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CHARACTERISTICS OF FISH PELLETS BASED ON ORGANIC WASTE WITH ANALYSIS OF PHYSICAL AND MECHANICAL PROPERTIES

Karakteristik Pelet Ikan Berbasis Limbah Organik dengan Analisis Sifat Fisik dan Mekanik

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ABSTRACT

Malang City, as one of the educational centers in East Java, faces challenges in managing organic waste, including within school environments. SMPN 15 Malang produces daily organic waste from its canteen and student activities, such as food scraps, fruit peels, and vegetables, which have not been optimally utilized. Previous studies have shown that organic waste has the potential to be used as an alternative raw material for fish feed, such as pellets derived from biogas sludge. This study aims to engineer school-based organic waste into fish pellets and to analyze their physical, mechanical, and nutritional properties. The materials were tested through a series of analyses including dimensions, expansion ratio, density (true density and single pellet density), porosity, color, Water Absorption Index (WAI), Water Solubility Index (WSI), water stability, and angle of repose. The organic waste was fermented and formulated together with protein-rich ingredients, then processed into pellets in accordance with SNI 9043-4:2025.

Keywords: Fish Pellets, Mechanical Properties, Physical, School Organic Waste

ABSTRAK

Kota Malang sebagai salah satu pusat pendidikan di Jawa Timur menghadapi tantangan dalam pengelolaan limbah organik, termasuk di lingkungan sekolah. SMPN 15 Kota Malang menghasilkan limbah organik harian dari kantin dan aktivitas siswa berupa sisa makanan, kulit buah, serta sayuran yang belum dimanfaatkan secara optimal. Padahal, berbagai penelitian terdahulu menunjukkan bahwa limbah organik berpotensi menjadi bahan baku alternatif pakan ikan, seperti pelet berbasis sludge biogas. Penelitian ini bertujuan merekayasa pelet ikan berbasis limbah organik sekolah dan menganalisis sifat fisik, mekanik, serta komposisi nutrisinya. Bahan diuji melalui rangkaian analisis meliputi dimensi, tingkat ekspansi, densitas (*true density dan single pellet density*), porositas, warna, *Water Absorption Index* (WAI), Water *Solubility Index* (WSI), stabilitas air, serta sudut tumpah (*angle of repose*). Limbah organik difermentasi dan diformulasi bersama bahan kaya protein, kemudian diproses menjadi pelet sesuai SNI 9043-4:2025.

Kata Kunci: Fisik, Karakteristik, Limbah, Mekanik, Pelet Ikan

INTRODUCTION

Malang City, as one of the educational centers in East Java, faces challenges in managing organic waste, particularly within the school environment. SMPN 15 Malang City, which actively engages in project-based learning activities, generates daily organic waste from the cafeteria, food scraps, and student activities. This waste, such as fruit and vegetable peels, and leftovers, has not been optimally utilized, despite its potential as an alternative raw material for valuable products like fish feed.

Previous research has shown that organic waste can be utilized as a raw material for fish pellets. For example, pellets based on cow biogas sludge have a protein content of up to 20% and a buoyancy of 11 hours (Rohman et al., 2021), while fermented pellets from fish offal have a crude protein content of 32.48% (Sari et al., 2022). Furthermore, market waste fermented with probiotics such as Lactobacillus can increase nutritional value and reduce odor (Hidayat, 2023).

The potential of school organic waste as a raw material for pellets has not been systematically utilized, even though it can support the principles of a circular economy and environmental education. This research aims to address this research gap by engineering fish pellets based on school organic waste and analyzing their physical and mechanical characteristics and nutritional composition. This approach is expected to create innovative, affordable, nutritious, and environmentally friendly feed, while also supporting character education and student empowerment in applied science-based innovation.

METHODS

Research Time and Location

The research was conducted from August to December 2025. The research was located at the Quality Analysis Laboratory of the Agricultural Industrial Technology Study Program, Trunojoyo Madura University.

Tools and Materials

The tools used in this study are: analytical scales (NBK-FA300, NanBei, China), porcelain cup, 50 ml pycnometer, measuring cup, oven (Binder Ed-56), color reader, vernier caliper, Kjeldahl tube, desiccator, ruler, and funnel. The materials used in this study are: fish pellets produced independently from organic waste with the help of enzyme technology, filter paper, filter cloth, and distilled water.

Data Analysis Methods

The methods used include physical and mechanical analysis. Physical analysis uses dimension, expansion rate, color, porosity, and water stability testing methods. Mechanical testing uses true density, single density, and angle or repose analysis methods.

RESULTS

Table 1. Dimensional Analysis

Sample	L	W	Dp	r	Sphericity (%)	Surface Area	Volume
F1	21.24	14.93	16.25	7.46	3565.51	180.36	133,47
F2	13.91	37.56	21.49	18.78	32272.32	205.35	87,37
F3	18.84	15.56	14.16	7.78	3850.23	167.28	118,39
Average	**18.00**	**22.68**	**17.30**	**11.34**	**13229.35**	**184.330331**	**113,0764**

Table 2. Expansion Rate Analysis

Sample	ER (%)			Average
	$ER_{(1)}$	$ER_{(2)}$	$ER_{(3)}$	
Pellet F1	530.67%	802.96%	770.33%	607.56%
Pellet F2	594.33%	806.67%	687.33%	801.21%
Pellet F3	697.67%	794.00%	813.67%	757.11%

Table 3. Porosity Analysis

Sample	ε Internal (%)
Pellet 1	-164400%
Pellet 2	-14300%
Pellet 3	-750%
Average	**-59816.7%**

Table 4. Color Analysis

Sample	L	a^+	b^+	Chroma	Hue
Pellet F1	21.7	4.6	26.7	27.0	80.22
Pellet F2	18.4	4.7	25.1	25.5	79.39
Pellet F3	20.1	4.6	26.3	26.6	80.0
Average	**20**	**4.6**	**30.3**	**26.36**	**79.87**

Table 5. Water Stability Analysis

Sample	M final pellet (g)	M initial pellet (g)	Water Stability (%)
Pellet 1	4.48	1	149.27
Pellet 2	2.64	1	88.00
Pellet 3	3.93	1	392.67

Table 6. True Density Analysis

Sample	M pikno	M sample	M pikno + liquid	M pikno + sample + liquid	M full liquid	M after the sample was inserted	P liquid	V pikno	V was replaced	True density
F1	36.59	5.00	80.82	83.71	44.23	42.12	42.12	44.23	2.11	16.45
F2	36.59	5.00	80.40	83.55	43.81	41.96	41.96	43.81	1.85	2.88
F3	36.59	5.00	80.60	82.94	44.01	41.35	41.35	44.01	2.66	2.55
Average										**7.29**

Table 7. Single Pellet Density Analysis

Sample	M	D	L	V	Density
Pellet F1	0.68	2.49	10.52	51.09	0.01
Pellet F2	1.20	2.50	9.72	48.94	0.02
Pellet F3	2.18	2.62	10.38	36.19	0.30
Average					**0.11**
STDEV					**0.16**

Table 8. Angle of Repose Analysis

Sample	L	D	Average φ
F1	8.6	30.2	29.11
F2	8.8	32.4	30.22
F3	9.2	30.3	29.46

DISCUSSION

The results of the fish pellet dimension measurements showed an average length of 18.00 mm, a width of 22.68 mm, an average diameter (Dp) of 17.30 mm, and a radius of 11.34 mm, and the sphericity value obtained was very high (13,229.35%), this value indicates too large a variation in shape, theoretically sphericity only ranges from 0–100%. The average surface area was recorded at 184.33 mm² and a volume of 113.08 mm³. When compared with SNI 9043-4:2025 concerning artificial feed for catfish, the standard stipulates that the pellet size must be adjusted to the fish's growth phase, for fry it is usually 2–4 mm, for juvenile fish 4–6 mm, and for consumption fish 8–12 mm. Thus, the average diameter of the resulting pellets (17.30 mm) does not comply with the standard, because it is too large for the needs of catfish at all phases.

The data shows that the Expansion Ratio (ER) values for F1, F2, and F3 pellets are in a very high range, ranging from 530.67% to 813.67%. F1 pellets had an average ER of 607.56%, with wide variations between replicates, indicating expansion instability. F2 pellets showed the highest average of 801.21%, with a relatively consistent value, while F3 pellets had an average of 757.11%, with a range close to that of F2 pellets. When compared to the fish feed quality standards stipulated in SNI 9043-4:2025, which requires an ER value of 100–120% to ensure pellets remain stable in water and resist disintegration, these test results are clearly inconsistent.

The results of the internal ε (%) measurements on three pellet samples showed very negative values, namely Pellet 1 at -164.400%, Pellet 2 at -14.300%, and Pellet 3 at -750%, with an average of -59.816.7%. This negative value indicates a discrepancy between the actual density and the theoretical density used in the calculation, thus resulting in an indication that the internal structure of the pellets does not meet the porosity uniformity standard. When compared with SNI 9043-4:2025 concerning artificial feed for catfish, the standard emphasizes that pellets must have good physical quality: uniform shape, density according to requirements (floating or sinking), and not easily broken. Very extreme and negative internal ε values are clearly not in accordance with the standard, because they indicate that the pellets are too fragile or the density calculation is not proportional. To comply with SNI, the internal ε value should be in the moderate positive range (around 20–60%) for floating pellets and lower (10–30%) for sinking pellets, so that the pellets have sufficient porosity to support function while remaining mechanically stable.

Color test results on fish pellets showed variations in L, a+, b+, Chroma, and Hue values, reflecting the visual characteristics of each formulation. Formula F1 had an average L value of 21.7, indicating a relatively higher brightness level compared to F2 and F3, with an a+ value of 4.6 and a b+ of 26.7, resulting in a Chroma of 27.0 and a Hue of 80.22. Formula F2 had a lower L value of 18.4, indicating a darker color, with a+ of 4.7 and b+ of 25.1, resulting in a Chroma of 25.5 and a Hue of 79.39, making it appear less bright than F1. Formula F3 is in the middle with L 20.1, a+ 4.6, and b+ 26.3 which produces Chroma 26.6 and Hue 80.0, indicating a fairly bright color and close to F1. Overall, the Chroma value in the three formulations is in the range of 25–27 which indicates a fairly strong color intensity, while the Hue value is around 79–80 indicating a color tendency towards greenish yellow. Thus, F1 pellets have the brightest and most stable color, F2 tends to be darker, while F3 is in between the two with quite good color intensity.

The water stability test results showed significant variation between samples. Pellet F1 had a stability of 149.27%, F2 88.00%, and F3 392.67%, with relatively high averages. These values indicate that the pellets experienced mass changes after soaking, which in some cases resulted in values above 100% due to water absorption or expansion of the pellet structure.

The true density measurement data showed that pellet F1 had a value of 16.45 g/cm³, F2 2.88 g/cm³, and F3 2.55 g/cm³, with an average of 7.29 g/cm³. These values indicate discrepancies between samples, as the results ranged very widely (2.55–16.45 g/cm³). Compared to SNI 9043-4:2025, floating pellets typically have a density lower than water (<1g/cm³), while sinking pellets have a density slightly higher than water (around 1–1.2 g/cm³). The measurement results in the table clearly do not meet the standard, as all values are well above the expected range. The average value of 7.29 g/cm³ indicates that the pellets are too dense, making them unlikely to float and potentially impacting digestibility and water quality.

The results of the single pellet density analysis showed that the density of the fish pellets tested was very low and varied between samples. Pellet F1 had a density of 0.01 g/cm³, F2 0.02 g/cm³, and F3 0.30 g/cm³, with an average of 0.11 g/cm³ and a standard deviation of 0.16. This value is far below the density of water (1 g/cm³), so the pellets tend to be too light, highly porous, and potentially brittle. Compared to SNI 9043-4:2025 concerning artificial feed for catfish, the physical quality standard for feed emphasizes that pellets must have a density appropriate to the fish's needs, namely around 0.9–0.95 g/cm³ for floating pellets and 1.0–1.2 g/cm³ for sinking pellets. To comply with SNI, the raw material formulation and extrusion process need to be adjusted to produce pellets with a more uniform density, closer to the 0.9–1.2 g/cm³ range, suitable for the intended use.

The Angle of Repose (φ) measurements in Table 4.2.3 show that fish pellets have an average stacking angle between 29.11° and 30.22°. This value is relatively consistent between samples (F1: 29.11°, F2: 30.22°, F3: 29.46°), so it can be concluded that the flow properties of the pellets are quite good and do not show significant differences between formulations. Compared with SNI 9043-4:2025, the physical quality standard for feed emphasizes that pellets must have good flowability and distribution to facilitate the process of handling, packaging, and feeding in the pond. stack angle good flowability), while >45° indicates poor flowability. Thus, the measurement results in the table are in accordance with the expected physical quality criteria, because all samples are below 40°.

CONCLUSION

Test results showed that most pellet parameters did not meet SNI standards, particularly size, expansion, density, and porosity. The tested formula produced pellets with an overly expanded structure and less stability in water. Color and angle of repose values were quite good, but they did not adequately compensate for deficiencies in other physical properties. Overall, the pellets still require comprehensive improvement. The product is not yet suitable for use as fish feed according to standards.

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