Vol. 12(2): 219-229, May 2024 DOI: https://doi.org/10.23960/jsl.v12i2.791

Jurnal Sylva Lestari

P-ISSN: 2339-0913
E-ISSN: 2549-5747

Journal homepage: https://sylvalestari.fp.unila.ac.id

Full Length Research Article

Palatability of Cuscus (*Spilocuscus maculatus*) to the Combinations of Pellet Feed Based on Organic Value

Anton Sinery[1,2,*], Jacob Manusawai[1,2], Meliza Worabay[1], Denisa Taran[1], Elieser Sirami[1,2]

[1] Department of Forestry, Faculty of Forestry, University of Papua, Manokwari, Indonesia
[2] Graduate School of Environmental Science, University of Papua, Manokwari, Indonesia
[*] Corresponding Author. E-mail address: anton_sineri@yahoo.com

ARTICLE HISTORY:

Received: 22 August 2023
Peer review completed: 12 December 2023
Received in revised form: 6 February 2024
Accepted: 15 February 2024

KEYWORDS:

Cuscus
Feed
Organic matter
Palatability
Spilocuscus maculatus

ABSTRACT

Cuscus (*Spilocuscus maculatus*) in captivity that were given a dominant fruit diet needed additional feed from their natural habitat because of the higher nutritional potential and fiber components. This study aims to determine the palatability of cuscus to the feed based on organic value. An experimental method was used, consisting of 4 treatment groups: 100% banana (*Musa paradisiaca*) as control, 70% banana mixed with 30% matoa (*Pometia pinnata*) leaves, 70% banana mixed with 30% ironwood (*Pongamia pinnata*) leaves, and 70% banana mixed with 30% crickets (*Gryllus bimaculatus*). The results showed that banana was the most preferred feed ingredient, either alone or as a supplementary feed mixture. In terms of quantity, its mixture with matoa leaves had a higher consumption level than ironwood leaves and crickets. The consumption level of organic matter was higher in the treatment with 100% banana than in other treatments. This information will help support ex-situ and in-situ conservation programs formulated by the government and other parties, including the community.

1. Introduction

The Indonesian government protects animals under Law Number 5 of 1990 concerning the Conservation of Living Natural Resources and their Ecosystems and the Government Regulation Number 7 of 1999 concerning the Preservation of Plant and Animal Species, which was amended by the Regulation of the Minister of Environment and Forestry Number 106 of 2018. Cuscus (*Spilocuscus maculatus*) is categorized as a threatened species globally under the International Union for Conservation of Nature and Natural Resources (IUCN) as well as the Appendix II Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). These protection considerations were implemented due to species endemicity, population dynamics in the wild, hunting threats, illegal trading, and habitat degradation (Farida 2022; Pattiselanno 2022; Pattiselanno et al. 2022; Pramatana et al. 2022; Sinery 2022; Widayanti et al. 2015).

Cuscus is one of the endemic species of marsupial in Eastern Indonesia, whose distribution includes Papua, Maluku, Sulawesi, and Timor (Helgen and Jackson 2015). In Papua, there are two genera of cuscus, namely the spotted (*Spilocuscus*) and the northern common cuscus (*Phalanger*), with *Spilocuscus* as an endemic species (Leary et al. 2016). There are seven species found among

11 living in New Guinea, namely *S. maculatus*, *S. rufoniger*, *S. papuensis*, *Phalanger orientalis*, *P. gymnotis,* and *P. vestitus* (Farida 2022; Kunda et al. 2016; Widayanti et al. 2016). Several studies also reported that some areas have a rich diversity of animals. The wide distribution and diversity in the family Phalangeridae caused a lack of information on the species level (Farida 2018; Kealy 2018; Kunda and Widayanti 2022; Sinery et al. 2016).

The high rate of hunting accompanied by clearing forest areas in the Papua region can cause a population decline and extinction. Habitat damage, hunting, catching, and uncontrollable trading can threaten this animal's existence in its habitat. Cuscuses have long been hunted for meat, fur, and teeth by local peoples, especially in Papua, North Sulawesi, and East Nusa Tenggara. Until now, several species of Phalangeridae have been categorized as critically endangered and towards extinction (vulnerable) (Farida 2022). This population of endemic wild animals should be protected as their habitat area was degrading due to uncontrolled illegal logging and hunting by the local community (Kiroh et al. 2021). A study of genetic variation for an endemic species (Lakor goat breed) found that the genetic erosion seen in this population was due to the low genetic diversity of the population and was caused by high inbreeding and bottleneck populations. This will cause a decrease in biological fitness and is strongly suspected to increase the risk of extinction of this population in the future (Rumanta et al. 2020). Since the condition of natural ecosystems is continually pressed, conservation efforts must also be done. This condition could affect the biocapacity of forest and land resources and the ecological footprint that could fulfill the needs (Marwa et al. 2020).

A fundamental study is needed to support their preservation by understanding cuscus characteristics, especially feeding behavior in captivity. Furthermore, as an ex-situ conservation measure, captivity has constraints in providing food throughout the day. This is due to the necessity for human intervention to provide for the animal's needs. The adequacy of the nutritional value contained in the food consumed plays a significant role in survival. It is also necessary to analyze the palatability of several food ingredients as a source of carbohydrates, crude fiber, and animal protein. According to Kayadoe et al. (2020), the formulation of pellet rations was based on the study of the preferred level of seven types of cuscus feed (banana, sweet starfruit, matoa leaves, ironwood leaves, water spinach leaves, green mustard leaves, and crickets) that are useful as a source of carbohydrates.

Cuscuses living in captivity in Papua New Guinea consume a variety of feeds, including vegetables, fruits, bread, corn, and sweet potatoes (Farida 2020; Kayadoe et al. 2014; Sinery 2015), but the main types are those containing fiber. However, species fed a low-fiber diet, mainly fruits, often die from intestinal inflammation. Several studies on cuscuses in captivity showed that the types of food given frequently include bananas, star fruit, as well as leaves of *Pometia pinnata, Pongomea pinnata*, *Ipomea aquatica*, *Brassica juncea*, *Ipomea batatas*, *Terminalia catappa*, and *Mangifera* sp. (Farida et al. 2005; Kayadoe et al. 2014; Saragih et al. 2010). Farida (2018) reported that giving a slurry formulation containing fruit increased the digestibility of dry matter, ash, protein, fat, crude fiber, nitrogen-free extract material, and gross energy. In nature, these animals eat various tree saps rich in carbohydrates, nectar, pollen, insects, and arachnids (Johnson 2019). Vegetation parts were primarily consumed in the form of shoots, flowers, ripe fruit, ripe seeds, and juice (Sawen and Sinery 2020). The formulation of pellet ration in this study is based on the preferred food chosen by seven species of cuscus (Kayadoe et al. 2020). Food is useful as a source of carbohydrates, fiber, and protein. Sinery (2015) and Farida (2018) revealed that the animals do not drink water directly. However, their water needs are obtained from ripe and sweet fruit extracts

and fiber in vegetation shoots. There are 43 plants that are the sources of cuscus feed (Repi et al. 2019).

Research conducted by Kayadoe et al. (2014) showed that cuscuses in captivity with a dominant fruit diet needed additional feed from their natural habitat because of the higher nutritional potential and fiber components. Based on this information, it is necessary to carry out a study on the palatability of mixed feeds for cuscus, namely bananas as basal feed and other supplementary ingredients from nature through the drying and milling process to increase the effectiveness and efficiency of providing feed which can fulfill all the nutrients needed for cuscus in captivity. Kayadoe et al. (2020) state that it is necessary to study the physical quality of pellet rations. It is important to conduct research to recognize deer's preference towards its served feeder (drop-in) and availability (Indriyani et al. 2017). Therefore, this study aims to determine the palatability of dry and organic matter in mixed feed for common spotted cuscus.

2. Materials and Methods

2.1. Materials

This study used common spotted cuscus (*S. maculatus*) from Numfor Island, Biak Numfor Regency (**Fig. 1**). The cuscuses that had just been caught from the forest were reared for three weeks. Four common spotted cuscuses consisting of two males and two females were used. The species has spotted fur without a dorsal center strip, striking red circles around the eyes, while the ears are almost invisible due to fur, but the pinna is more visible. Furthermore, the males are bigger than the females, and they have a size of 650 mm, weigh 3.5–4.5 kg, and are aged 2–2.5 years, which shows dimorphism due to sex. The length of the tail is almost equal to the length of the body, and only 1/4–1/3 of the distal end is not covered with fur. The dorsal part of the male spots is dark brown or reddish brown, but the spots are sometimes not visible in some populations. Males and females can also be yellowish with a slightly cream color (Sinery 2015).

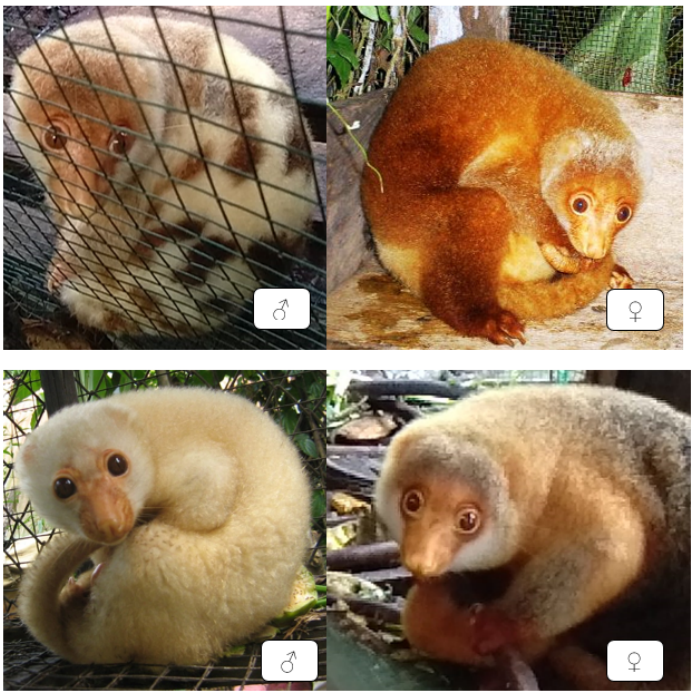

Fig. 1. *S. maculatus* with symbols of ♂ as male and ♀ as female.

The feed ingredients used consisted of banana (*Musa paradisiaca*), matoa leaves (*Pometia pinnata*), ironwood leaves (*Pongamia pinnata*), and crickets (*Gryllus bimaculatus*). The feed ingredients were dried using an oven at 60°C. After drying, the feed ingredients were ground using a blender, and each formulation was molded into pellets with a diameter of 5 mm. The feed ingredients that have been ground were then mixed based on different compositions (**Table 1**).

Table 1. The composition of feed ingredients in the treatment

No.	Treatment	Replication
1	100% banana (*Musa paradisiaca*) as control	3
2	70% banana + 30% matoa (*Pometia pinnata*) leaves	3
3	70% banana + 30% ironwood (*Pongamia pinnata*) leaves	3
4	70% banana + 30% crickets (*Gryllus bimaculatus*)	3

2.2. Research Methods and Procedures

This study was carried out for ten months from July 2021 to April 2022 at the Laboratory of Forest Products Technology, Faculty of Forestry and Agrostology Laboratory, Faculty of Animal Science, Unipa, the Nutrition Laboratory, Faculty of Animal Husbandry, Padjadjaran University, Bandung and the Ciawi Livestock Research Institute, Bogor. The procedures are explained in the next section.

2.2.1. Preparatory stage

The cuscus cage measuring 100 cm × 45 cm × 45 cm was weighed before being used. The cuscus was weighed before being put in the cage. Places to eat and drink were then placed in cages. The drying process for the additional feed ingredients was performed in the laboratory. The dry additional feed ingredients were then ground using a blender.

2.2.2. Analysis of dry matter content

The feed ingredients were oven-dried at 60°C then put into a porcelain cup (the cup's weight is known) as much as 3 g. Furthermore, the cups containing the samples were put into the oven at 105ºC for 24 hours. After that, they were cooled in a desiccator for 20 minutes and weighed.

2.2.3. Preference test

Bananas as basal feed are mixed with each additional feed based on dry matter adequacy, which is 70% banana and 30% additional feed, and 100% banana as a control treatment (based on dry matter adequacy). Feeding was given in the morning at 08.00, and the leftover feed was weighed the next day before the next portion was provided. Mixed feeding is given for three weeks; every week, mixed feeding is changed for each cuscus. At the beginning of mixed feeding, a feed adaptation period of 5 days was carried out. The data was collected for one week for each mixed feeding period, lasting three periods (Danieli et al. 2019).

2.2.4. Analysis of organic matter content

Three grams of mixed feed ingredients were put into a porcelain cup (the cup's weight was known). The porcelain cup containing the sample was put into a kiln and incubated at 600°C for 6

hours. After becoming ashes, the samples were cooled until the next day, then they were placed in a desiccator for 20 minutes and then weighed (Danieli et al. 2019).

2.3. Data Analysis

2.3.1. Feed palatability

The analysis of the palatability was based on the difference between the amount of given mixed feed and the amount of un-consumed feed calculated using Equation 1 (Danieli et al. 2019).

$$Average\ consumption\ (g/head/day) = A - B \quad (1)$$

where A is the average amount of feed given (g/head/day), and B is the average amount of feed not consumed (g/head/day).

2.3.2. Dry matter content

To determine the dry matter content, it is analyzed using Equation 2 and Equation 3.

$$Dry\ matter\ content\ (\%) = 100\% - Water\ content\ (Z)\ (\%) \quad (2)$$

$$Water\ content\ (\%) = \frac{(W + S\ before\ oven) - (W + S\ after\ oven)}{S\ before\ oven} \times 100\% \quad (3)$$

where W is the container weight, S is the sample weight, and Z is the actual water level.

Measurement of water content at 60°C (G) and 105°C (P) were used to determine the dry weight and actual water content, respectively, and were calculated using Equation 4 (Danieli et al. 2019).

$$Actual\ water\ content\ (Z)\ (\%) = G + \frac{(100 - 6)}{100} \times P \quad (4)$$

2.3.3. Organic matter content

Organic matter content was obtained using 100% dry matter minus % ash content, calculated using Equation 5.

$$Ash\ content\ (\%) = \frac{(C + S\ before\ furnace) - (C + S\ after\ furnace)}{sample} \times 100\% \quad (5)$$

where C is the dish weight, and S is the sample weight.

2.3.4. Organic matter consumed

The amount of organic matter consumed was determined by the ratio consumed in the dry matter multiplied by the % organic matter content calculated using Equation 6.

$$Organic\ matter\ consumed\ (\%) = KBKR \times BO \quad (6)$$

where $KBKR$ is the consumption of rations in dry matter, and BO is the organic matter (%).

3. Results and Discussion

3.1. Nutrient Composition of Feed Ingredients

Cuscuses and other animals choose the food that their bodies need most. Moreover, Food preference is influenced by food availability and competition between individuals. The diet of

cuscus and other species in the Phalangeridae family has formed a pattern of feeding interactions with various specific food types. Food is a source of various chemical substances that contribute to the defenses and cell resistance to animal stress. Food quality and foraging strategies can expose animals to various challenges and rewards. Numerous ecological studies have focused on the link between diet and stress (Costantini 2014). However, this condition only occurs in their natural habitat. In captivity, the animals are given food and can choose from what is available. In this experiment, the most preferred feed was matoa leaves, followed by *G. bimaculatus*, *M. paradisiaca,* and *Pongamia pinnata* leaves, as shown in **Table 2**.

Table 2. Composition of dry and organic matters in common spotted cuscus feed

Feed Ingredient	Nutrient Composition (%)	
	Dry Matter	Organic Matter
Banana (*Musa paradisiaca*)[1]	27.56	93.09
Matoa (*Pometia pinnata*) leaves[1]	32.90	96.66
Ironwood (*Pongomia pinnata*) leaves [1]	15.78	91.68
Cricket (*Gryllus bimaculatus*)[2]	31.91	94.82

Notes: [1] = The results of the analysis at the Laboratory of Forest Products Technology, Faculty of Forestry and Agrostology Laboratory, Faculty of Animal Science, Unipa, and the Nutrition Laboratory, Faculty of Animal Husbandry, Padjadjaran University, Bandung. [2] = the results of the analysis at the Ciawi Livestock Research Institute, Bogor.

The highest dry matter content of 32.90% was obtained from matoa leaves, followed by crickets and bananas. In comparison, the lowest of 15.78% was recorded in ironwood leaves. This indicates that cuscus consumed more matoa leaves, with the highest dry and organic matter content than other ingredients. However, the consumption of dry and organic matter was balanced, and there was no fundamental difference in the amount consumed. Dry matter digestibility is a crucial determinant for evaluating the nutrients absorbed. The digestibility of organic matter is the proportion of organic matter in feed that is digested in the total digestive tract, and the digestibility of organic matter is influenced by respiration and fermentation. Borreani et al. (2018) revealed that the difference in dry matter content of the leaves was influenced by respiration and fermentation, which decomposes many nutrients, thereby causing a reduction in the content of the feed.

The highest organic matter of 96.66% was obtained in matoa leaves. In comparison, the lowest of 91.68% was recorded in ironwood leaves. This indicates that cuscus consumed more amount of nutrients in matoa leaves. The different plant species have dissimilarity in nutrient content; therefore, they are fed on various plants, and selectivity in both species chosen and items eaten reflects the need to optimize the mix of nutrients and the total bulk of diets. This condition shows a direct correlation between the dry and organic matter composition for each type of feed. The higher the dry matter, the higher the organic matter in the feed ingredients, so the more dry matter consumption, the higher the organic matter. Cuscuses like bananas and star fruit because they are sweeter than the others (jackfruit, papaya, avocado), while the preferred leaves are matoa leaves, ironwood leaves, and others (Kayadoe et al. 2015). The formulation of the pellet was based on the study performed by Kayadoe et al. (2020), which discovered seven types of cuscus feed (banana, sweet starfruit, matoa leaves, ironwood leaves, water spinach leaves, green mustard leaves, and crickets). These feeds are sources of carbohydrates, fiber, and protein sources (Kayadoe et al. 2020). Handayani and Kunda (2019) state that feed ingredients contain nutrients consisting of water and dry matter, which consists of organic and inorganic materials.

3.2. Feed Combination

Combined feed (ration) given to the common spotted cuscus contains primary and supplementary feeds. Furthermore, the weight of the main feed was the same, while that of the supplementary was different (**Table 3**). Based on **Table 3**, the ratio consumption for basal feed and supplementary feed, as well as 100% banana, was converted into dry matter weight, namely 50 g.

Table 3. Ration combination of common spotted cuscus in captivity

Treatment	Provision of Ration Combination (g/head/day)	
	Basal Feed	Supplementary Feed
100% banana (*Musa paradisiaca*)	181.42	-
70% banana + 30% matoa (*Pometia pinnata*) leaves	126.99	45.59
70% banana + 30% ironwood (*Pongamia pinnata*) leaves	126.99	95.06
70% banana + 30% crickets (*Gryllus bimaculatus*)	126.99	47.01

After the feed was mixed and administered, some were left the next day. **Table 4** shows that the remaining feed was small or tended to be consumed, mainly basal or main feed. It can then be assumed that cuscus prefers bananas. Hence, any supplementary ingredient, such as matoa leaves, ironwood leaves, or crickets, can be consumed after mixing with bananas. However, this study cannot calculate the amount of banana and other feed separately since they are mixed when served. Fruits become more dominant in the cuscus diet. The part of the fruit that is most commonly eaten in the captivity habitat is pulp because before being fed to the animals, the fruit has been peeled first by the owner, and this was completely different in the natural habitat when complete fruit was taken, processed and eaten by cuscus. This finding is consistent with Farida (2022).

Table 4. Leftover cuscus feed in captivity (g dry matter/head/day)

Treatment	Feed Leftover (g dry matter/head/day)
100% banana (*Musa paradisiaca*)	0
70% banana + 30% matoa (*Pometia pinnata*) leaves	3.13
70% banana + 30% ironwood (*Pongamia pinnata*) leaves	1.96
70% banana + 30% crickets (*Gryllus bimaculatus*)	3.29

Sinery (2015) stated that feed is one of the factors affecting growth rate, and animal activities affect animal consumption. Types of food and environmental factors affect the level of animal feed consumption. Feed consumption is the most crucial factor in determining how much food substances animals get. The need for food substances will increase with the increase in body weight until the age limit, when growth does not occur anymore (Indriyani et al. 2017). Environmental factors like ambient temperature can also affect the consumption rate. Furthermore, consumption increases when the ambient temperature exceeds the critical point, and vice versa. The palatability factor obtained for certain ingredients through experimental studies significantly improves the survival of cuscus in captivity.

3.3. Palatability of Organic Matter in Ration Combination

Table 5 shows that the consumption level of organic matter is higher in treatment with 100% banana than in other treatments, showing that cuscus prefers more bananas without additional matter. In captivity, bananas are preferable since it is a sweater. However, cuscuses consume more fruit and forest vegetation in their natural habitat. The low consumption in the treatment of 70% banana mixed with 30% crickets was influenced by the nature of cuscus, an herbivore, not a carnivore. Although the feed has been mixed with bananas, the animals can still feel a different taste or fiber from the crickets. Sinery (2015) stated that all cuscus species in Papua are herbivores or frugivores, and only cuscus is a carnivorous animal that mainly feeds on insects, such as beetles.

Table 5. Palatability of organic matter in ration combination given to common spotted cuscus in captivity

Treatment	Palatability (g/head/day)
100% banana (*Musa paradisiaca*)	49.87
70% banana + 30% matoa (*Pometia pinnata*) leaves	45.51
70% banana + 30% ironwood (*Pongamia pinnata*) leaves	45.04
70% banana + 30% crickets (*Gryllus bimaculatus*)	44.54

That of dry matter influenced the consumption level of organic matter. Sinery (2015) stated that cuscus tends to consume ripe fruit because it has a sweet taste and contains much water, thereby increasing the ease of digestion. Furthermore, cuscus is a wild animal less dependent on water for its activities. Ningrum (2002) revealed that *S. maculatus* and *P. orientalis* consume 41.78% fruits, 12.01% forages, 22.16% tubers, and 23.05% supplementary feed in captivity. Sinery (2015) stated that the types of feed selected by bear cuscus in captivity based on palatability include fruits, leaves, supplemental feed, and tubers. The most preferred leaves are obtained from *Terminalia catappa*, *Mangifera* sp., and water spinach, with preference levels of 36.97%, 34.55%, and 18.48%, respectively. Farida et al. (2004) showed that the feed consumption of *Ailurops ursinus* was 23.74 g dry weight per kg, with the consumption of 6.38% ash, 13.76% crude protein, 3.20% crude fat, 14.58% crude fiber, 62.41% nitrogen-free extract, and 404.44 kcal/head/day gross energy. The composition of the food substances consumed includes 51.91% ash, 43.11% crude protein, 82.17% crude fat, 45.87% crude fiber, 78.41% extract material without nitrogen, and 73.16% energy.

In general, couscous has varying levels of consumption. Estimation of the availability of cuscus feed illustrates the habitat carrying capacity with the assumption that the average food requirement was 0.3–0.7 kg/head/day. This value was also used for open populations in the Arfak Mountains Nature Reserve (Sinery. 2022), where the individual density was one head per ha (in Numfor Island, it was 0.41/ha). Based on the measurement, *Ficus septica*, *Syzygium* sp., and *Aglaia* sp. produce fruit 16, 12, and 9–16 kg/season with an average of 12.5 kg/season and an average frequency of 6 times per year. It was estimated that the feed availability is less for the cuscus population in this area. Hence, food outside the forest area is likely to be exploited by the animals. This result is lower compared to the estimated population in Obi Island (Tamalene et al. 2019) and Arfak Mountains Nature Reserve, which was relatively abundant (Sinery 2022).

4. Conclusions

Banana is a favorable feed ingredient for common spotted cuscus either alone or after being mixed with supplementary feed. Furthermore, regarding quantity, cuscus prefers its mixture with matoa leaves compared to ironwood leaves or crickets. The results showed that the consumption level of organic matter was higher in the treatment with 100% banana than in other treatments. This feed palatability experiment will be beneficial to support ex-situ and in-situ conservation programs formulated by all relevant institutions from the government and other parties, including the community.

Acknowledgments

The authors are grateful to the management of the Forest Products Technology Laboratory, Faculty of Forestry and Agrostology Laboratory, Faculty of Animal Science, University of Papua, and the Nutrition Laboratory, Faculty of Animal Husbandry, Padjadjaran University, Bandung. The authors are also grateful to Ciawi Livestock Research Institute, Bogor, for assisting in analyzing the study material.

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