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INDIGOFERA PELLET STORAGE TIME ON DRY MATTER CONTENT, ORGANIC MATTER, PHYSICAL PROPERTIES, AND PALATABILITY IN SHEEP

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Abstract
I. zollingeriana as a feed ingredient requires attention in the storage process due to its bulky properties. Compaction through pelletization aimed to improve storage and transportation efficiency. This study aims to observe the interaction between adhesive (cassava by-product) levels and shelf life on *I. zollingeriana* pellets characteristics, including: dry matter, organic matter, physical properties, and palatability. The research was carried out with a nested design. Sun-dried *Indigofera zollingeriana* was ground using a hammer mill and mixed with 10%, 20%, and 30% cassava by-product adhesive. The pellets were sun-dried and stored for 0, 4, and 8 weeks. Analysis of variance (ANOVA) revealed no interaction (P>0.05) between adhesive levels and pellets shelf life. The findings suggest that *I. zollingeriana* can be pelletized with or without adhesive, and storage up to 8 weeks has no impact on its dry matter, organic matter, physical properties, or palatability.
Keywords: *I. zollingeriana* pellets, dry matter, organic matter, physical properties, palatability

LAMA PENYIMPANAN PELET INDIGOFERA TERHADAP KANDUNGAN BAHAN KERING, BAHAN ORGANIK, SIFAT FISIK DAN PALATABILITASNYA PADA DOMBA

Abstrak
I. zollingeriana merupakan bahan pakan kaya protein yang membutuhkan perhatian dalam penyimpanan karena memiliki sifat amba (bulky). Pemadatan partikel pakan dengan pembutan pelet dapat meningkatkan efisiensi penyimpanan dan transportasinya. Penelitian ini bertujuan untuk mengetahui interaksi antara tingkat perekat (Onggok) dengan lama simpan pelet I. zollingeriana terhadap kandungan bahan kering, bahan organik, sifat fisik dan palatabilitasnya. Penelitian dilaksanakan dengan rancangan tersarang (nested). Indigofera zollingeriana yang telah dikeringkan dengan sinar matahari digiling menggunakan hammer mill dan dicampur dengan onggok sebagai perekat sebanyak 10%, 20% dan 30%. Pelet dijemur menggunakan sinar matahari dan disimpan selama 0, 4 dan 8 minggu. Hasil analisis ANOVA menunjukkan bahwa tidak terdapat interaksi (P > 0.05) antara tingkat perekat dengan lama simpan pelet. I. zollingeriana dapat dibuat menjadi pelet dengan maupun tanpa perekat, dan penyimpanan hingga 8 minggu tidak berpengaruh terhadap kandungan bahan kering, bahan organik, sifat fisik dan palatabilitasnya.
Kata Kunci: pelet I. zollingeriana, bahan kering, bahan organik, sifat fisik, palatabilitas

INTRODUCTION

Indigofera zollingeriana, a legume tree with a high vegetable protein content (26-29%), is a potential feed ingredient. *I. zollingeriana* has a fresh-crop production of 1.65 tons/ha, and its forage production will increase by 0.049 tons/ha daily. *Indigofera zollingeriana* can adapt and produce in heat-stress conditions, particularly thriving during the rainy season. Postharvest processing becomes imperative to sustain availability throughout the year, especially given the spatial requirements for storage.

One way to preserve *I. zollingeriana* is to process them into pellets (pelletization). Pelletization enhance material density, making it easier to store and distribute. This process contributes to the creation of a sustainable protein source for livestock feed, and to protect feed availability in seasonal variations.

Stored pellets are susceptible to physical changes over time due to environmental factors. The quality of feed stored can change after a certain period. The physical properties of feed need to be considered to determine the area of space required in the storage process and the length of time the feed is stored in the warehouse while still containing good quality. In addition to environmental factors and storage time, the physical properties of the pellets are affected by the binder added in the pellet-making process. *I. zollingeriana* pellets require a binder as a binding agent, so the pellets are not easily damaged. Binder pellets can be derived from feed ingredients containing starch. When heated in a pellet machine, the starch gelatinization process makes the pellets solid. The choice of binder needs to be considered regarding availability and price. Tapioca by-product (*onggok*) is a feed ingredients that contains high energy, easy to obtain and cheap. Tapioca waste can be used as a pellet binder, however, its ideal composition as a binder in *I. zollingeriana* pellets and its influence on pellet quality remains unknown.

Feed consumed in the form of pellets will reduce the animal's selection of certain feeds because of the uniformity of shape. The feed given in pellet form will increase the palatability of livestock. However, the effect of *I. zollingeriana* feed pellets' storability on the highest palatability for sheep is not yet known. Based on the following description, the authors are interested in examining the storage time of *I. zollingeriana pellets* on their physical quality and palatability in sheep.

MATERIALS AND METHODS

This research was conducted from October 2022 to January 2023 at the Mini Feedmill Laboratory of Poultry and Non-ruminant Nutrition Faculty of Animal Husbandry, Padjadjaran University, Laboratory of Ruminant Animal Nutrition and Animal Feed Chemistry, Padjadjaran University and the Sheep Barn in Cimekar Village, Cileunyi District, Bandung Regency. The *Indigofera zollingeriana* used in this study came from Cinnaggerang Village, Pamulihan District, Sumedang Regency. *Indigofera zollingeriana* was dried under sunlight for three days, grounded using a hammer mill, and 10, 20, and 30% of cassava as an adhesive (Table 1). This study used a pellet machine without steam, so adding 10% water to the material was necessary. Pellets were made with a length of 2 cm and a diameter of 0.5 cm. The pellets were dried in the sun and put in plastic and sacks. Then, the top was sewn using a sack sewing machine and stored in the feed warehouse for 0, 4, and 8 weeks. Pellet production was carried out at the Mini Feedmill, Faculty of Animal Husbandry, Padjadjaran University.

Table 1. Pellet Composition in this Study

	P0	**P1**	**P2**	**P3**
Indigofera zollingeriana	100	90	80	70
Tapioka by Product (Onggok)	0	10	20	30
Amount	100	100	100	100

Tabel 2. Nutrient Content of Feed Materials in this Study

Nutrien	***I. zollingeriana (%)***	**Tapioca by-product (*Onggok*) (%)**
Water	7,11	9,79
Ash	7,99	3,05
Crude protein	24,41	2,06
Crude fiber	23,46	17,49
Crude fat	3,81	2,68
Nitrogen-free extracts	40,33	74,72
TDN	66,23	65,23

Source: Laboratory of Ruminant Animal Nutrition and Animal Feed Chemistry, Faculty of Animal Husbandry, Padjadjaran University, 2023.

Parameters observed included specific gravity, pile density, pile compaction density, durability, dry matter, organic matter, and palatability. The feed's specific gravity, pile density, and compaction density were estimated using the Khalil method (1999a). The durability was measured using the pfost tumbling method (Susilawati *et al*., 2012). The dry matter and organic matter were estimated using the AOAC method (1998). Palatability testing was carried out by adapting the livestock for seven days to the treated feed, and then after three days, the consumption of body weight/head/hour was measured (Christi, 2018). Temperature and humidity were measured using a digital temperature and humidity meter.

Feed's dry matter, organic matter, and physical quality tests were carried out using the nested method (stage 1), while the palatability was carried out using a completely randomized design (stage 2). The best treatment results based on the stage 1 test were used as a reference for testing the palatability of pellets (stage 2). The data obtained was analyzed to an ANOVA test. If a significant difference was found, it would be continued with Duncan's test.

RESULTS AND DISCUSSION

Dry Matter and Organic Matter Content of *I. zollingeriana* Pellets

There was no significant interaction ($p > 0.05$) between dry matter and organic matter content of I. *zollingeriana* pellets with various storage time or cassava adhesive compositions (Table 3). The dry matter of pellets stored for 0, 4, and 8 weeks ranged from 90.39 to 96.55%. Pellet organic matter stored for 0, 4 and 8 weeks ranged from 90.93 to 93.72%.

Indigofera pellets stored for eight weeks were still classified as good-quality pellets. Ilmiawan (2015) also stated that good pellets have a dry matter ranging from 88 – 86%. The dry matter content of the pellets was affected by the water content of the pellets. The water content, which ranges from 3.45 – 9.61%, reducesd the risk of damage. According to SNI (2019), the maximum water content of sheep concentrate is 13%. Pellet storage packaging that uses plastic as a first protector and then given a sack causes pellet storage to last up to 8 weeks. Feed was stored for two months using plastic, and then sacks protect the feed more from a decrease in feed nutrient content and rancidity than without being given plastic (Halimatuddini et al., 2019).

Table 3. Dry Matter Content of I. *zollingeriana* Pellets during Storage

Pellet	Time storage (week)	Test			Total	Average	Average
		1	2	3			
		…..%……..					
P0	(W0)0	90.95	87.88	98.87	277.70	92.57	93.81
	(W1)4	96.55	95.59	94.26	286.40	95.47	
	(W2)8	92.66	97.26	90.31	280.23	93.41	
P1	(W0)0	91.64	89.32	90.21	271.17	90.39	93.57
	(W1)4	94.08	93.92	94.95	282.95	94.32	
	(W2)8	97.79	97.81	92.40	288.00	96.00	
P2	(W0)0	94.90	96.78	95.67	287.35	95.78	94.72
	(W1)4	96.18	93.03	92.46	281.67	93.89	
	(W2)8	96.35	90.48	96.61	283.44	94.48	
P3	(W0)0	94.34	95.35	99.96	289.65	96.55	95.08
	(W1)4	95.34	97.08	92.38	284.80	94.93	
	(W2)8	93.87	90.72	96.72	281.31	93.77	

Description: P0: 100% *I. zollingeriana*; P1: 90% *I. zollingeriana* + 10% tapioca By-product; P2: 80% *I. zollingeriana* + 20% tapioca by-product; P3: 70% *I. zollingeriana* + 30% tapioca By-product.

Table 4. Organic Matter Content of I. *zollingeriana* Pellets during Storage

Pellet	Storage time (Week)	Test			Total	Average	Average
		1	2	3			
		……g/cm^3……..					
P0	(W0)0	91.18	92.99	92.05	276.22	92.07	92.06
	(W1)4	91.79	92.42	92.91	277.12	92.37	
	(W2)8	91.83	91.63	91.73	275.19	91.73	
P1	(W0)0	91.53	92.82	89.98	274.33	91.44	91.77
	(W1)4	92.82	91.86	91.88	276.56	92.19	
	(W2)8	91.60	91.09	92.36	275.05	91.68	
P2	(W0)0	91.79	91.80	92.07	275.66	91.89	91.81
	(W1)4	91.47	93.35	92.98	277.80	92.60	
	(W2)8	90.95	91.49	90.36	272.80	90.93	
P3	(W0)0	91.15	91.51	91.18	273.84	91.28	91.54
	(W1)4	91.57	93.70	91.89	277.16	92.39	
	(W2)8	90.78	91.36	90.75	272.89	90.96	

Description: P0: 100% *I. zollingeriana*; P1: 90% *I. zollingeriana* + 10% tapioca by-product; P2: 80% *I. zollingeriana* + 20% tapioca by-product; P3: 70% *I. zollingeriana* + 30% tapioca by-product

Plastic packaging protects the pellets from absorption of water content from the environment, which can increase the water content and decrease the dry matter content. During the study, temperature and humidity were normal, with an average of 27.28 ± 0.75 and 82.30 ± 6.49.

The dry matter and organic matter contents of I. *zollingeriana* pellets were not significantly different due to the same dry matter and organic matter content of the pellets. This result follows the statement of Kayaode et al. (2020) that the ingredients for making pellets cause the same dry matter content. The same pellet formulation causes the dry matter content of the pellets to not differ during eight weeks of storage (Supriawan et al., 2020).

Physical Properties of Pellets During Storage

The physical properties of feed, including specific gravity, pile density, pile compaction density, and durability, were examined in relation to tapioca byproduct and the shelf life of *I. zollingeriana* pellets. The results showed no interaction ($P > 0.05$) between tapioca byproduct and shelf life of *I. zollingeriana* pellets. This negative correlation was caused by no significant difference between dry matter content ($P > 0.05$) and each treatment.

When the water content of the pellets is high, the pellets will expand, thereby increasing the volume of the pellets (Rahmana *et al*., 2016). The water content in the material affects the pile density. The results of the physical properties test of the pellets in this study are described in Table 5.

Specific gravity describes the amount of material that can be filled in a unit volume. The specific gravity of *I. zollingeriana* pellets produced from this study ranged from 0.83 to 1.07 g/cm ^{3}. This result is smaller than Gamal leaf pellets given several types of adhesive, resulting in 1.77 – 2.00 g/cm ^{3} of (Royani & Herawati, 2020). However, it aligns closely with substitution of chicken pellets with fermented *I. zollingeriana*, resulting in specific gravity ranging from 1.07 to 1.33 (Febriyanti et al., 2019). A higher specific gravity indicates that the material can accommodate more weight in a given container. The composition of the pellet constituents can influence the difference in specific gravity. In addition, the particle sizes of Indigofera and cassava are similar. Smaller particle size of the pellet ingredients will increase their physical quality (Rahmana et al., 2016).

This study's heap density and compaction density produced different values. The compaction density of the pile, in principle, is measuring the material pile's density that has undergone shifting or compaction. The density value of the feed pile will go hand in hand with the density value of the pile compaction (Septian *et al*., 2018).

Table 5. Specific Gravity Test Results of *I. zollingeriana* Pellet During Storage

Pellet	Storage time (Week)	Test			Total	Average	Total Average
		1	2	3			
		……g/cm³…….....					
P0	(W0)0	1.00	1.11	0.91	3.02	1.01	0.97
	(W1)4	1.00	1.00	0.91	2.91	0.97	
	(W2)8	1.00	0.91	0.91	2.82	0.94	
P1	(W0)0	1.11	0.91	1.25	3.27	1.09	1.02
	(W1)4	0.91	0.91	1.11	2.93	0.98	
	(W2)8	0.91	1.00	1.11	3.02	1.01	
P2	(W0)0	1.00	1.00	0.91	2.91	0.97	0.97
	(W1)4	1.00	1.00	1.00	3.00	1.00	
	(W2)8	1.00	0.91	0.91	2.82	0.94	
P3	(W0)0	1.00	1.00	1.00	3.00	1.00	1.01
	(W1)4	1.00	1.00	1.00	3.00	1.00	
	(W2)8	1.00	1.00	1.11	3.11	1.04	

Description: P0: 100% *I. zollingeriana*; P1: 90% *I. zollingeriana* + 10% tapioca by-product; P2: 80% *I. zollingeriana* + 20% tapioca by-product; P3: 70% *I. zollingeriana* + 30% tapioca by-product

Table 6. Density of *I. zollingeriana* Pellets During Storage

Pellet	Storage time (Week)	Test			Total	Average	Total Average
		1	2	3			
		……kg/m³…….....					
P0	(W0)0	393.96	317.78	322.25	1033.99	344.66	341.09
	(W1)4	345.51	320.33	331.49	997.34	332.45	
	(W2)8	355.39	312.68	370.38	1038.45	346.15	
P1	(W0)0	405.44	373.56	321.29	1100.29	366.76	348.74
	(W1)4	430.30	428.70	276.98	1135.99	378.66	
	(W2)8	284.95	276.35	341.05	902.35	300.78	
P2	(W0)0	320.97	339.94	314.12	975.02	325.01	344.20
	(W1)4	299.62	416.91	383.44	1099.97	366.66	
	(W2)8	304.08	375.79	342.96	1022.84	340.95	
P3	(W0)0	375.48	355.08	346.47	1077.02	359.01	336.77
	(W1)4	359.54	370.06	366.55	1096.15	365.38	
	(W2)8	346.15	261.37	250.21	857.73	285.91	

Description: P0: 100% *I. zollingeriana*; P1: 90% *I. zollingeriana* + 10% tapioca by-product; P2: 80% *I. zollingeriana* + 20% tapioca by-product; P3: 70% *I. zollingeriana* + 30% tapioca by-product

Table 7. Compaction Density of *I. zollingeriana* Pellets During Storage

Pelet	Time Storage (Week)	Test			Total	Average	Total Average
		1	2	3			
		……kg/m³…….					
P0	(W0)0	471.04	381.34	379.79	1232.17	410.72	411.47[a]
	(W1)4	413.11	419.61	387.91	1220.63	406.88	
	(W2)8	420.36	380.76	449.35	1250.47	416.82	
P1	(W0)0	476.14	443.44	384.15	1303.72	434.57	399.86[a]
	(W1)4	365.40	523.97	332.38	1221.75	407.25	
	(W2)8	332.28	339.01	401.95	1073.24	357.75	
P2	(W0)0	372.96	404.25	377.63	1154.84	384.95	413.40[a]
	(W1)4	363.50	519.17	439.36	1322.04	440.68	
	(W2)8	383.00	447.70	413.06	1243.75	414.58	
P3	(W0)0	450.57	427.65	421.90	1300.12	433.37	405.72[a]
	(W1)4	439.44	439.44	446.35	1325.22	441.74	
	(W2)8	402.22	327.95	295.95	1026.12	342.04	

Description: The same superscript signifies no apparent influence (P>0,05); P0: 100% *I. zollingeriana*; P1: 90% *I. zollingeriana* + 10% tapioca by-product; P2: 80% *I. zollingeriana* + 20% tapioca by-product; P3: 70% *I. zollingeriana* + 30% tapioca by-product

Table 8. Durability of *I. zollingeriana* Pellets During Storage

Pellet	Storage time (Week)	Test			Total	Average	Total Average
		1	2	3			
		…… kg/m^3 ……					
P0	(W0)0	94.80	93.60	92.80	281.20	93.73	93.56[a]
	(W1)4	95.00	91.20	94.60	280.80	93.60	
	(W2)8	93.60	93.60	92.80	280.00	93.33	
P1	(W0)0	96.20	94.40	95.40	286.00	95.33	94.31[a]
	(W1)4	91.40	92.80	97.60	281.80	93.93	
	(W2)8	93.20	92.40	95.40	281.00	93.67	
P2	(W0)0	94.80	96.00	94.40	285.20	95.07	94.71[a]
	(W1)4	94.80	92.80	95.00	282.60	94.20	
	(W2)8	94.20	96.00	94.40	284.60	94.87	
P3	(W0)0	96.40	93.00	96.40	285.80	95.27	95.29[a]
	(W1)4	94.00	93.00	95.20	282.20	94.07	
	(W2)8	96.40	96.80	96.40	289.60	96.53	

Description: The same superscript signifies no significant influence (P>0,05); P0: 100% *I. zollingeriana*; P1: 90% *I. zollingeriana* + 10% tapioca by-product; P2: 80% *I. zollingeriana* + 20% tapioca by-product; P3: 70% *I. zollingeriana* + 30% tapioca by-product

Durability is the weight of pellets that remain intact after rotation to determine their strength. In this study, the durability of the *I. zollingeriana* pellets ranged from 93.33 – 96.53%, with or without adhesive. These high durability values indicate excellent physical quality, surpassing the threshold of 80% considered indicative of good pellets (Rakhmawati *et al*., 2017). High durability in pellets are related to stability during transportation and storage (Widyastuti *et al*., 2004). Pellets will undergo heating in the pellet machine, which results in the gelatinizing starch and denaturing proteins. This process enhances adhesion and contributes to the structural integrity of the pellets. As a result, the pellets are more resilience and resist breakage, protecting them throughout handling, storage, and transportation (Abdollahi et al., 2013).

Palatability

Palatability, defined as the preference level of livestock for a given feed, is a multifaceted aspect influenced by various factors, including physical appearance, smell, texture, and taste (Christi, 2018). There was no interaction (P > 0.05) between adhesive levels in the pellets and shelf life with dry matter, organic matter, and physical properties in feed, even after storage for up to 8 weeks (Table 9). However, as storage time progresses, odour, colour, and texture changes will affect the pellets' palatability. The physical quality of the feed is known to deteriorate with prolonged storage, affecting factors such as color, texture, and aroma (Jaelani, 2016). Consequently, these changes may influence the overall palatability of the pellets over time.

Table 9. Sheep's Palatability of *I. zollingeriana* Pellets

Test	Palatability (grams DM/Hour)			
	P0	P1	P2	P3
1	361.19	478.40	475.45	468.85
2	460.51	480.00	475.45	446.66
3	432.80	444.80	470.70	396.33
4	320.71	480.00	475.45	468.85
5	463.94	324.80	366.10	468.85
Average	407.83 ± 63.86[a]	441.60 ± 67.00[a]	452.63 ± 48.42[a]	449.91 ± 31.45[a]

Description: The same superscript signifies no apparent influence (P>0,05); P0: 100% *I. zollingeriana*; P1: 90% *I. zollingeriana* + 10% tapioca by-product; P2: 80% *I. zollingeriana* + 20% tapioca by-product; P3: 70% *I. zollingeriana* + 30% tapioca by-product.

The study found that the composition of pellets stored for eight weeks did not significantly impact their palatability ($P > 0.05$). This outcome can be attributed to the high dry matter content of the pellets, measuring less than 14%. The low moisture content likely inhibited the growth of fungi, preventing the development of rancid odors in the pellets over time.

The level of palatability in this study, or the amount of dry matter in Indigofera pellets consumed for one hour in one day, ranged from 320.71 to 480.00 grams of DM consumption (g/head/hour). This amount of consumption aligns with the standard set by NRC (1982), which recommends a forage-to-concentrate ratio of 60:40 for sheep weighing 40 kg. Sheep with body weight gain of 100 are recommended with 1,190 grams of DM, of which the 40% concentrate equals to 476 grams. The observed crude protein consumption in the study varied from 89.73 to 128.19 grams of dry matter, meeting the recommended intake of 121 grams.

CONCLUSION

I. zollingeriana pellets can be made without adding a binder substance. Storage of *I. zollingeriana* pellets for eight weeks can maintain the quality of dry matter, organic matter, physical properties and palatability.

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