceptability in sensory attributes because fish dries quickly, safe from contamination of dust, flies and rodents. Other than if the products were not totally dried for the day the fish product can be left in the facility.

V. CONCLUSION AND RECOMMENDATION

From the studies drying time depends on brine concentration and drying conditions. It was also observed the higher the temperature and the lower RH is the faster the drying rate of the split mullet fish. Quality evaluation indicated that fish dried under MSD is superior to other dryers due to its controlled drying conditions, and received highest overall acceptability in sensory qualities. For further investigation of this study it is recommended that the storage life, microbiological and nutritional analysis should be conducted. On rainy days Modified Solar Dryer's Facility needs an additional heating source to continue drying the product and prevent the product from spoilage. Quality evaluation indicated that fish dried under a modified solar dryer is superior and received highest overall acceptability in sensory attributes because fish dries quickly, safe from contamination of dust, flies and rodents.

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