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The Influence of Forced and Natural Convection on the Sensory Characteristics of Dried Fish.

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***Abstact*- Indonesia is one of the countries with the largest archipelagos in the world, boasting an abundant wealth of natural biodiversity. One of these resources is fisheries. The production of dried fish is one of the community's efforts to increase the selling price of fish. The dried fish produced by the community is usually sold in traditional markets and has few buyers due to the lack of attention to the quality of the dried fish. To increase buyers' interest in dried fish, the quality must be improved. The aim of this study is to enhance the production system and quality of dried fish through the use of drying equipment with different drying methods, namely natural convection and forced convection drying systems. In natural convection, the drying process utilizes the movement of air flows caused by density differences, while in forced convection drying, the air flow rate is controlled with the help of a fan. This study involves the use of four variations of air velocity that will be tested: 1 m/s, 2 m/s, 3 m/s, and a gradual reduction from an initial speed of 3 m/s, decreasing by 1 m/s every 3 hours of drying until reaching 1 m/s. Drying is then continued at an air flow rate of 1 m/s until the desired moisture content is achieved. The results of the study indicate that the use of natural convection and forced convection drying methods affects the drying rate and the final product quality, including color, texture, and taste. From the results obtained, the use of forced convection drying method with a gradual reduction in air velocity proved to be the best treatment, with a drying rate of 0.036 kg/h, yielding the best final quality in terms of color, texture, and taste.**

***Keywords*:** *Dried fish, Drying, Forced convection, Natural convection, Temperature*

I. INTRODUCTION

Indonesia is a nation with a vast number of islands, making it the largest archipelago in the world. A significant portion of Indonesia's territory is surrounded by water, with its total water area comprising 65% of the country's total land area [1]. Indonesia is endowed with a wide variety of abundant natural biological resources, one of which is its fisheries. The fisheries potential in Indonesia includes pelagic and demersal fisheries, which are widely distributed across all parts of Indonesia's waters [2]. Fish is a type of food that is consumed almost daily by humans. Fish is favored for its various health benefits, as it contains numerous proteins that are beneficial to the human body [3].

Fish is a perishable food product that easily experiences quality degradation. This is caused by enzymatic autolysis, oxidation, and microbial growth [4]. Therefore, fish needs to be preserved to inhibit the decline in quality [5]. Preservation is an effort to prevent the decline in the quality of a food product. In the case of fish, preservation is conducted with the aim of stopping or inhibiting the growth of microorganisms, which are the main causes of spoilage and damage in fish [6]. One of the fish preservation techniques commonly used is drying [7]. Drying is a common technique for preserving vegetables and fruits. Sun drying is a primitive method of removing water content from food by spreading it on the floor, bamboo mats, or elevated pavements [8]. Drying is a complex process that involves stages of heat and mass transfer occurring transiently through the stages of the process rate. Drying is carried out until the moisture content of the product reaches a level similar to that found in the normal atmospheric state (Equilibrium Moisture Content) or within certain limits that make the dried product safe for storage and of good quality until the next processing stage [9]. In addition to extending the shelf life of fish, drying also serves to increase the economic value of the fish. The business of selling dried fish is one of the promising businesses in Indonesia [10], [11].

Dried fish resulting from the drying process is usually sold in traditional markets. The production process of dried fish in Indonesia still uses conventional methods, namely sun drying, resulting in suboptimal quality of dried fish, which reduces public interest in the product. Additionally, the use of conventional drying methods has several drawbacks, including fluctuating weather conditions [12], the need for larger drying areas [13], unexpected rainfall [14], uneven drying temperatures [15], dust contamination [16], and the threat of microorganisms such as mould, yeast, and bacteria due to prolonged drying times [8]. Therefore, to achieve a good final quality of dried fish, modern management is essential, one of which involves the use of drying equipment [17].

The drying equipment commonly used by the Indonesian community is the cabinet dryer [18]. The

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Figure 1. drying equipment

development of cabinet dryers has been extensively carried out to dry various agricultural commodities, including potatoes [19], pineapples [20], sweet potatoes [21], and shrimp [22]. The drying system in these dryers generally has two systems: natural convection drying and forced convection drying. In the natural convection drying process, the temperature distribution during drying does not occur rapidly, resulting in a relatively slow drying rate[8].

To enhance the production of dried fish and maintain its final quality, an appropriate drying system is essential to accelerate the drying rate. One way to speed up the drying process is by using forced convection drying systems [23]. The drying rate in natural convection is slower compared to forced convection drying [24]. Research on cabinet drying with forced convection systems has been extensively reported. Ankur Gupta (2022) studied the enhancement of energy and exergy performance in starfruit drying using semi-transparent PV in solar drying systems [25]. Ilhem Hamdi (2023) compared tomato drying in greenhouse solar drying systems with open sun drying [26]. Mulatu Chake GilagoA (2023) compared the thermal characteristics of carrot drying in indirect natural and forced convection solar dryers [24]. Ekka (2020) analyzed the efficiency of cabinet dryers with forced convection mixing using two airflow rates: constant and gradual reduction in black ginger drying [27]. Koehuan (2022) tested varying airspeeds in drying Moringa leaves using greenhouse effect drying methods with airspeeds of 0.5, 1.0, and 1.36 m/s [28]. Mirzaee (2023) conducted an energy and exergy analysis of tomato slice drying equipped with phase change materials (PCM) by varying airspeeds at 1, 1.5, and 2 m/s [29].

Based on the literature mentioned, most research uses non-fish materials such as starfruit, tomatoes, carrots, and ginger, and there is not much research specifically comparing the final quality of dried fish. Reported studies show that variations in airflow speed can affect the drying rate and the quality of the final product; however, this research is mainly applied to materials other than fish. In this study, the author aims to compare the final quality of dried fish using natural and forced convection drying processes in a tiered cabinet dryer. This research will explore how variations in airflow rate affect the final quality of dried fish, which is still under-researched in the context of fish drying.

II. METHOD

A. *Materials and Equipment*

The materials used in this study were fresh stone snapper fish, with a size of 0.4±0.5 kg per fish, obtained from the Samudera Fishery Port Kutaraja Lampulo Banda Aceh, salt, and water. The equipment used in the research included a tray dryer (Figure 1) with a total of eight trays. The heat source for the dryer used a gas stove. The drying cabinet was equipped with an exhaust fan with a power output of 20 W and a duct diameter of 12 cm on the chimney, which functions to control the airflow speed during the drying process. The dryer consists of five main components: the combustion chamber, deflectors, drying chamber, drying racks, fan compartment, and chimney. Other equipment used included a digital scale, anemometer, thermometer, exhaust fan, gas stove, and LPG gas.

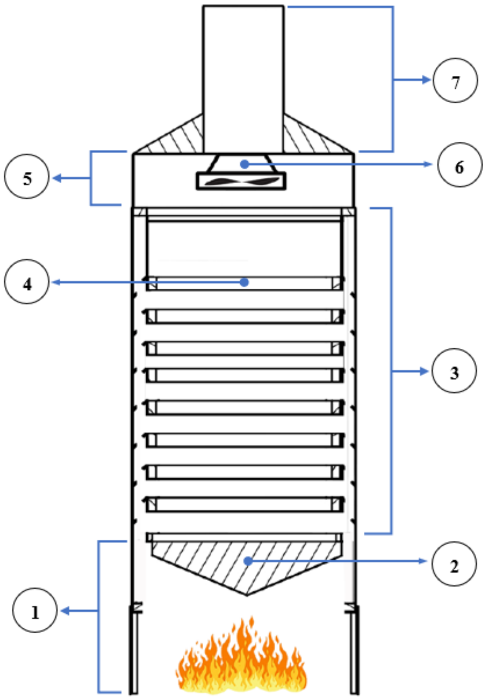

Figure 2. dryer parts: 1. Combustion Chamber, 2. Flow Guide Vane, 3. Drying Chamber, 4. Drying Rack, 5. Fan Chamber, 6. Fan, 7. Exhaust Chimney.

B. Methodology

Before the drying process, the fish are soaked in saltwater with a salt concentration of 30% for 6 hours. The drying temperature follows a stepwise reduction system. This system involves gradually decreasing the temperature as the fish's moisture content reduces. Drying begins at 80°C and is reduced by 10°C every 2 hours until reaching 60°C. Drying is then continued at 60°C until the desired moisture content is achieved. Gas fuel is used as the energy source for the drying process.

In this study, the focus is on testing the airflow speed during the drying process. The airflow speed consists of two variables: constant and stepwise reduction. The airflow speed at the outlet is set at constant speeds of 1 m/s, 2 m/s, and 3 m/s. For stepwise reduction, the airflow speed is adjusted from 3 m/s to 1 m/s over a 3-hour period from the start of the drying.

C. Analysis of Drying Rate

The drying rate is a measure of the speed at which water or moisture is removed from a material during the drying process. The drying rate can be calculated using the following formula:

$$\text{Drying Rate} = \frac{(M_i - M_f)}{t}$$

Where:
M_i is the initial mass of the material (kg or g).
M_f is the final mass of the material after drying (kg or g).
t is the drying time (hours or minutes).

D. Organoleptic Testing

The dried products will be used as samples for hedonic testing. The hedonic test will be conducted with 30 semi-trained panelists from the local community where the research is conducted. The purpose of the hedonic test is to determine the level of preference or liking that the panelists have for the tested samples. In the hedonic test, panelists will evaluate how much they like the appearance, taste, and texture of the samples by providing scores based on their personal preferences.

The results of the hedonic test will be analyzed using the Kruskal-Walli's test to determine if there are significant differences in the panelists' preferences for fish dried using different drying methods. If the Kruskal-Walli's test indicates significant differences, a Dunn test will be performed to analyze the significant differences in the organoleptic quality of the fish between each pair of drying groups.

III. Results and Discussion

A. Drying Rate

The experiment was conducted on fish using five different drying methods: natural convection (P1), forced convection with an air velocity of 1 m/s (P2), forced convection with an air velocity of 2 m/s (P3), forced convection with an air velocity of 3 m/s (P4), and forced convection with a gradual decrease in air velocity from 3 m/s to 1 m/s (P5).

Figure 1 shows the drying rate results. The curve's decline increases as the drying time progresses. The highest drying rate is observed during the first 4 hours of drying. After 4 hours, the drying rate slows significantly because most of the moisture has been removed. The average drying rates for P1, P2, P3, P4, and P5 are 0.024 kg/h, 0.028 kg/h, 0.034 kg/h, 0.038 kg/h, and 0.036 kg/h, respectively. The fastest drying rate was achieved using the P4 drying method with a flow rate of 0.038 kg/h.

Rapid drying processes often involve high temperatures, which accelerate fat oxidation in fish. This oxidation causes the color to change to brown. Drying using convection methods exposes fish to more direct and intense heat. The surface of the fish absorbs heat quickly, causing the outer layer to brown more [30].

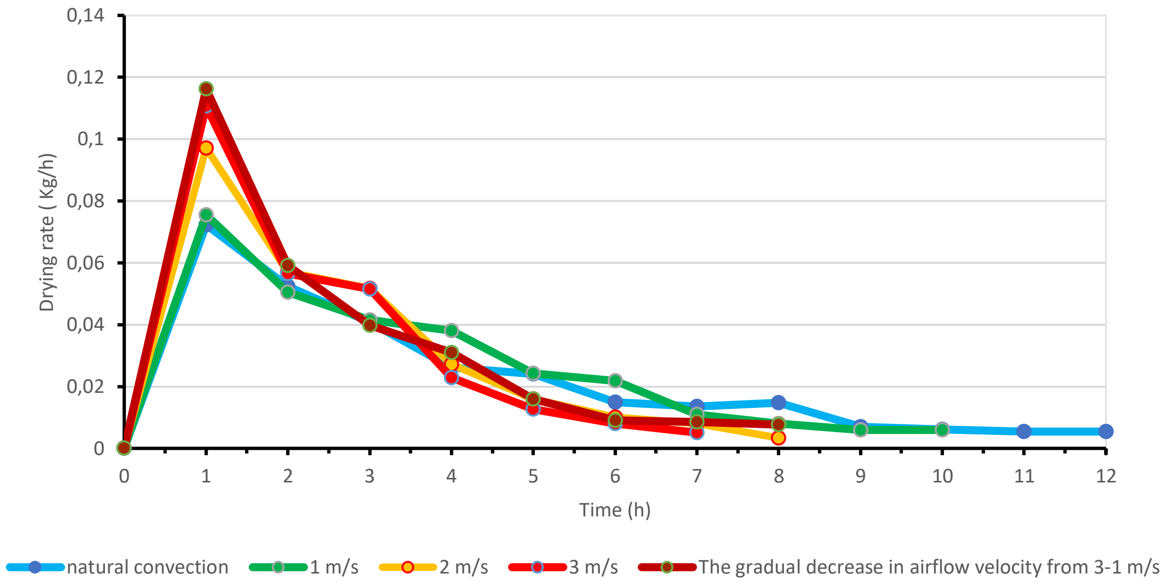

Figure 3. Drying rate of dried fish

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TABLE 1.
THE LEVEL OF COLOUR PREFERENCE OF DRIED FISH WITH DIFFERENT DRYING METHODS

Drying Treatment	Colour assessment of Dry Fish (%)				
	Extremely Like	Like	Neutral	Dislike	Extremely Dislike
P1	0,00	0,00	3,30	46,67	50,00
P2	0,00	20,00	43,30	36,70	0,00
P3	0,00	80,00	20,00	0,00	0,00
P4	3,33	6,67	90,00	0,00	0,00
P5	93,33	6,67	0,00	0,00	0,00

Type of drying treatment: P1 (Natural convection), P2 (forced convection air speed 1 m/s), P3 (forced convection air speed 2 m/s), P4 (forced convection air speed 3 m/s), and P5 (Forced convection with a gradual decrease in airflow speed from 3 m/s to 1 m/s).

B. *Data Analysis*

A hedonic test was conducted with 30 semi-trained panelists.

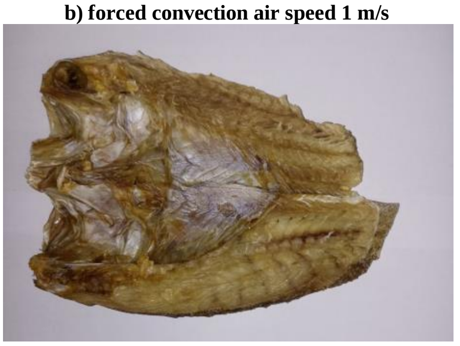
1. *Color*

The results of the hedonic test for dried fish with various drying treatments regarding color characteristics are presented in Table 1. The highest preference score among panelists was for treatment P5, with a score of 93%, producing a bright cream color. The lowest preference score was for treatment P1, with a score of 50%, resulting in a dull brown color. For treatments P2 and P4, most panelists were neutral, with scores of 40% and 90%, respectively. In treatment P3, most panelists liked the color, with a score of 80%.

The Kruskal-Wallis analysis for fish color indicates that there are significant differences in the use of natural

a) Natural convection

b) forced convection air speed 1 m/s



c) forced convection air speed 2 m/s

d) forced convection air speed 3 m/s

e) Forced convection with a gradual decrease in airflow speed from 3 m/s to 1 m/s

Figure 4. Dried fish with different types of drying treatment.

and forced convection drying methods. The Dunn's post hoc test results showed that treatment P1 is significantly different from all other treatments, P2 is significantly different from all other treatments, P3 is significantly different from all other treatments, P4 is significantly different from all other treatments, and P5 is significantly different from all other treatments.

1. Texture

The hedonic test results for dried fish with various drying treatments regarding texture characteristics are presented in Table 2. The highest preference scores

TABLE 2.
THE LEVEL OF TEXTURE PREFERENCE OF DRIED FISH WITH DIFFERENT DRYING METHODS

Drying Treatment	Texture assessment of Dry Fish (%)				
	Extremely Like	Like	Neutral	Dislike	Extremely Dislike
P1	80,00	20,00	0,00	0,00	0,00
P2	36,67	63,33	43,30	36,70	0,00
P3	0,00	6,67	43,33	50,00	0,00
P4	0,00	0,00	10,00	73,33	16,67
P5	63,33	36,67	0,00	0,00	0,00

Type of drying treatment: P1 (Natural convection), P2 (forced convection air speed 1 m/s), P3 (forced convection air speed 2 m/s), P4 (forced convection air speed 3 m/s), and P5 (Forced convection with a gradual decrease in airflow speed from 3 m/s to 1 m/s).

TABLE 3.
The level of flavor preference of dried fish with different drying methods

Drying Treatment	Flavor assessment of Dry Fish (%)				
	Extremely Like	Like	Neutral	Dislike	Extremely Dislike
P1	76,67	23,33	0,00	0,00	0,00
P2	23,33	73,33	3,33	0,00	0,00
P3	0,00	23,33	43,33	33,33	0,00
P4	0,00	3,33	13,33	63,33	20,00
P5	53,33	46,67	0,00	0,00	0,00

Type of drying treatment: P1 (Natural convection), P2 (forced convection air speed 1 m/s), P3 (forced convection air speed 2 m/s), P4 (forced convection air speed 3 m/s), and P5 (Forced convection with a gradual decrease in airflow speed from 3 m/s to 1 m/s).

among the panelists were for treatments P1 and P5, with scores of 80% and 63%, respectively. In treatment P2, the majority of panelists preferred the texture with a score of 63%. In treatment P3, most panelists expressed a dislike with a score of 50%. For treatment P4, the majority of panelists indicated a dislike with a score of 73%. Drying at excessively high temperatures can cause case hardening, which is a drying process that results in the surface drying faster than the interior [31].

The Kruskal-Wallis analysis for fish texture shows significant differences in the use of natural and forced convection drying methods. Dunn's post hoc test results indicate that treatment P1 is not significantly different from treatment P5 but is significantly different from the other treatments. Treatment P2 is not significantly different from treatment P5 but is significantly different from all other treatments. Treatment P3 is not significantly different from treatment P4 but is significantly different from the other treatments.

2. *Flavor*

The hedonic test results for dried fish with various treatments regarding flavor characteristics are presented in Table 3. The highest preference scores among panelists were found for treatments P1 and P5, with scores of 76% and 53%, respectively, with a savory and delicious flavor. In treatment P2, the majority of panelists liked the flavor, scoring 73%. In treatment P3, most panelists were neutral with a score of 43%. In treatment P4, the majority of panelists disliked the flavor, scoring 63%.

Consumers prefer the flavor of dried fish due to its savory and delicious taste, which is attributed to the presence of glutamic acid in the fish. Glutamic acid exists in two forms: bound and free. The bound form is glutamic acid that is attached to other amino acids forming proteins, while the free form is glutamic acid that is not bound to proteins [32]. The Kruskal-Wallis analysis of fish flavor shows significant differences between natural and forced convection drying methods. Dunn's post hoc test results indicate that treatment P1 is not significantly different from treatments P2 and P5 but is significantly different from all other treatments. Treatment P2 is not significantly different from treatments P5 and P1 but is significantly different from all other treatments. Treatments P3 and P4 are significantly different from all other treatments.

IV. CONCLUSION

The use of drying treatments affects the drying rate and final quality characteristics of fish. The fastest drying rate occurred in the P4 variation test with a drying rate of 0.038 kg/h. Based on hedonic characteristics, the panelists' acceptance level showed a preference for the P5 treatment for color characteristics with a score of 93%, P1 for texture characteristics with a score of 80%, and P1 for taste characteristics with a score of 76%. According to the Kruskal-Wallis and Dunn test results, the best treatment was achieved using the P5 variation, which involved forced convection drying with a gradual decrease in airspeed, resulting in a drying rate of 0.036 kg/h.

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