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Comparative studies on drying characteristics, proximate composition, and microbial characteristics of marine silver belly fish.

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ABSTRACT
This research's objective was to compare the effects of hot air-microwave heating powered by solar energy and Traditional drying on drying characteristics, proximate composition analysis, and microbial characteristics of fresh silver belly (Leiognathus Bindus) sea fish. Microwave drying tests on silver belly fish were performed to identify the microwave drying characteristics of marine fish. This study investigated the effects of microwave powers and loads on the microwave drying characteristics of fish by using moisture content, drying rate, and drying temperature as parameters. After hot air drying at a temperature of 50^0C and a constant air-velocity of 1 m/s, experimental drying curves were obtained at a microwave power of 200 watts. In the sun drying process four major parameters Solar Radiation, Relative Humidity, Temperature, and Air velocity were investigated. Comparative proximate compositions Such as moisture, crude protein, crude fiber, crude fat, ash, calcium, and phosphorus, of these samples were 28%, 51.28%, 0.68%, 13.57%, 8.88%,2.3%, and 1.27% respectively for hot air-microwave heating and 37.26%,46.38%,1%,9.11%,8.87%,2.6%,1.41% respectively for sun drying. The number of bacterial loads was found 5.6×10^8 CFU/gm for sun drying and 8.3×10^7CFU/gm for hot air-microwave drying. However, the data indicate that lower microwave power and hot air temperatures are effective in maintaining the quality of marine dry fish.

Keywords: Hot air microwave, Sun drying, marine fish, proximate composition.

1. Introduction

Fish is a valuable source of protein content, which is necessary for human nutrition. It has a very short shelf life and is a highly perishable product. Fish drying is required to preserve the fish by inactivating enzymes and removing the moisture required for bacterial and mold growth. [1, 2]. Drying affects not only the product's water content, but also its physical, biological, chemical, and physicochemical properties such as enzyme activity, microbial spoilage, viscosity, hardness, aroma, flavor, and palatability [3]. Dried fish is a major commercial product in Bangladesh's southern region. Sunlight is the traditional energy source for drying fish. Fish drying is a traditional process. However, sun-drying has several draw backs, including a long drying period in non-sterile conditions, as well as poor handling throughout processing, resulting in a low-quality and undesirable finished product [4]. Various conventional thermal methods such as hot air drying, vacuum drying, solar drying, and freeze drying are utilized in the drying of biological products, resulting in poor drying rates in the decreasing rate period and undesired thermal damage of the final product.[5]. The benefits of microwave drying include quick and relatively uniform heating, shorter operating times, excellent thermal efficiency, space utilization, hygienic settings, energy savings, accurate process control, quick start-up and ,shut-down circumstances, and high-quality final products. [6,7]. In recent years Consumers in developed countries are increasingly aware of the impact of diet on health and well-being [8]. As a result, there has been an increase in demand for high-quality, low-fat food that meets nutritional needs, provides health benefits, and reduces the risk of certain diseases; additional benefits can include an extended shelf risk, economical processing, improved palatability, and ease of preparation [9].

One of these alternative technologies is microwave processing, which has been used successfully for a variety of chemical industry applications as well as, more recently, for a variety of unit processes in the food industry, such as thawing/tempering, dehydration/drying, cooking, blanching/baking, sanitization, or pasteurization of various food matrices. Microwaves are non-ionizing electromagnetic waves with frequencies ranging from 300MHz to 300GHz. The ISM frequency, which is more or less steady and is close to 2.45MHz, is located between infrared rays and radio and television waves. When used, convection and condition phenomena occur simultaneously with internal heat generation or volumetric heating, albeit at very distinct time frames. As a result, when compared to traditional thermal methods, microwave heating generally offers many advantages in terms of shorter start-up time, faster heating, greater energy efficiency, smaller footprint precise equipment control, selective heating, and final products with improved nutritional quality [10]. Sea fish is currently primarily dried using hot air and conventional natural methods. Additionally, several innovative drying techniques have been created and applied to aquatic products, including microwave drying [11] vacuum freezing drying [12], hot pump drying, and infrared drying . However, almost every procedure has a drawback. Natural drying, for example, is greatly influenced by external factors, resulting in low production efficiency. Because of the poor sanitary conditions, it is difficult to adapt to the increasing requirements of food quality and safety systems [1]. The limitation of hot-air drying is a long time and high energy consumption, browning effect, possible nutrition loss,

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and color and texture quality deterioration. [13]. High-frequency electromagnetic waves are used for heating in microwave drying, and the energy from the microwaves directly transforms into thermal energy inside the material [14]. Microwave drying is a highly effective internal heating form as compared to other dry processes, greatly reducing drying time and maximizing energy savings. In this study, an improved method involving high-power microwave heating has been established. The process of dielectric heating, which involves a high-frequency electric field interacting with the fish, is an efficient way to turn electrical energy into heat for drying fish.

2. Research study sites

This study explores the two types of drying processes of silver belly (Leiognathus Bindus) fish, Microwave and Sun-dried. Constructed improved microwave fish drying was performed at the Institute of Energy Technology Lab, Chittagong University of Engineering & Technology figure-1.and Traditional sun-drying & Environmental data were collected from the Top floor of IET, CUET Academic Building during December, 2021. Nutritional and microbial study was conducted in Poultry Research and Training Center, Chittagong Veterinary and Animal Sciences University.

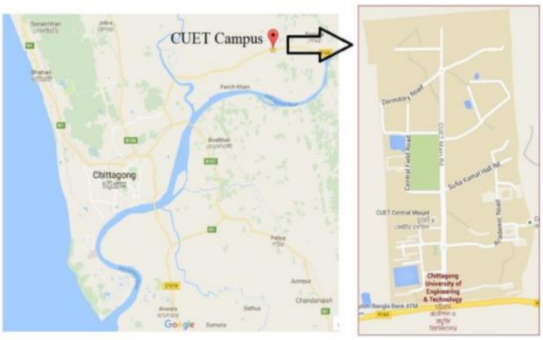

Fig.1 Geographical map of CUET, Chittagong

The duration of fish drying is depended upon how quickly the moisture will be removed from the fish. Several factors influence the rate of drying such as solar radiation, relative humidity, temperature and air velocity. The environmental parameters were found in CUET, Chattoragam from 19/12/2021 to 22/12/2021.

3. Materials

In this experiment, the fresh silver belly (Leiognathus Bindus) fish which is locally known as Tek Chanda was used for drying.

Fig 2, 3. Raw Silver belly fish prepare for microwave drying & Traditional fish drying process.

The raw materials were collected from Fishery Ghat, Chittagong during the winter season of 2021. Sorted silver belly fish of the same size were collected from the market. The silver fish size of $13cm \times 4.5cm \times 0.9$ cm. Fish were quickly transported to the Laboratory in sealed polystyrene boxes containing ice. The selected samples were cleaned with tap water to make samples free from foreign materials. After that, the belly of the silver belly fish is cleaned and prepared for drying. Surface water was removed by blotting with absorbent paper and then placed in a single layer.

4. Drying Procedure

A technique for preserving food called drying involves eliminating the water from the food, which prevents the growth of bacteria. To carry out this study, silver belly fish collected at the same time were dried in two ways 1) Hot air microwave heating and 2) Sun drying.

4.1 Hot air heating

A hot air-drying oven that primarily consists of a fan, a heat source, a drying chamber, and trays can uniformly dry fish. The air is directed to a heat source during drying, which is provided by an inverter. The experimental hot air dryer is given in fig.4. The fish would not be overheated or underheated with an automatic temperature control system. To use an automated constant temperature blast dryer, the fresh fish was pre-dried for 5 hours at 50^0C with a constant air speed of 1 m/s. The pre-dehydrated fish were immediately put into a laboratory microwave drying.

Fig .4 Pre-dried heater with constant air velocity.

4.2 Microwave heating

The drying method is based on microwaves penetrating the moist material, where the microwaves are converted into heat. The moisture turns into vapor and is transported from the building using a fan. The pre-dehydrated fish were put into a laboratory microwave drying to dry for 10 minutes at constant microwave power at 200watt. The experimental microwave drying set-up is given in fig.5 which consists of three main parts of the waveguide, cavity, and air duct. One, the waveguide part is used to transfer microwave power from the magnetron probe into the cavity. It is a rectangular hollow tube which is made of stainless steel. One end side of the waveguide is mounted with a magnetron and the other end, the cavity part is a rectangular hollow conductor wall that is made of stainless steel. The cavity has a rotating plate that is rotated at 5 rpm on a ball-bearing shaft driven by an electrical motor. The dimensions of the microwave cavity are 305✕204✕356 mm^3. The presence of the rotating disc was necessary to obtain homogeneous drying and to decrease the level of the reflected microwaves onto the magnetrons.

Fig5. Microwave Experimental Set-up

The oven has ventilation holes on the left side. Another part of the experimental setup is the air duct that is attached to the outer surface of the microwave oven. The air duct is used to measure the speed of the air inside the oven. The air flowing through the air duct is blown through a hole in the orifice meter inside the duct. The Pitot tube is attached to the hole in the center of the orifice meter. Manometric height is found on a millimeter scale on the manometer attached to the pitot tube. The Microwave drying system is powered entirely by solar energy.

5 Sun drying

After collecting the cleaned fish, it was taken to the roof of CUET Academic building-3 for fish drying. After that fish were hung up on strings. It takes a total of 4 days to dry the fish from 19/12/2021 to 22/12/2021. Environmental parameters (Solar Radiation, Temperature, Relative Humidity, and Air velocity) are measured every half hour during these four days of fish drying.

6 Result and discussions

6.1 Sun drying is accomplished by physically exposing the target fish to the sun. This is normally done outside in the open air, using solar energy to evaporate the fish's water content. The evaporated water from the fish body was transported away by natural air. Sun drying curves and drying data

Table 1 Environmental parameter of CUET December

Parameters	Date	Day Time												
		Am				PM								
		10	10.30	11	11.30	12	12.30	1	1.30	2	2.30	3	3.30	4
Solar Radiation w/m^2	19/12/21	450	490	500	570	610	596	516	470	399	355	320	210	184
	20/12/21	478	528	511	550	578	522	320	228	254	195	188	170	165
	21/12/21	374	430	470	530	586	230	245	352	280	230	220	200	170
	22/12/21	438	517	570	560	554	245	394	500	542	500	370	278	198
Tem (^0C)	19/12/21	23.6	24.6	25	27	28.6	30	29.6	28.7	27.5	27	26.3	25.2	24.3
	20/12/21	24	24.3	25.2	29	29.2	27	26	25.6	26	24.9	23.9	22.9	22
	21/12/21	22.5	24.5	25.9	25	24	25.4	25.3	25.5	24.3	24.6	24	24	23.6
	22/12/21	23	24.5	25.9	26	27	30	26	27	23.8	24.6	23	23	22.6
Relative Humidity (%)	19/12/21	78	75	73	69	60.6	63.8	51.9	65.9	52	55.5	60.7	65	68
	20/12/21	79	73.8	69.9	62.8	60.5	63.6	65	65.6	64.6	66.2	66.5	67	68
	21/12/21	70	65	60.1	65	69.9	50.5	60	63.2	63	64	63	62	63.6
	22/12/21	79.9	77	71.1	70	69.2	60	63	64	65.1	66	67	68	69
Air velocity (m/s)	19/12/21	1.4	1.6	15	1.8	1.9	1.5	1.9	2.2	1.1	1.4	0.8	1	1.3
	20/12/21	1.2	1.1	0.8	1.9	1.8	2.2	2.5	3	3.3	3.2	3.4	3.2	3
	21/12/21	1.5	1.8	1.5	1.7	1.9	1.5	1.5	1.7	1	0.8	0.9	1.2	1.5
	22/12/21	0.5	0.8	0.6	1	1.2	0.5	0.8	0.5	0.5	1.1	1.5	1.8	2

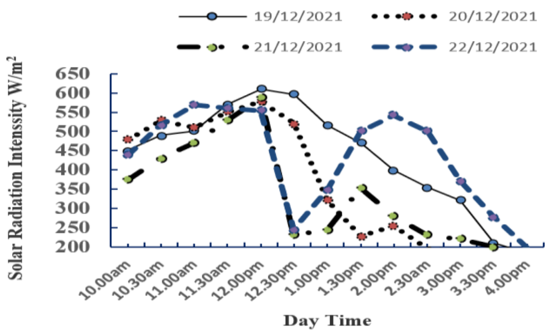

Fig .6 Solar Radiation in CUET in December 2021

Figure-6, shows the difference in intensity of solar radiation every half hour from 10 am to 4 pm on 19/12/2021 to 22/12/2021. It is seen that the intensity of radiation of the sun is high from 10 am to 12.30 pm.
The solar radiation measurements are taken using DS-05A solar meter.

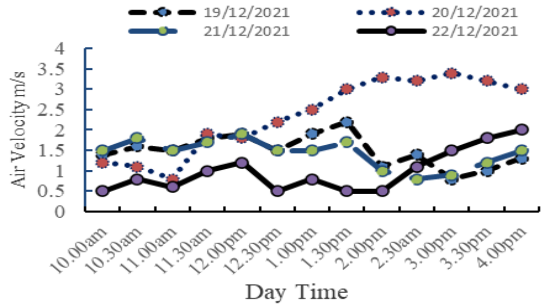

Fig .7 Air Velocity in CUET in December 2021

For drying fish, one of the most significant parameters is wind velocity. It was found that during air drying, moisture is eliminated from the fish's surface first, and subsequently, water flows from the deeper layers to the surface. Once all of the surface moisture has been transported away, the falling rate period begins, which is determined by the pace at which moisture can be delivered to the fish's surface. As the moisture concentration in the fish decreases, the rate of moisture migration to the surface slows and the drying rate slows until it reaches zero at equilibrium between the product and the surrounding drying conditions[2] .As can be seen from Figure-7, Date19/12/2021 to 22/12/2021 one of the elements of drying fish is wind speed which is observed more from morning to afternoon. The maximum wind speed of 3.4 m/s at 3.00 pm was recorded for drying the fish on 20/12/2021.

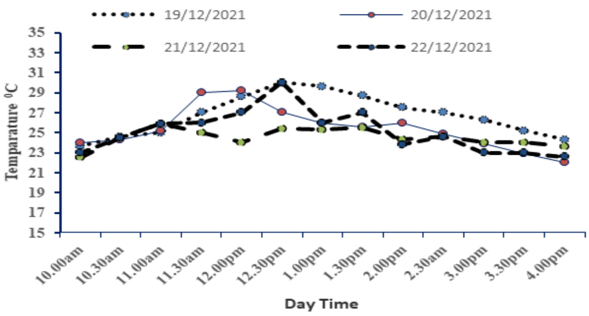

Fig .8 The Temperature in CUET in December 2021

The temperature of the fish is reduced below ambient at the start of drying; after a short time, it reaches a steady value, and the heat energy required for evaporation is reasonable by the heat supplied by the surrounding air. Warm air can provide more heat energy, and if the air speed and relative humidity allow for rapid water movement, the rate of drying will be accelerated.

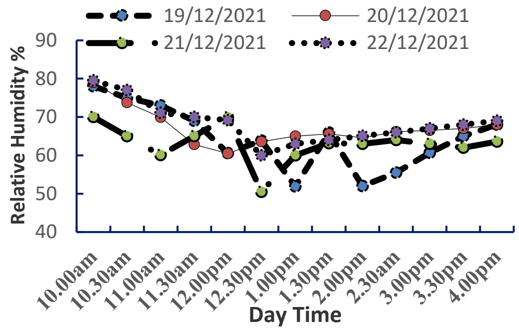

Fig .9 Relative Humidity in CUET in December 2021

According to the data obtained from fig-9, the drying curves of silver belly fishes are shown below. The moisture contents decreased with the increase in drying day time. If the resulting value is less than 0.1, the sample is considered sufficiently dry. The figure shows that the drying rate of 19/12/2021 was close to 1.4 which gradually decreased. After drying on 22/12/2021, the moisture content decreased to 0.1. After that, all the dried fish was packed for the test.

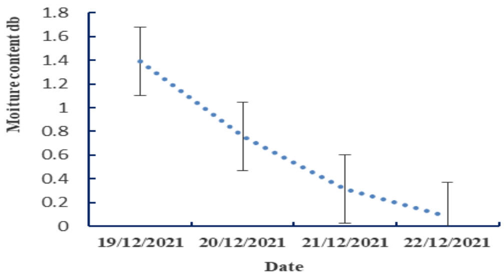

Fig 10. Effect of moisture content on the drying rate for the sun drying.

6.2 Hot air Microwave curves and drying data

Figure -10 shows the changes in moisture ratio as a result of drying time for silver belly fish in hot air drying. It was discovered that the constant 50^{0}C hot air power input has an impact on the moisture content and that the drying time of the silver belly fish was greatly decreased.

Table 2 pre-hot air-drying rate of silver belly fish

Time (min)	00	30	60	90	120	150	180	210	240	270	300
Weight (gm)	510	497	478	439	403	379	359	339	318	295	266

In table 2 shows, Initial condition raw fish weight was 510 gm after a duration of time it decreased to 266 gm. Then it was ready for microwave heating.

Table 3 The microwave drying rate of silver belly fish after pre- hot air drying.

Time (min)	0	1	2	3	4	5	6	7	8	9	10
Weight (gm)	266	259	252	246	239	235	229	225	222	219	217
Tem (^{0}C)	27	36.5	39	43	46	46.5	48	48.5	48.7	49	49.5
RH (%)	85	84	82	82	83	81	81.5	80	79.5	79	78

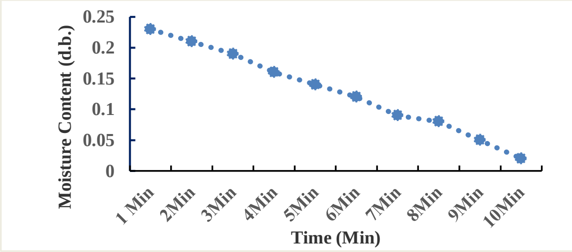

Fig.11 Effect of moisture content on the drying rate for the microwave drying of fish

During the first stage of drying, the fish moisture content was high, which increased the power of the microwaves being used as well as the rate at which moisture was diffused. As the drying process advanced, the product's loss of moisture led to a decline in the microwave's power absorption, which in turn decreased the drying rate. Therefore, the drying rate was significantly influenced by the microwave output power.

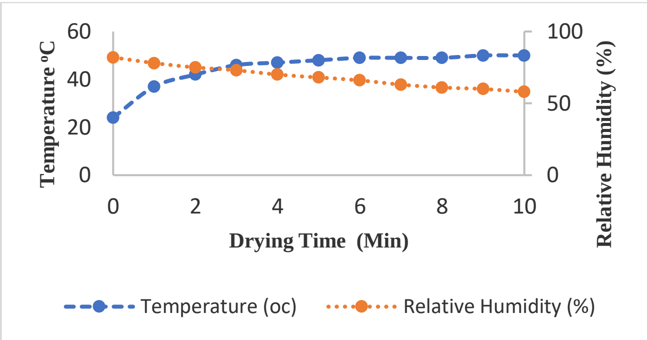

Fig.12 Variation of microwave oven temperature and relative humidity with drying time.

The variation in actual relative humidity and temperature with drying time is depicted in Fig.11. The graph shows that as air temperature increases, the relative humidity of the air decreased. It also demonstrates that relative humidity was relatively high at the start. When the temperatures were relatively high and the humidity was relatively low. It improved the drying process.

6. Proximate Composition Analysis

Two-way (Hot air microwave and sun drying) dried silver belly fish were taken randomly and separately and they were finely chopped. Then the fish sample was finally ground with an electric blender to make a homogeneous sample and packed separately for quality test. This sample was used for proximate Composition analysis.

Crude Protein analysis: The crude protein concentration was determined using the Kjeldahl technique. Among the reagents used were concentrated H_2SO_4, digestion mixture (Potassium sulfate 100gm+ Copper sulfate 10gm+ Selenium powder 1gm), NaOH solution (35%), 4 percent boric acid solution, 0.1 gm mixed indication in 100 ml ethanol, combine bromocresol green and 0.1 g methyl red, and standard HCL (0.2N). The protein content proportion was calculated using the following formula:

% Nitrogen =

$$\frac{(A - B) \times \text{Normality of acid} \times \text{Milli equivalent weight of Nitrogen } (0.014) \times 100}{\text{Weight (gm) of sample}}$$

Where, A= ml of titrant of the sample, B=ml of titrant of the blank. Percentage (%) of crude protein = Nitrogen (%) ×6.25

Fat content analysis:

A Soxhlet device was used to determine the fat content of these samples (FOOD ALYTRD40). First, weigh the empty beaker, and then fill it with 75 ml of ether. Exactly 2 grams of sample was obtained in the thimble paper. Boiling was done for 15 minutes, rising for 25 minutes, and extraction was done for 10 minutes, with the temperature of the Soxhlet apparatus set at 100^0C throughout the operation. Most of the solvent had evaporated after about 10 minutes. The following formula was used to calculate

fat content: % Fat $=\frac{W1-W2}{W} \times 100$

Here, W_1 = weight of evaporated flask with the sample W_2= weight of empty flask, W= weight of the sample

Carbohydrate content: - The carbohydrate content was estimated using the different formula

[Carbohydrate =100% - (% moisture + % ash + % Crude protein + % fat)].

Ash content analysis: 3 grams of powdered material was placed in a pre-weighted porcelain crucible in triplicate. After that, the crucibles were placed in a muffle furnace (Nabertherm-L9/13) and heated to 550^0C for 6 hours. The crucibles were then placed in desiccators to cool for 30 minutes. The percentage of residual components in each sample was calculated. It was calculated using the formula:

Ash content (%) $=\frac{\text{weight (gm) of ash}}{\text{Weight (gm)of sample}} \times 100$

Moisture content analysis: Empty crucibles were first dried in a hot air oven for 1 hour at 1800C. The sample was then placed in a pre-weighed porcelain crucible using an electric balancer. After that, the crucible was placed in a hot air oven (BINDER-ED115) set to 105^0C for about 12 hours, or until the appropriate weight was reached. After that, the crucible was weighed once more. The moisture loss was determined from these weights using the following formula:

Moisture content (%) $=\frac{\text{Weight (gm) of ash}}{\text{Weight (gm) of sample}} \times 100$

Bacteriological aspect

The overall aerobic plate count of the samples was calculated using the traditional plate count (SPC) process plate count system, and was expressed as colony-forming units per gram of sample (CFU/g). Coliform tests were performed by following standards.

Colony forming unit (CFU/g)

$$=\frac{No\ of\ colonies \times 10 \times dilution\ factor \times weight\ of\ sample\ solution}{\text{Weight (gm) of sample}}$$

5 Experimental results & Discussion:

The proximate composition analysis test of marine silver belly fish from the improved and traditional products is presented in table 4. The improved microwave-dried silver belly fish had whitish color with a firm and elastic texture. The traditional dried fish was slightly grayish and had less firm and elastic in texture than improved microwave -dried fish. The Proximate composition of the improved microwave and traditional dried samples of silver belly fish was determined and showed lower moisture content 28.00% the traditional dried sample than the improved dried sample 37.26%.

Table 4 Proximate composition of dry fish

Proximate Composition	Silver belly Fish	
	Traditional dry	Microwave dry
Moisture (%)	28.00	37.26
Protein (CP) (%)	51.28	46.38
Crude Fiber (CF) (%)	0.68	1.00
Crude Fat (EE) (%)	13.57	9.11
Ash (%)	8.88	8.87
Calcium (%)	2.30	2.60
Phosphorus (%)	1.27	1.41
SPC(CFU/g)	5.6×10^8	8.3×10^7

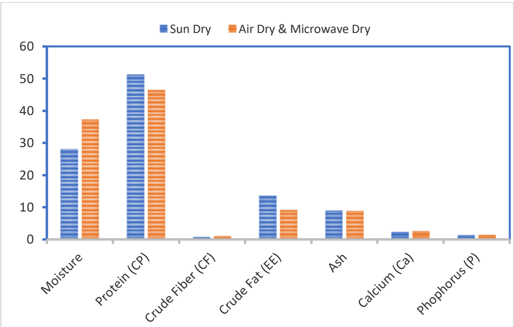

Fig.13 proximate composition of dry silver belly fish

Standard plate count (SPC) of improved microwave and the traditional dried sample silver belly fish were8.3×10^7, 5.6×10^8 CFU/g respectively. The results of the study on bacterial load were slightly higher than the permissible limit of 1×10^4 CFU/g [15].

6. Conclusion:

This research compared the biochemical and microbial content of dried marine fish from the hot air- microwave heating and traditional sun drying. After drying the fish in hot air, it is dried in the microwave which takes much less time than drying in the sun. Prolonged drying times result in significant deterioration, blowfly infestation, contamination with soil particles, and the extensive use of various pesticides. We developed improved hot air Microwave drying has been created to improve the food quality of traditional dried fish and to prevent infestation and widespread contamination. The six components of Protein, Crude fiber, crude fat, ash, calcium, and phosphorus important for the human body have been compared to show that the quality of fish dried in the sun and dried in the hot air- microwave is very close. Total microbial load in this tested sample 5.6×10^8 CFU/gm from sun drying and 8.3×10^7 CFU/gm from microwave drying and which is lower than sun drying. In terms of demand, the study opened up the way for the production and application of microwave-assisted hot air drying for marine fish in the near future.

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NOMENCLATURE

CFU : Colony forming unit (CFU/g)
Hz : One cycle per second, S^{-1}
w/m^2 : Solar radiation, watt/meter ^{2}
m/s : Air velocity, meter per second
T : Degree Celsius, ^{0}C