

Study of physic-organoleptical characteristics of functional pellets based on fermented tofu and cassava dregs with different types and binder levels

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ABSTRACT

Feed plays an important role in livestock productivity. Local raw materials such as tofu pulp and cassava pulp have potential as poultry feed, but must first be processed to increase their nutritional value. Fermentation with fermented vegetable extract (FVE) 2019 can improve feed quality by increasing protein and reducing crude fiber. Feed efficiency can be improved through pelletization, as it reduces scattered particles. The addition of binders such as cassava flour, corn flour, or molasses in pellets plays a role in improving stability and feed distribution efficiency. Fermentation and pelletization methods are highly effective in preparing poultry feed based on local materials. This study aimed to investigate the effect of functional feed pellet production based on fermented tofu and cassava pulp with various binders and concentration levels on its physical-organoleptic characteristics. This study uses a completely randomized design (CRD) with a 3×3 factorial pattern and 5 replications. The first factor was the type of binder, namely B0 (molasses), B1 (corn flour), and B2 (tapioca flour). The second factor was the binder concentration, namely A0 (0%), A1 (2.5%), and A2 (5%). The parameters observed in this study were physical quality (hardness, PDI, and moisture content) and organoleptic quality (color, odor, and texture). The results of this study indicate that pellets supplemented with 5% molasses binder can maintain organoleptic characteristics, as seen in the interaction of pellet color parameters. Long-term storage of pellets can reduce their physical and organoleptic quality.

Introduction

Feed is an aspect that plays a crucial role in livestock production systems, as it serves as a source of energy and provides essential nutrients necessary for the growth and well-being of livestock. One of the challenges facing the livestock industry in optimizing productivity is ensuring the availability of high-quality feed at an economical price (Amole *et al.*, 2022). Feed costs that can reach for over 70% of the total expenses in livestock production (Sugiarti *et al.*, 2024), making the efficient formulation and utilization of feed ingredients vital. Inadequate nutritional needs of livestock can decline their performance (Salim and Hariyono, 2025), impacting growth rates, feed efficiency, and the overall quality of livestock products.

One effective strategy to reduce costs while increasing self-sufficient in feed production is to utilize local feed ingredients. These local materials can include by-products or waste from the agro-industrial sector (Quintero-Herrera *et al.*, 2023). Examples of alternative feed raw materials include cassava pulp which is by-product from tapioca processing (Wulan *et al.*, 2024; Widiastuti *et al.*, 2021) and tofu dregs (Kusumaningtyas *et al.*, 2020). These ingredients are generally available in large quantities at a lower price, but they have limitations in terms of nutritional content and digestibility. Factors that limit its use if used directly in ration formulation are high crude fiber content (Kusumaningtyas *et al.*, 2020), low protein levels, and the presence of antinutrient compounds (Raji *et al.*, 2021).

Efforts that can be made to increase the nutritional value and utility of local feed ingredients are processed by the fermentation method. Fermentation is the process of bioconversion of substrates by microorganisms, especially lactic acid bacteria (LAB). LAB can increase nutrient content and produce bioactive compounds such as enzymes, vitamins, linoleic acid, exopolysaccharides, and gamma-aminobutyric acid that have functional properties (Kondrotiene *et al.*, 2023). The use of LAB as an inoculum in feed is also able to reduce crude fiber (Wu *et al.*, 2025).

One of the innovations in terms of fermentation of feed ingredients is the use of fermented vegetable extracts (FVE) as a microbial starter. FVE is rich in lactic acid bacteria such as and allisin which is a natural compound from garlic (Sulistiyanto *et al.*, 2019). Alisine is an active compound of the organosulfur group which is antibacterial (Bhatwalkar *et al.*, 2021). The use of this FVE-based starter not only improves the quality of nutrients, but also provides probiotic effects that support digestive tract health and feed absorption, as well as improve the immune system of livestock (Liu *et al.*, 2023)

Tofu pulp is known to contain high amounts of soybean oligosaccharides (SOS) and crude fiber, while Cassava dregs contains more than 50% starch which makes it a potential substrate source for microbial growth (Srinurfitri *et al.*, 2022). Fermentation is able to increase crude protein levels and change the structure of crude fibers, thus having an impact on improving the quality of rations (Wang *et al.*, 2025). Efforts need to be made to support the efficiency of storage, handling, and distribution of fermented feed materials, namely being processed into pellet form. Pelleting or making feed into a compact form (granule) is known to reduce the spread of feed particles, the nutrients are more concentrated, and increase the palatability and physical stability of the feed (Yermukanova *et al.*, 2024). Incorporating of binders or binding agents, such as tapioca flour, cornstarch, and molasses, is essential for enhancing the adhesion between particles. This process results in pellets that possess good density and physical durability (Binti Ismail *et al.*, 2021). The variation in the types and levels of binders added to the pellet dough can yield different outcomes, highlighting the need for further research to explore the relationship between these two factors. Additionally, integrating fermentation with pelleting in the processing of local feed ingredients not only improves the nutritional quality and digestibility but also enhances the physical characteristics of the feed.

This study aimed to examine the effects of creating functional feed pellets made from tofu pulp and fermented cassava dregs, using various

binders and levels, on their physical and organoleptic characteristics. The goal was to provide insights into how these factors influence the quality of the feed pellets.

Materials and methods

Research materials

The materials used in the process include tofu dregs, Cassava dregs, FVE-2019, corn, soybean meal, a mineral mix, DL-methionine, tapioca flour, cornstarch, molasses, and water. The tools utilized are mixers, silo barrels, analytical scales, digital scales, measuring cups, pellets, and various physical quality testing instruments, such as pellet hardness testers, PDI testers, and grain moisture meters.

Method

Experimental design

The research was carried out experimentally using a Complete Random Design (CRD) factorial pattern of 3 x 3 treatments, and 5 replications. The first factor is the type of binder, namely B0 (molasses), B1 (cornstarch) and B2 (tapioca flour). The second factor is the level or level of the binder, namely A0 (0%), A1 (2.5%) and A2 (5%). The combination of each treatment is as follows:

- B0A0 = Pellets with 0% molasses binder
- B0A1 = Pellets with 2.5% molasses binder
- B0A2 = Pellets with 5% molasses binder
- B1A0 = Pellets with 0% cornstarch binder
- B1A1 = Pellets with 2.5% cornstarch binder
- B1A2 = Pellets with 5% cornstarch binder
- B2A0 = Pellets with 0% tapioca flour binder
- B2A1 = Pellets with 2.5% tapioca flour binder
- B2A2 = Pellets with 5% tapioca flour binder

Research procedure

The stage of making functional feed pellets begins with the preparation of the formulation. The composition of the treatment feed is presented in Table 1. Fermented ingredients such as Cassava dregs and tofu pulp are fermented first with the reference of previous research, namely by adding 2-6% of the starter weight of the feed material (Mulyasari *et al.*, 2022). The starter used in this study is FVE-2019. The feed material is fermented for 5 days anaerobically.

The next step involves pureeing the remaining feed ingredients and mixing them with Cassava dregs and fermented tofu pulp until the mixture reaches a uniform consistency. The mixture of materials is added with

a binder according to the treatment formulas, as stated in Table 1. The combined materials are placed into a pellet molding machine and stored in containers. After gathering the pellets, they are dehydrated until they achieve a moisture content of 11-12%. The dehydrated pellets are then stored and regularly checked for any variations over time. The parameters to monitor include both the physical traits and sensory characteristics.

Physical testing is essential for evaluating the properties of pellets, specifically assessing their hardness, durability, and moisture content. Conversely, organoleptic testing is crucial for a thorough evaluation, as it directly involves the five senses to analyze attributes such as color, odor, texture, and appearance. The scoring standards and organoleptic descriptions refer to Utama *et al.* (2020), and have been adapted to:

Index of colour, Dark brown= 4; light brown= 3; light light brown= 2; pale brownish yellow= 1.

Index of Odor, smell like mixed ingredients (corn/meal/fresh acid)= 5; Odorless= 3; Musty smell = 1; Foul odor = 0.

Index of texture, Fine (no cracks, flat surface)= 5; Relatively smooth (no cracks, uneven surface)= 4; Slightly rough (there are small cracks)= 2; Coarse/ curly= 1.

Index of the general appearance, very interesting= 5; Attractive= 4; Unattractive= 2; Very unattractive= 1.

Index of likes, very likes= 5; Likes= 4; Dislikes= 2; Strongly dislike= 1

Data analysis

Data analysis is carried out using a descriptive method. The data of the research results are compiled in the form of a table and then interpreted according to the results of existing observations. Pellet durability and hardness data were analyzed using a variety of analyses with a significance level of 5% to determine the effect of treatment. If there is an effect of treatment, a further test is carried out, namely the Duncan Double Area Test to find out the difference between treatments.

Results

This study observed the physical and organoleptic characteristics of functional feed pellets made from fermented tofu dregs and cassava residue, with variations in binder types and levels during storage periods of 0, 4, 8, and 12 weeks. The research results are presented in Table 2, 3, 4, and 5. The results showed that there was a significant interaction ($P < 0.05$) between the types and levels of binder on horizontal hardness and moisture content parameters during the storage period (0, 4, 8, and 12 weeks). There was a significant interaction ($P < 0.05$) between the types and levels of binder on the PDI parameter at week 0 and week 12. The findings indicate a significant interaction between the types and levels of binder used on the parameters of color, odor, and texture throughout the entire storage period (0, 4, 8, and 12 weeks).

Table 1. Formula of pellet feed with fermented tofu and cassava dregs, with different types and levels of binders.

Material	Molasses			Cornstarch			Tapioca flour		
	M0	M1	M2	TM0	TM1	TM2	TT0	TT1	TT2
Yellow corn *	31.25	28.13	27.27	31.25	28.13	27.27	31.25	28.13	27.27
Soybean meal*	25	25	24.24	25	25	24.24	25	25	24.24
Fermented tofu pulp	18.75	18.75	18.18	18.75	18.75	18.18	18.75	18.75	18.18
Fermented Cassava dregs	18.75	18.75	18.18	18.75	18.75	18.18	18.75	18.75	18.18
Mineral mixed*	6.13	6.13	5.94	6.13	6.13	5.94	6.13	6.13	5.94
DL-Methionine	0.13	0.13	0.12	0.13	0.13	0.12	0.13	0.13	0.12
Molasses	0	3.13	6.06	0	0	0	0	0	0
Cornstarch	0	0	0	0	3.13	6.06	0	0	0
Tapioca Flour	0	0	0	0	0	0	0	3.13	6.06
Sum	100	100	100	100	100	100	100	100	100

Table 2. Physical quality – organoleptic functional feed pellets based on tofu pulp and fermented cassava dregs stored for 0 days.

Parameters	BINDER (B)	Binder Layer (A)			Average (B)
		A0	A1	A2	
Durability (%)	B0	98.8 ^{ab} ±0.84	97.2 ^a ±1.30	97.6 ^{bc} ±1.14	97.87±1.25
	B1	99.00 ^a ±0.71	99.40 ^a ±0.55	97.20 ^c ±1.1	98.53±1.25
	B2	98.60 ^{abc} ±0.55	97.40 ^c ±1.14	98.60 ^{abc} ±1.14	98.20±1.08
	Average (A)	98.8 ^a ±0.68	98.00 ^b ±1.41	97.80 ^b ±1.21	
Pellet Hardness Horizontal (kg)	B0	8.1 ^c ±0.68	12.4 ^b ±1.21	14.55 ^a ±0.76	11.68±2.90
	B1	9.55 ^d ±0.74	9.25 ^d ±0.64	10.85 ^c ±0.49	9.88 ^b ±0.93
	B2	10.00 ^{cd} ±0.79	9.60 ^d ±0.58	10.75 ^c ±0.90	10.12 ^b ±0.87
	Average (A)	9.22 ^c ±1.08	10.42 ^b ±1.66	12.05 ^a ±1.95	
Vertical Pellet Hardness (kg)	B0	3.65 ^c ±0.45	6.5 ^a ±0.18	7.35 ^a ±1.69	5.83 ^b ±1.89
	B1	6.90 ^a ±0.14	7.40 ^a ±1.01	6.65 ^a ±0.58	6.98 ^a ±0.70
	B2	4.70 ^{bc} ±0.97	4.30 ^{bc} ±0.48	5.10 ^b ±1.56	4.70 ^c ±1.07
	Average (A)	5.08 ^b ±1.52	6.07 ^a ±1.47	6.37 ^a ±1.6	
Moisture Content (%)	B0	11.16 ^{ab} ±1.35	9.62 ^d ±0.11	10.32 ^{bcd} ±0.34	10.37 ^b ±0.99
	B1	11.72 ^a ±1.06	11.00 ^{abc} ±0.71	12.04 ^a ±1.05	11.59 ^a ±0.99
	B2	11.84 ^a ±0.93	11.78 ^a ±0.27	10.04 ^{cd} ±0.58	11.22 ^a ±0.93
	Average (A)	11.57 ^a ±0.97	10.80 ^b ±1.01	10.80 ^b ±1.13	
Color	B0	2.11 ^c ±0.16	3.81 ^a ±0.14	3.96 ^a ±0.06	3.29 ^a ±0.88
	B1	2.31 ^{bc} ±0.16	2.37 ^{bc} ±0.22	2.20 ^{bc} ±0.21	2.29 ^b ±0.2
	B2	2.35 ^{bc} ±0.24	2.31 ^{bc} ±0.21	2.40 ^b ±0.20	2.35 ^b ±0.21
	Average (A)	2.25 ^b ±0.21	2.83 ^a ±0.74	2.85 ^a ±0.83	
Smell	B0	4.73 ^a ±0.00	4.27 ^{bc} ±0.23	4.27 ^{bc} ±0.52	4.42±0.38
	B1	4.76 ^a ±0.24	4.15 ^c ±0.12	4.36 ^{abc} ±0.48	4.42±0.39
	B2	4.63 ^{ab} ±0.37	4.57 ^{abc} ±0.22	3.40 ^d ±0.25	4.20±0.64
	Average (A)	4.71 ^a ±0.24	4.33 ^a ±0.26	4.01 ^c ±0.60	
Texture	B0	4.15 ^b ±0.19	3.03 ^d ±0.28	3.44 ^c ±0.39	3.54±0.55
	B1	4.45 ^{ab} ±0.19	2.80 ^d ±0.29	3.56 ^c ±0.17	3.60±0.73
	B2	4.59 ^a ±0.19	3.63 ^a ±0.53	2.92 ^d ±0.24	3.71±0.78
	Average (A)	4.40 ^a ±0.26	3.15 ^b ±0.51	3.31 ^b ±0.39	
Appearance	B0	3.81 ^a ±0.21	3.19 ^{bc} ±0.13	2.89 ^d ±0.25	3.30 ^{ab} ±0.25
	B1	3.77 ^a ±0.15	2.61 ^c ±0.21	3.12 ^{bcd} ±0.16	3.17 ^b ±0.52
	B2	3.91 ^a ±0.22	3.39 ^b ±0.15	3.00 ^{cd} ±0.26	3.43 ^a ±0.43
	Average (A)	3.83 ^a ±0.19	3.06 ^b ±0.37	3.00 ^b ±0.23	
Favorite	B0	3.80 ^a ±0.2	3.24 ^b ±0.18	2.95 ^{bcd} ±0.20	3.33±0.40
	B1	3.79 ^a ±0.13	2.61 ^d ±0.32	3.13 ^{bc} ±0.13	3.18±0.53
	B2	3.89 ^a ±0.38	3.27 ^b ±0.32	2.88 ^{cd} ±0.30	3.35±0.53
	Average (A)	3.83 ^a ±0.24	3.04 ^b ±0.40	2.99 ^b ±0.23	

Different superscripts in the interaction rows and columns show a noticeable difference (P<0.05). B0A0 = Pellets with 0% molasses binder. B0A1 = Pellets with 2.5% molasses binder; B0A2 = Pellets with 5% molasses binder; B1A0 = Pellets with 0% cornstarch binder; B1A1 = Pellets with 2.5% cornstarch binder; B1A2 = Pellets with 5% cornstarch binder; B2A0 = Pellets with 0% tapioca flour binder; B2A1 = Pellets with 2.5% tapioca flour binder; B2A2 = Pellets with 5% tapioca flour binder.

Discussion

The presence of interactions and significant differences in the data of horizontal hardness and moisture indicate that the selection of binder type and level simultaneously greatly affects that parameters content of functional feed pellets. The highest value of horizontal hardness is, 14.55 kg (B0A2, 0th week); 11.90 kg (B1A2) and 11.55 kg (B0A1) in week 4; 10.55 kg (B0A1, 8th Week); and 13.30 kg (B2A2, Week 12). Based on this data, it can be seen that the highest pellet hardness level is in the range of 10.55 kg to 14.55 kg. This value is higher than the results of the study which

Table 3. Physical quality – organoleptic functional feed pellets based on tofu pulp and fermented cassava dregs stored at a storage time of 4 weeks.

Parameters	BINDER (B)	Binder Layer (A)			Average (B)
		A0	A1	A2	
Durability (%)	B0	98.60±0.55	98.60±1.14	96.80±1.79	98.00 ^{ab} ±1.46
	B1	98.60±1.14	97.60±1.14	96.80±1.10	97.67 ^b ±1.29
	B2	98.60±1.52	98.60±0.55	99.00±1.00	98.73 ^a ±1.03
	Average (A)	98.60±1.06	98.27 ^{ab} ±1.03	97.53 ^b ±1.64	
Pellet Hardness Horizontal (kg)	B0	9.20 ^c ±0.97	11.55 ^a ±1.15	10.90 ^{ab} ±0.55	10.55 ^a ±1.34
	B1	9.75 ^{bc} ±0.59	10.15 ^{bc} ±1.21	11.90 ^a ±0.89	10.60 ^a ±1.29
	B2	9.15 ^c ±1.05	9.05 ^c ±0.97	10.25 ^{bc} ±0.43	9.48 ^b ±0.98
	Average (A)	9.37 ^c ±0.88	10.25 ^b ±1.48	11.02 ^a ±0.93	
Vertical Pellet Hardness (kg)	B0	4.90 ^{bc} ±1.04	5.10 ^{bc} ±1.02	6.40 ^a ±0.49	5.47±1.07
	B1	4.70 ^{bc} ±0.69	4.55 ^c ±0.76	5.75 ^{ab} ±0.40	5.00±0.81
	B2	5.15 ^{bc} ±0.34	4.80 ^{bc} ±0.87	4.55 ^c ±0.69	4.83±0.67
	Average (A)	4.92 ^b ±0.72	4.82 ^b ±0.86	5.57 ^a ±0.94	
Moisture Content (%)	B0	11.30 ^b ±0.19	8.04 ^f ±0.13	8.90 ^d ±0.31	9.41 ^c ±1.44
	B1	11.28 ^b ±0.35	11.72 ^a ±0.04	8.38 ^e ±0.19	10.46 ^a ±1.55
	B2	11.30 ^b ±0.23	10.42 ^c ±0.08	7.46 ^e ±0.33	9.73 ^b ±1.71
	Average (A)	11.29 ^a ±0.25	10.06 ^b ±1.58	8.25 ^c ±0.67	
Color	B0	2.16 ^c ±0.23	3.87 ^a ±0.08	3.96 ^a ±0.06	3.33 ^a ±0.87
	B1	2.29 ^{bc} ±0.22	2.29 ^{bc} ±0.16	1.95 ^d ±0.11	2.18 ^c ±0.23
	B2	2.31 ^{bc} ±0.09	2.21 ^c ±0.09	2.44 ^b ±0.17	2.32 ^b ±0.15
	Average (A)	2.25 ^b ±0.19	2.79 ^a ±0.80	2.78 ^a ±0.89	
Smell	B0	4.20 ^a ±0.38	3.48 ^b ±0.18	3.80 ^{ab} ±0.34	3.83 ^a ±0.42
	B1	4.15 ^a ±0.12	3.43 ^b ±0.49	3.68 ^b ±0.37	3.75 ^a ±0.45
	B2	4.15 ^a ±0.42	3.53 ^b ±0.23	2.60 ^c ±0.16	3.43 ^b ±0.71
	Average (A)	4.16 ^a ±0.31	3.48 ^b ±0.31	3.36 ^b ±0.63	
Texture	B0	4.28 ^a ±0.34	2.67 ^c ±0.27	2.83 ^{dc} ±0.20	3.26 ^b ±0.80
	B1	4.20 ^a ±0.27	3.08 ^d ±0.15	3.81 ^{bc} ±0.22	3.70 ^a ±0.52
	B2	4.15 ^{ab} ±0.22	3.58 ^c ±0.29	2.99 ^{dc} ±0.42	3.57 ^a ±0.57
	Average (A)	4.21 ^a ±0.27	3.11 ^b ±0.45	3.21 ^b ±0.52	
Appearance	B0	3.68 ^a ±0.07	2.92 ^b ±0.19	2.97 ^b ±0.15	3.19 ^a ±0.38
	B1	3.60 ^a ±0.08	2.59 ^c ±0.20	2.88 ^b ±0.11	3.02 ^b ±0.46
	B2	3.73 ^a ±0.10	2.91 ^b ±0.09	2.69 ^c ±0.20	3.11 ^{ab} ±0.48
	Average (A)	3.67 ^a ±0.10	2.81 ^b ±0.22	2.85 ^b ±0.19	
Favorite	B0	3.67 ^a ±0.16	2.97 ^b ±0.12	2.88 ^b ±0.16	3.17 ^a ±0.39
	B1	3.54 ^a ±0.12	2.59 ^d ±0.09	2.79 ^{bc} ±0.11	2.97 ^b ±0.44
	B2	3.67 ^a ±0.14	2.89 ^b ±0.11	2.64 ^{cd} ±0.20	3.07 ^b ±0.47
	Average (A)	3.63 ^a ±0.14	2.82 ^b ±0.20	2.77 ^b ±0.18	

Different superscripts in the interaction rows and columns show a noticeable difference (P<0.05). B0A0 = Pellets with 0% molasses binder. B0A1 = Pellets with 2.5% molasses binder; B0A2 = Pellets with 5% molasses binder; B1A0 = Pellets with 0% cornstarch binder; B1A1 = Pellets with 2.5% cornstarch binder; B1A2 = Pellets with 5% cornstarch binder; B2A0 = Pellets with 0% tapioca flour binder; B2A1 = Pellets with 2.5% tapioca flour binder; B2A2 = Pellets with 5% tapioca flour binder.

showed the hardness value of pellets for broiler poultry of 2.1 – 4.8 kg (Svihus *et al.*, 2024; Teixeira Netto *et al.*, 2019). It shows that the hardness value of poultry pellets is in the range of 4.42 – 7.53 kg. The hardness level of pellets can affect the level of livestock consumption. Feed that is too hard can affect the morphology of the digestive organs, such as making the gizzard muscles work harder and become thicker (Hafid *et al.*, 2022)

Pellet durability index (PDI) is one of the important aspects for determining the physical quality of pellets. In the PDI parameter, several interactions can be seen in week 0 and week 12. The PDI values from week 0 to week 12 range from 92.00% to 99.00%. These values are con-

Table 4. Physical quality – organoleptic functional feed pellets based on tofu pulp and fermented cassava dregs stored at 8 weeks storage time.

Parameters	BINDER (B)	Binder Layer (A)			Average (B)
		A0	A1	A2	
Durability (%)	B0	98.40±0.89	98.60±0.55	98.40±0.55	98.47±0.64
	B1	98.40±0.55	97.60±1.52	97.00±1.00	97.67±1.18
	B2	98.20±1.30	98.00±0.71	98.60±0.55	98.27±0.88
	Average (A)	98.33±0.90	98.07±1.03	98.00±1.00	
Pellet Hardness Horizontal (kg)	B0	8.10 ^{cd} ±0.80	10.55 ^{ab} ±0.82	9.80 ^{ab} ±0.21	9.48±1.23
	B1	9.30 ^{abc} ±0.33	9.90 ^{ab} ±0.96	7.45 ^d ±1.25	8.88±1.38
	B2	8.80 ^{bc} ±0.69	8.90 ^{bc} ±1.52	9.90 ^{ab} ±1.26	9.20±1.23
	Average (A)	8.73 ^b ±0.78	9.78 ^a ±1.27	9.05 ^b ±1.51	
Vertical Pellet Hardness (kg)	B0	4.70±0.60	6.00±1.24	4.95±0.67	5.22±1.00
	B1	4.60±0.72	5.45±0.82	5.65±0.72	5.23±0.84
	B2	4.80±0.69	5.40±0.55	5.80±1.05	5.33±0.85
	Average (A)	4.70 ^b ±0.63	5.62 ^a ±0.89	5.47 ^a ±0.86	
Moisture Content (%)	B0	11.78 ^{ab} ±0.13	9.56 ^d ±0.29	10.04 ^{cd} ±0.30	10.46 ^b ±1.01
	B1	12.08 ^a ±0.31	11.88 ^a ±0.13	10.62 ^b ±0.28	11.53 ^a ±0.71
	B2	11.96 ^a ±0.15	10.50 ^{bc} ±0.63	7.18 ^e ±0.70	9.88 ^c ±2.13
	Average (A)	11.94 ^a ±0.24	10.65 ^b ±1.06	9.28 ^c ±1.62	
Color	B0	2.34 ^{cd} ±0.17	3.77 ^b ±0.14	4.00 ^a ±0.00	3.37 ^{ab} ±0.77
	B1	2.31 ^{cd} ±0.19	2.11 ^c ±0.11	2.15 ^{de} ±0.21	2.19 ^b ±0.19
	B2	2.33 ^{cd} ±0.09	2.15 ^{de} ±0.19	2.40 ^c ±0.10	2.29 ^b ±0.17
	Average (A)	2.33 ^c ±0.15	2.68 ^b ±0.82	2.85 ^a ±0.86	
Smell	B0	4.31 ^{ab} ±0.17	3.85 ^{cd} ±0.15	4.08 ^{abc} ±0.23	4.08 ^a ±0.26
	B1	4.36 ^a ±0.20	3.59 ^d ±0.43	3.83 ^{cd} ±0.41	3.92 ^a ±0.47
	B2	3.99 ^{abce} ±0.45	3.91 ^{bcd} ±0.29	2.55 ^c ±0.24	3.48 ^b ±0.75
	Average (A)	4.22 ^a ±0.33	3.78 ^b ±0.32	3.48 ^c ±0.75	
Texture	B0	4.00 ^{ab} ±0.26	2.91 ^c ±0.31	3.17 ^c ±0.21	3.36 ^b ±0.54
	B1	3.97 ^{ab} ±0.28	3.07 ^c ±0.08	3.20 ^c ±0.34	3.41 ^{ab} ±0.48
	B2	4.21 ^a ±0.16	3.64 ^b ±0.41	3.04 ^c ±0.44	3.63 ^a ±0.60
	Average (A)	4.06 ^a ±0.25	3.20 ^b ±0.43	3.14 ^b ±0.33	
Appearance	B0	3.81 ^a ±0.26	2.89 ^{cd} ±0.23	2.69 ^{de} ±0.10	3.13±0.54
	B1	3.85 ^a ±0.21	2.50 ^e ±0.24	3.01 ^{bc} ±0.18	3.12±0.61
	B2	3.83 ^a ±0.24	3.20 ^b ±0.16	2.57 ^e ±0.29	3.20±0.57
	Average (A)	3.83 ^a ±0.22	2.87 ^b ±0.35	2.76 ^b ±0.27	
Favorite	B0	3.77 ^a ±0.19	3.04 ^b ±0.16	3.04 ^b ±0.15	3.28±0.39
	B1	3.85 ^a ±0.20	2.59 ^c ±0.37	3.11 ^b ±0.20	3.18±0.59
	B2	3.85 ^a ±0.19	3.31 ^b ±0.28	2.57 ^c ±0.29	3.24±0.59
	Average (A)	3.83 ^a ±0.18	2.98 ^b ±0.40	2.91 ^b ±0.32	

Different superscripts in the interaction rows and columns show a noticeable difference ($P<0.05$). B0A0 = Pellets with 0% molasses binder; B0A1 = Pellets with 2.5% molasses binder; B0A2 = Pellets with 5% molasses binder; B1A0 = Pellets with 0% cornstarch binder; B1A1 = Pellets with 2.5% cornstarch binder; B1A2 = Pellets with 5% cornstarch binder; B2A0 = Pellets with 0% tapioca flour binder; B2A1 = Pellets with 2.5% tapioca flour binder; B2A2 = Pellets with 5% tapioca flour binder.

sidered good, as they are similar to previous studies. Based on research (Harnentis *et al.*, 2019) the PDI value of free-range chicken feed is 98.50% - 99.12%. This indicates that the addition of binder as a pellet adhesive can improve the shape and durability of the pellets (Bain *et al.*, 2024).

The study's results showed that the moisture content of pellets varied as follows: in week 0, it ranged from 9.62% to 12.04%; in week 4, from 7.46% to 11.72%; in week 8, from 7.18% to 12.08%; and in week 12, from 7.76% to 12.60%. Based on the result, the moisture content of the pellets tended to decrease from week 0 to week 8, but showed a slight increase by week 12. Several factor that may affected the fluctuations of moisture content, including storage conditions and environmental humidity (Dar-

Table 5. Physical quality – organoleptic functional feed pellets based on tofu pulp and fermented cassava dregs stored at a storage time of 12 weeks.

Parameters	BINDER (B)	Binder Layer (A)			Average (B)
		A0	A1	A2	
Durability (%)	B0	97.60±2.79	97.40±1.67	97.00±3.08	97.33±2.41
	B1	97.60±1.95	98.00±0.71	92.00±3.08	95.87±3.46
	B2	97.80±2.39	93.20±2.49	97.00±1.73	96.00±2.93
	Average (A)	97.67±2.22	96.20 ^{ab} ±2.76	95.33 ^{bc} ±3.50	
Pellet Hardness Horizontal (kg)	B0	9.00 ^d ±0.77	11.10 ^b ±1.21	10.60 ^{bc} ±0.86	10.23 ^{ab} ±1.29
	B1	8.90 ^d ±0.82	9.60 ^{cd} ±0.45	9.20 ^d ±0.57	9.23 ^b ±0.66
	B2	9.05 ^{di} ±0.84	9.55 ^{cd} ±1.12	13.30 ^a ±1.64	10.63 ^a ±2.28
	Average (A)	8.98 ^c ±0.75	10.08 ^b ±1.18	11.03 ^a ±2.04	
Vertical Pellet Hardness (kg)	B0	4.55±0.32	5.80±0.92	5.40±1.11	5.25 ^a ±0.96
	B1	5.40±0.80	5.45±0.45	4.75±0.71	5.20 ^a ±0.70
	B2	4.60±0.65	4.20±0.41	4.85±1.27	4.55 ^b ±0.84
	Average (A)	4.85±0.71	5.15±0.92	5.00±1.02	
Moisture Content (%)	B0	11.82 ^{bc} ±0.08	8.06 ^c ±0.15	10.32 ^d ±0.19	10.07 ^c ±1.60
	B1	12.60 ^a ±0.07	11.50 ^a ±0.23	11.46 ^{ab} ±0.13	11.85 ^a ±0.57
	B2	11.98 ^{bc} ±0.31	11.32 ^c ±0.08	7.76 ^e ±0.48	10.35 ^b ±1.94
	Average (A)	12.13 ^a ±0.39	10.29 ^b ±1.64	9.85 ^c ±1.63	
Color	B0	2.17 ^c ±0.17	3.80 ^a ±0.05	3.92 ^a ±0.11	3.30 ^a ±0.83
	B1	2.23 ^{bc} ±0.08	2.12 ^c ±0.22	2.14 ^c ±0.09	2.16 ^c ±0.14
	B2	2.26 ^{bc} ±0.09	2.21 ^c ±0.16	2.40 ^b ±0.08	2.29 ^b ±0.13
	Average (A)	2.22 ^c ±0.12	2.71 ^b ±0.81	2.82 ^a ±0.82	
Smell	B0	4.57 ^a ±0.15	3.92 ^a ±0.05	4.18 ^b ±0.14	4.23 ^b ±0.30
	B1	4.55 ^a ±0.20	4.47 ^a ±0.14	4.47 ^a ±0.19	4.49 ^a ±0.17
	B2	4.41 ^{ab} ±0.24	4.36 ^{ab} ±0.17	2.52 ^d ±0.20	3.76 ^c ±0.93
	Average (A)	4.51 ^a ±0.20	4.25 ^b ±0.27	3.72 ^c ±0.90	
Texture	B0	4.19 ^a ±0.13	2.84 ^d ±0.13	2.86 ^d ±0.21	3.30 ^b ±0.67
	B1	4.12 ^a ±0.31	3.53 ^{bc} ±0.17	3.56 ^{bc} ±0.13	3.74 ^a ±0.35
	B2	4.23 ^a ±0.24	3.71 ^b ±0.15	3.33 ^c ±0.18	3.76 ^a ±0.42
	Average (A)	4.18 ^a ±0.22	3.36 ^b ±0.41	3.25 ^b ±0.34	
Appearance	B0	4.15 ^a ±0.10	2.96 ^c ±0.19	2.65 ^d ±0.16	3.25 ^b ±0.68
	B1	4.00 ^a ±0.07	2.97 ^c ±0.25	3.36 ^b ±0.15	3.44 ^a ±0.47
	B2	4.04 ^a ±0.19	3.36 ^b ±0.22	3.04 ^c ±0.11	3.48 ^a ±0.46
	Average (A)	4.06 ^a ±0.14	3.10 ^b ±0.28	3.02 ^b ±0.33	
Favorite	B0	4.09 ^a ±0.19	3.04 ^{bcd} ±0.14	2.91 ^{cd} ±0.27	3.35 ^a ±0.58
	B1	2.91 ^{cd} ±0.27	3.07 ^{bc} ±0.19	3.29 ^b ±0.11	3.09 ^b ±0.25
	B2	3.93 ^a ±0.16	3.28 ^b ±0.29	2.76 ^d ±0.14	3.32 ^a ±0.53
	Average (A)	3.64 ^a ±0.58	3.13 ^b ±0.23	2.99 ^b ±0.29	

Different superscripts in the interaction rows and columns show a noticeable difference ($P<0.05$). B0A0 = Pellets with 0% molasses binder; B0A1 = Pellets with 2.5% molasses binder; B0A2 = Pellets with 5% molasses binder; B1A0 = Pellets with 0% cornstarch binder; B1A1 = Pellets with 2.5% cornstarch binder; B1A2 = Pellets with 5% cornstarch binder; B2A0 = Pellets with 0% tapioca flour binder; B2A1 = Pellets with 2.5% tapioca flour binder; B2A2 = Pellets with 5% tapioca flour binder.

majana *et al.*, 2021). Maintaining the moisture content of pellets within an optimal range is essential for ensuring feed quality and preventing the growth of undesirable microorganisms. The ideal moisture content for feed is around 12 – 14 % (Bain *et al.*, 2024), as this helps prevent spoilage during storage.

These interactions suggest that changes in the color, smell, and texture of the pellets are influenced not only by the type of binder but also by the amount added. The combination of different binder types and levels leads to varying organoleptic responses, highlighting the importance of considering both factors when formulating functional feed pellets to achieve the desired organoleptic characteristics. Notably, pellets made

with a 5% molasses binder were able to maintain their color even after 12 weeks of storage. The addition of organic binder up to a level of 5% can improve the quality of the pellets (Gopar *et al.*, 2022). The pelleting process can cause the color to become darker or redder (Gao *et al.*, 2019).

The findings from the study highlighted a notable interaction between the type and quantity of binder used and the sensory attributes of the pellets, specifically their color, odor, and texture, over the course of the entire storage period (0, 4, 8, and 12 weeks). These interactions suggest that the changes observed in the pellets' color, aroma, and feel are not solely dictated by the type of binder employed but are also significantly affected by the amount incorporated. The interplay between various binder types and their respective quantities leads to distinct organoleptic responses, underscoring the importance of carefully considering both elements when formulating functional feed pellets aimed at achieving desirable sensory properties. Interestingly, pellets that utilized a 5% molasses binder demonstrated impressive stability, maintaining their rich color even after 12 weeks of storage, which speaks volumes about the effectiveness of this particular binder choice.

Conclusion

The study concluded that adding 5% molasses binder helps preserve the organoleptic characteristics of the pellets, particularly in terms of color. However, storing the pellets for an extended period may degrade their physical and organoleptic quality.

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Conflict of interest

The authors declares that there is no conflict of interest regarding the publication of this paper.

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