Nutritional and Functional Characterization of the Anchovy (*Stolephorus indicus*) Powder Produced by Conventional Drying and Foam Mat Drying

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Abstract. Anchovies (*Stolephorus indicus*) are abundant in both macro and micronutrients, including protein, carbohydrates, fat, and calcium. Their rich nutritive value has led to numerous applications in the food industry, particularly in fortifying food products for vulnerable groups. Proximate analysis is indispensable in the food industry for product development and quality control. The objectives of this study were to assess the proximate composition and functional properties of anchovy powder obtained through oven drying and foam mat drying. The characterization of anchovy powder encompassed functional properties, such as water solubility index, water absorption capacity, and physical parameters like colour and bulk density, as well as proximate chemical parameters. The results demonstrated that the protein content of anchovy powder obtained through oven drying was significantly higher than that from foam mat drying ($p<0.05$). The primary component of fish powders was protein (71.43±0.14%), followed by lipids (4.45±0.06%), ash (14.59±0.09%), moisture (8.55±0.01%), and carbohydrates (1.00±0.01%). Nevertheless, increasing the quantity of foaming agent did not enhance the solubility or water absorption capacity of the anchovy powder, despite the concurrent increase in its protein content.
Keywords: Anchovy, oven drying, foam mat drying.

1 Background

Indonesia, as a maritime nation, rich in marine resources, notably nutrient-rich fish such as anchovies (*ikan teri*). Despite their small size, anchovies are a valuable source of essential nutrients, including protein, calcium, and iron. Protein is indispensable for tissue repair and growth, calcium regulates cellular function and growth processes, and iron is crucial for preventing anaemia by facilitating haemoglobin formation [1]. In a 100 g serving of fresh anchovies, one can find 77 kcal of energy, 16 g of protein, 1 g of fat, 500

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mg of calcium, 500 mg of phosphorus, 1 mg of iron, 47 IU of vitamin A, and 0.1 mg of vitamin B [2]. According to the Indonesian Food Composition Table, anchovy powder reveals a nutritional profile of 48.8 g of protein per 100 g, along with 2381 mg of calcium and 23.4 mg of iron [3]. In economic terms, anchovies are a cost-effective and widely available food source, found in both marine and inland areas as well as through aquaculture. Due to their high nutritional value, it is reasonable to investigate their incorporation into contemporary functional food and beverage products to address community nutrition concerns.

Currently, the use of anchovies is primarily limited to salted drying, non-salted drying, and fresh consumption. Dehydration, one of the oldest and most commonly used methods of food preservation, serves the main purpose of reducing microbial activity and preventing product deterioration to extend shelf life [4]. Sun drying, a traditional fish preservation method, comes with several limitations. It is affected by variations in sunlight intensity depending on the season and air humidity, making it challenging to sufficiently dry the fish. The slow drying process renders the product vulnerable to insect infestation and air-dust contamination, resulting in inconsistent and lower product quality. Furthermore, it leads to a decrease in protein levels, unsaturated fatty acids, particularly omega-6 fatty acids, and lipid oxidation [4]. The reduction in protein content due to slow drying results in trapped water vapor within the material. Hence, more effective dehydration methods are necessary to produce products with stable nutritional value.

Oven dehydration technology, with the principle of convection heat transfer directly to the material, can minimize changes in the nutrient content, aroma, taste and rehydration properties of the material [5]. In addition, drying conditions can be set at the optimal temperature and time for the material. Before starting the drying process, pre-treatment of the raw material is often carried out, for example by adding salt and boiling. The functions of adding salt is to reduce water content, reduce drying speed and maintain the nutritional composition of fish [6]. Before drying, it is typical to prepare the raw material by adding salt and boiling it. The salt helps reduce water content, slow down the drying process, and preserve the fish's nutritional value . Boiling or blanching the anchovies for 5 minutes also reduces their water content, making the drying process faster [6].

Foam mat drying is a method used to dry liquid materials by creating foam with a foaming agent and a heat-resistant agent. This process is designed to increase the surface area, reduce surface tension, create voids, expand the material, speed up water evaporation, and maintain material quality [7]. In this study, various concentrations of egg albumin were tested to determine the optimal concentration for the physical and chemical properties of anchovy powder. Foam-mat drying of anchovies required the use of maltodextrin as a filler. Maltodextrin was added to encapsulate flavour components, increase total solids, enhance volume, expedite the drying process, protect the material from heat damage, and improve solubility and organoleptic qualities [7].

This study aimed to examine the composition and functional properties of anchovy powder made using oven dehydration and foam mat drying. The characterization of anchovy powder in terms of functional properties such as solubility index, water absorption capacity and physical parameters such as bulk density, colour and proximate chemical parameters has been studied.

2 Materials and method

Fresh anchovies were purchased from the fish market in Muara Angke, Jakarta. Ginger and lemon rhizomes were obtained from the traditional market in Serpong, Tangerang. The materials used included maltodextrin, egg albumin, ginger, lemon, distilled water, and materials for analysis, such as hexane solvent, a selenium reagent mixture, concentrated H_2SO_4, filter paper, 30% NaOH, PP indicator, 2% boric acid, and 0.01 N HCl. The equipment used consisted of dehydrators, colourimeters, Kjeldahl tubes, vortex mixers, grinders, analytical scales, centrifuges, and furnaces.

2.1 Dehydration of anchovies

A total of 1000 g of fresh anchovies were cleaned by removing the head and stomach dirt. Then, the fish was washed under tap water until clean and drained. Approximately 40 g of fresh ginger were peeled or their epidermis had scraped off and then sliced thinly. Meanwhile, the juice was squeezed from 2 lemons. About 1000 mL of tap water were poured into a pot, then lemon juice and sliced ginger were added. The mixture was boiled on the stove (approximately at 100°C) for 15 minutes. The cleaned anchovies were added and stirred slowly until all the fish were submerged in water, then the heat was turned off. The anchovies were blanched in the ginger-lemon water for 10 minutes. Subsequently, the anchovies were drained, arranged on a tray, and dried in a dehydrator at 40°C for 18 hours. After drying, the anchovies were ground using a grinder. The anchovy powder was stored in an airtight container and placed in the refrigerator until needed.

2.2 Foam mat drying method

The drying process of anchovies using the foam-mat drying method based on Widarti et al. (2021), with some modifications. A total of 1000 g of anchovies were cleaned by removing the heads and any stomach dirt. They were then blanched in boiled ginger and lemon water for 10 minutes. After blanching, the anchovies were removed, drained, and ground into a slurry. The anchovy slurry was then mixed with a foaming agent and filler in the following ratios : 0% egg albumin : 20% maltodextrin (K); 10% egg albumin : 10% maltodextrin (F1); 15% egg albumin : 5% maltodextrin (F2); and 20% egg albumin : 0% maltodextrin (F3). Each mixture was whipped using a mixer for 5 minutes to create stable foams. The foam mixture was poured onto a tray lined with paper with a thickness of 1 mm and then dried using a dehydrator set at 40°C for 18 hours. Once dry, the anchovy sheets were crushed using a grinder. The resulting anchovy powder was sieved through an 80-mesh sieve, and the yield was calculated [8].

2.3 Physical characterization of anchovy powder

2.3.1 Bulk density

The bulk density is the ratio of the mass of anchovy powder to its volume, including the contribution of the interparticulate void volume. Bulk density is expressed in g/mL, because the measurements are made using cylinders, which provide volume in mL [9]. The formula used is:

$BD = \frac{M}{V}$, where:

M = mass of the anchovy powder in the density cup in grams and V = volume of the density cup in mL. The bulk properties of the anchovy powder are dependent upon how it has been handled.

2.3.2 Colour testing

Colour testing is performed using the Chromameter tool. Colour readings are based on the Hunter (Lab) colour system developed by Hunter in 1952. In this system, colour assessment involves three parameters : L, a, and b. The colour location is determined by coordinates L∗, a∗, and b∗. The L* notation ranges from 0 (black) to 100 (white) and represents reflected light that produces achromatic colours like white, gray, and black. A higher L value indicates a brighter product. The a* notation represents a red-green mixed chromatic colour, with a positive a* value ranging from 0 to +80 for red and a negative a* value ranging from 0 to -80 for green. The b* notation represents a mixed chromatic colour of blue-yellow, with a positive b* value ranging from 0 to +70 for yellow and a negative b* value ranging from 0 to -70 for blue [10].

2.4 Chemical characterization of anchovy powder

Chemical testing of anchovy powder was conducted following the guidelines for testing food and beverages according to the Indonesian National Standard SNI 01-2891-1992 [11] and the Association of Official Analytical Chemists 2007 [12]. This included testing for water content, ash content, protein content, fat content, and carbohydrate content.

2.5 Functional properties testing of anchovy powder

2.5.1 Water absorption capacity

Water absorption capacity consists of adding water or an aqueous solution to material, followed by centrifugation and quantification of the water retained by the pelleted material in the centrifuge tube. It is used as a reference for determining the volume of water needed to make dough. The difference between the weight of the sample after absorbing water and the initial dry sample weight, expressed per 100 g, represents the amount of water absorbed by the powder [13]. The anchovy powder sample was mixed with water in a ratio of 1:10 (w/w) and shaken evenly for 5 minutes. The resulting mixture was then centrifuged at 1500 rpm for 30 minutes. The weight of the supernatant was measured to calculate the water absorption capacity. The formula used is: Amount of water absorbed = [(initial water weight – final weight (sediment)) / initial weight] x 100%.

2.5.2 Solubility index

Solubility in water, or dispersibility, refers to a material's ability to be distributed in water, including the ability of agglomerate lumps to dissolve and spread in water. A 1 g sample was dissolved in 20 mL of distilled water. The solution was heated in a water bath at 60°C for 30 minutes. The supernatant was separated using a centrifuge at 3000 rpm for 20 minutes, and then 10 mL was taken and dried in an oven. The weight of the dry sediment was recorded, and the percent solubility of the material was calculated based on the weight of the dry sediment divided by the initial weight of the material, multiplied by 100% [14].

3 Result and discussion

The results of physical characterization, chemical, and functional properties were tested using analysis of variance (ANOVA), as shown in Tables 1, 2, and 3, respectively. In the ANOVA test, it was observed that there were populations with different means, leading to the rejection of the null hypothesis (H0). Subsequently, a Tukey test was performed with a significance level of 5% to determine which populations had different mean values.

The bulk density of anchovy powder obtained from oven drying was 4.2 g/mL, which was significantly higher than that of anchovy powder from foam mat drying. Density is used to assess the compactness and texture of food. A compact food texture can withstand the pressing process, resulting in strong bonds between the constituent particles and minimal air spaces between them. Bulk density is also used to determine the required container size for holding the material.

A larger bulk density value means that the produced powder occupies less space for the same weight compared to other products with a smaller bulk density value. The typical bulk density value for powdered food products falls within the range of 0.3 to 0.8 g/ml, ensuring good physical quality for the instant powder material produced. It is important for an instant product not to have a low bulk density since this would lead to reduced satiety for the target consumer and lower nutritional intake [15].

Colour measurements indicated that the anchovy powder obtained from oven drying had a grayish appearance with a slight reddish tint, while the anchovy powder from foam mat drying exhibited a gray colour with a subtle yellowish hue.

Table 1 Physical characterization

		Sampel	**N**	**Mean ± SD**	**P value**
	L	O	3	$62.273^{e} \pm 0.057$	0.000
Colour testing		K	3	$68.773^{d} \pm 0.135$	
		F1	3	$70.587^{a} \pm 0.097$	
		F2	3	$70.240^{b} \pm 0.078$	
		F3	3	$69.703^{c} \pm 0.085$	
	a	O	3	$1.115^{b} \pm 0.021$	0.000
		K	3	$0.127^{a} \pm 0.012$	
		F1	3	$-0.093^{d} \pm 0.006$	
		F2	3	$-0.050^{d} \pm 0.040$	
		F3	3	$0.033^{c} \pm 0.015$	
	B	O	3	7.135 ± 0.007	0.083
		K	3	6.627 ± 0.047	

	F1	3	7.433 ±0.059	
	F2	3	7.357 ± 0.907	
	F3	3	7.740 ±0.053	
Bulk Density (g/mL)	O	2	4.20^{a} ±0.12	0.000
	K	3	0.70^{b} ±0.05	
	F1	3	0.70^{b} ±0.05	
	F2	3	0.62^{b} ±0.00	
	F3	3	0.60^{b} ±0.01	

Means with different lowercase letters vertically differ significantly ($p < 0.05$). The abbreviations correspond to: O: anchovy powder from oven drying. K, F1, F2, F3: Anchovy powder from foam mat drying with a ratio of egg albumin and maltodextrin as follow: 0%: 20% (K); 10% : 10% (F1); 15% : 5% (F2) and 20% : 0% (F3).

The total energy of anchovy powder from oven drying was not significantly different from F3 (0% foaming agent, 20% maltodextrin), but it differed significantly from K, F1, and F2, with F1 having the highest total energy. The energy derived from fat in anchovy powder from oven drying was significantly greater than that in anchovy powder from foam mat drying ($p < 0.05$). The ash content in anchovy powder from oven drying was also significantly higher than in anchovy powder from foam mat drying ($p < 0.05$).

The moisture content in anchovy powder from oven drying was significantly lower than in anchovy powder from foam mat drying, including K, F1, F2, and F3 ($p < 0.05$), with F3 having the highest moisture content at 9.35%.

Table 2. Chemical characterization

Parameter		**N**	**Mean ± SD**	**P value**
Energy (kkal)	O	2	329.71^{b} ±0.02	0.000
	K	2	336.26^{a} ±0.89	
	F1	2	338.36^{a} ±0.81	
	F2	2	336.83^{a} ±0.17	
	F3	2	328.36^{b} ±1.16	
Energy from fat (kkal)	O	2	40.01^{a} ±0.57	0.000
	K	2	7.02^{c} ±0.13	
	F1	2	8.60^{b} ±0.19	
	F2	2	7.65^{b,c} ±0.25	
	F3	2	8.64^{b} ±0.25	
Ash (%)	O	2	14.59^{a} ±0.09	0.000
	K	2	7.88^{c,d} ±0.08	
	F1	2	7.44^{d} ±0.06	
	F2	2	8.10^{c} ±0.28	
	F3	2	9.77^{b} ±0.09	

Moisture (%)	O	2	8.55 ^{b}±0.01	0.000
	K	2	9.04 ^{a,b}±0.16	
	F1	2	9.17 ^{a,b}±0.11	
	F2	2	8.76 ^{a,b}±0.28	
	F3	2	9.35 ^{a} ±0.16	
Carbohydrate(%)	O	2	1.00 ^{e} ±0.01	0.000
	K	2	41.86 ^{a}±0.86	
	F1	2	25.04 ^{b}±0.27	
	F2	2	14.80 ^{c}±0.52	
	F3	2	2.89 ^{d}±0.06	
Fat (%)	O	2	4.45 ^{a}±0.06	0.000
	K	2	0.78 ^{c}±0.01	
	F1	2	0.96 ^{b}±0.02	
	F2	2	0.85 ^{b,c}±0.03	
	F3	2	0.96 ^{b} ±0.03	
Protein (%)	O	2	71.43 ^{b} ± 0.14	0.000
	K	2	40.45 ^{e} ±0.61	
	F1	2	57.40 ^{d} ±0.42	
	F2	2	67.50 ^{c} ±0.49	
	F3	2	77.04 ^{a} ±0.17	

Means with different lowercase letters vertically differ significantly ($p < 0.05$). The abbreviations correspond to: O: anchovy powder from oven drying. K, F1, F2, F3: Anchovy powder from foam mat drying with a ratio of egg albumin and maltodextrin as follow: 0%: 20% (K); 10% : 10% (F1); 15% : 5% (F2) and 20% : 0% (F3).

The collaboration of air bubbles forming foam is important and affects the drying speed. The drying rate of the foam-mat drying process is relatively high due to the large surface area exposed to the drying air, ensuring fast moisture removal. Foam stability during drying is critical ; if the foam collapses, it can lead to the breakage of cells and cause significant damage to the drying process. Foams become stable when there is high viscosity and low surface tension at the air/aqueous interface. However, many factors can influence foam characteristics and properties, such as food composition, type and concentration of the foaming agent, and mixing time [16].

The carbohydrate content of anchovy powder from oven drying was significantly lower than that of anchovy powder from foam mat drying, including K, F1, F2, and F3, with K having the highest carbohydrate content at 41.86%. This difference may be attributed to the addition of maltodextrin, which affects carbohydrate levels.

The fat content of anchovy powder from oven drying was significantly higher than that of the foam mat drying powder, including K, F1, F2, and F3. The decrease in fat content might occur during the blanching treatment before making the fish into porridge. The boiling process can reduce the fat content of the ingredients.

The protein content of F3 was significantly higher than in other formulas, namely O, K, F1, and F2. This might be because F3 contains the highest concentration of egg albumin compared to other formulas. Additionally, foam mat drying was shown to better maintain protein levels during the drying process compared to conventional oven drying.

The addition of egg albumin to the foam mat drying method functions to increase surface area, reduce surface tension, create voids, accelerate water evaporation, and maintain the quality of ingredients such as colour, taste, and nutrients [7]. Meanwhile, fillers, also known as bulking agents, are ingredients added to increase the volume and mass of the powdered product. Fillers also serve to coat flavor components, expedite the drying process, and prevent material damage due to heat [17]. The most commonly used filler is maltodextrin. According to Djaeni et al. (2016), maltodextrin is believed to maintain the bubbles formed by egg albumin, ensuring that the sample's surface remains in contact with heat until drying is complete [18].

Water absorption capacity (WAC) involved adding water or an aqueous solution to the material, followed by centrifugation and quantification of the water retained by the pelleted material in the centrifuge tube. WAC is economically significant for the food industry because moisture loss can negatively impact yield and product quality. High WAC values are important for maintaining product moisture content, improving product quality, and preserving desirable characteristics during shelf-life or when exposed to adverse conditions like high temperatures and freezing [18]. The WAC of anchovy powder from oven drying was 1.73 ± 0.39%, significantly lower than the WAC of anchovy powder from foam mat drying. Formulas with a high maltodextrin content exhibited high water absorption, with the order being K > F1 > F2 > F3. The addition of egg albumin in foam mat drying appeared to have décreuse the WAC. This was not in line with the findings of Haryanto's research, which reported that adding egg albumin would result in a final product that was highly porous, readily absorbed water, dissolved more quickly, and increased the WAC [7].

Table 3. Functional properties

Parameter	Kel	N	Mean	SD	P value
Water absorption capacity (%)	O	2	1.73^{b}	0.39	0.000
	K	3	36.58^{a}	4.56	
	F1	3	36.58^{a}	4.56	
	F2	3	31.25^{a}	0.96	
	F3	3	27.81^{a}	0.21	
Water solubility index (%)	O	2	$8,43^{d}$	0,11	0.000
	K	3	40.67^{a}	0.70	
	F1	3	40.67^{a}	0.70	
	F2	3	29.27^{b}	1.65	
	F3	3	20.73^{c}	2.85	

Means with different lowercase letters vertically differ significantly ($p < 0.05$). The abbreviations correspond to: O: anchovy powder from oven drying. K, F1, F2, F3: Anchovy powder from foam mat drying with a ratio of egg albumin and maltodextrin as follow: 0%: 20% (K); 10% : 10% (F1); 15% : 5% (F2) and 20% : 0% (F3).

The water solubility index of anchovy powder from oven drying was 8.43 ± 0.11%, significantly lower than the solubility index of anchovy powder from foam mat drying. Formulas with high maltodextrin content exhibited greater water solubility, with the order being K > F1 > F2 > F3. Foam mat drying demonstrated the ability to enhance the dispersion of anchovy powder in water, thereby increasing its solubility.

The addition of egg albumin also appeared to have decreased the solubility index of anchovy powder. This was suspected to be because egg albumin protein contains insoluble components that form a precipitate or residue, resulting from the denaturation of a significant amount of egg protein during the drying process. Apart from the added ingredients, the decreasing in the solubility of anchovy powder might be due to the equipment used and suboptimal drying conditions (temperature and time), thus reducing solubility.

4 Conclusion

The primary focus in food dehydration is to achieve high-quality food ingredients. These ingredients must retain their desired nutritional, physical, and chemical attributes while minimizing nutrient loss during the process.

Oven drying have resulted anchovy powder with higher chemical composition such as protein, fat, and ash content, as well as lower moisture content compared to the foam mat drying method. However, foam mat drying had been shown to better preserve protein levels during the drying process compared to conventional oven drying. Additionally, the addition of maltodextrin affected carbohydrate levels. Foam drying techniques had the potential to enhance food preservation quality.

On the other hand, the physical properties of anchovy flour produced through oven drying had a higher bulk density compared to those produced through foam mat drying. Maintaining an appropriate bulk density was crucial for instant products to ensure consumer satisfaction and adequate nutritional intake.

The addition of egg albumin in foam mat drying appeared to decrease the water absorption capacity (WAC), contrary to previous findings suggesting that it would result in a more porous product with increased WAC. The decreasing in the solubility of anchovy powder was believed to be due to the equipment used and suboptimal drying conditions (temperature and time), thus reducing solubility.

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