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Effect of Sweetness Level and Amino Acid Composition of Palm Sugar on Feed Intake of *Trichoglossus haematodus* in Captivity

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Abstract. Palm sugar solution diets that were offered to the Lorikeets contain high energy, low protein and rich in amino acids similar to nectar. The major components of palm sugar are sucrose, which has a sweet taste. The Lorikeets can detect energy-rich from the sweet taste of the feed. The aim of the study was to determine the influence of sweetness level and amino acid composition in palm sugar solution diets on feed intake of *T. haematodus*. The research method was completely randomized design arranged in a factorial with two factors. The first factor consisted of 4 types of palm sugars, i.e. aren, coconut, siwalan/palmyra, and nipah sugar with a different degree Brix in 13.5º, 14.0º, 14.5º, and 15.0º Brix.While the second factor consisted of two treatments, with and without the addition of the commercial baby biscuit. The results showed that the feed intake of Siwalan sugar was significantly higher than the other palm sugar solution diets. Siwalan sugar solution diet has high sweetness level, sucrose content and essential amino acid Lysine. This study provides the new information regarding the sweetness level of palm sugar and amino acid composition in the diet that can affect feed intake of *T. haematodus*. Therefore, this information will help to make a formulation of appropriate diet that meets the nutrient requirements especially amino acid for the birds.

Key words: Lorikeet; Nutrient; Palm Sugar

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INTRODUCTION

Palm sugar is also called brown sugar or in Indonesia called *gula merah* because of its colour. However, not all brown sugar called palm sugar since commercially brown sugars actually is often produced by adding sugar cane or molasses. Palm sugar is a processed product of tree sap (nectar) of palms such as aren (*Arenga pinnata* (Wurmb) Merr.), coconut (*Cocos nucifera* Linn), siwalan or palmyra (*Borassus flabellifer* Linn.), and nipah (*Nypa fruticans*) (Srikaeo & Thongta, 2015). Palm sugar is a natural sweetener with unique flavour and aroma as well as its nutritional content (Abdullah et al., 2015) that contain antioxidant compounds (Winarni et al., 2018). Sugar from palm sweeteners is mostly in the form of sucrose in addition to varying amounts of invert sugar present (Naknean et al., 2013). Invert sugar is the mixture of equal amounts of glucose and fructose (Yu et al., 2011). Sucrose has been accepted as a better energy source than starch in poultry diets (Hussein et al., 2016) since it can be easily utilized by poultry (Wang, 2014).

The lorikeets are highly efficient in utilising sugar (Köhler et al., 2010). According to Wolf et al. (2007), sugars are almost completely digested by lorikeets. It seems that differences in sucrase activity will make specialist nectarivores are higher in assimilation efficiencies for sucrose than in generalists (Napier et al., 2013). Prijono and Rachmatika (2019) reported that the lorikeets consumed 76.41% of its diet in the form of the brown sugar solution and the birds look healthy. Therefore, they concluded that the brown sugar solution based diet has potential to be used as an alternative carbohydrate source to substitute nectar based diets for lorikeet *(Trichoglossus haematodus)* in captivity. According to Gartrell (2000), the lorikeets predominantly feed on nectar and pollen in the wild, and other minor constituents of their diets are fruit, flowers and some invertebrates Nectar is a sugar rich food that provides the major energy source (Gelis, 2011) while pollen as a protein source for lorikeets (Pratt & Beehler, 2015)

Feeding lorikeets in captivity are one of the most challenging aspects of their care. Lorikeets prefer sweet diet, such as nectar. It is not practical to feed the birds with nectar in captivity. According to Prijono and Rachmatika (2019), nectar based diets could be substituted by the brown sugar solution based diet, which has potential to be used as an alternative carbohydrate source for *T. haematodus* in captivity. The major components of sugars are sucrose, fructose, glucose and maltose which make the sugars have a sweet taste (Sukoyo et al., 2014). In this study, we called brown sugar as palm sugar since all sugars types were used in this study were processed product of palm tree sap (nectar). Our objective was to determine the effect of sweetness level and amino acid composition of palm sugar solution on the feed intake of Coconut Lorikeet (*T. haematodus*) in captivity. The sweetness level of each palm sugar was assessed using sweetness index (sweetness as sucrose equivalent) and also tested using a hand held refractometer (REF-113 ATC, 0-32% BRIX/ATC) in degree Brix.The Brix reading indirectly indicates Total Soluble Solid (TSS) as well as the amount of sugar or the sweetness of the final product. Higher Brix means higher nutrient density (assumption), better taste (widely acknowledged), and resistance to rot, that mean a higher quality (Rane et al., 2016). The effort to feed the birds with proper diets to meet the nutritional requirements will support conservation effort for the birds.

METHODS

Birds care and housing

Ten wild coconut lorikeets (*T. haematodus*) from Ambon were kindly lent to us by Mr Suwita (CV Pasundan). The birds used in this study were kept in 5 cages measuring 90 x 55 x 60 cm. Each cage contained 2 birds (Figure 1).The cages used in this study were belonging to the Zoology Division, Research Center for Biology, The Indonesian Institute of Sciences (LIPI), Cibinong, Indonesia. In this study, the birds were fed with 4 types of palm sugar solutions-based diet (Figure 2) as the main diet. The types of palm sugar used were aren, coconut, siwalan/palmyra, and nipah sugar. The birds were also fed with supplemented diet including pellets, seeds (sunflower, red millet,and white millet seed) and fresh foods such as vegetables (cauliflower, broccoli, Chinese cabbage, long bean and corn on the cob), and fruit (apple). The birds were fed four types of palm sugar solution-based diet without commercial baby biscuit and with added three grams commercial baby biscuits.The palm sugar solution was placed in a cup (5 cm in diameter, 4 cm in height). Each two cups were put in the front and back of each cage, at the same height level (40 cm from the cage floor). This study was carried out with three replications.

Water for drinking was provided *ad libitum*. The coconut lorikeets enjoy bathing, therefore, the water in swallowing bowl was also provided in each cage for bathing.

Figure 1.Coconut lorikeet (*Trichoglossushaematodus*)

Aren Coconut Siwalan Nipah

Figure 2. Four types of palm sugar solution diets in cups (left to the right: aren (*Arenga pinnata* (Wurmb) Merr.), coconut (*Cocos nucifera* Linn), siwalan or palmyra (*Borassus flabellifer* Linn.), and nipah (*Nypa fruticans*)

To ensure that the birds were in a post-absorptive state at the beginning of each experiment, any uneaten food was removed at 06.00 a.m. on the previous day. Each experiment was run for 24 hours (from 06:00 a.m. to 06:00 a.m on the next day). For each bird, overall daily feed intake of each type of palm sugar solution diet was determined. Each cup containing the sugar solution diet was weighed before given to the birds in the morning, and the amount of the palm sugar solution left in the cup was weighed again in the next morning. Evaporative water loss was taken into account.

Temperature and humidity during the experiments varied from 20.3ºC to 31.9ºC and Relative Humidity = 49.3- 90.7%.

Sweetness level of palm sugar solution diet

The sweetness level of 4 types of palm sugar solution-based diets were assessed using sweetness index (sweetness as sucrose equivalent) and also tested using a hand held refractometer (REF-113 ATC, 0-32% BRIX/ATC) in degree Brix. Each type of palm sugar solution was tested in triplicate. A sweetness index was used to estimate the total sweetness perception as described by Obando-Ulloa et al. (2009) as sucrose equivalents (Suceq) according to the formula as follows:

$$\text{Suceq} = 1 \times [\text{Sucrose}] + 0.74 \times [\text{Glucose}] + 1.73 \times [\text{Fructose}]$$

Analysis

Sugar analysis was conducted at the Indonesian Center for Agro Industry (BBIA), Agro Based Industry Calibration and Analytical Laboratories (ABICAL), Ministry of Industry in Bogor is using HPLC (High-Performance Liquid Chromatography). While the proximate analysis and amino acid composition analysis were carried out at PT Saraswati Indo Genetech, Bogor. Data obtained of feed intake were analyzed using two-way Analysis. of Variance (ANOVA) and Duncan post hoc test by using a statistical analysis program SPSS. The research method was completely randomized design arranged in a factorial with two factors. The first factor consisted of 4 types of palm sugars i.e. aren, coconut, siwalan/palmyra, and nipah sugar, while the second factor consisted of two treatments, with and without the addition of commercial baby biscuit.

RESULTS AND DISCUSSION

Sweetnesss level (sweetness index and degree Brix)

Wild lorikeets obtain their carbohydrates predominately from the simple sugars in nectar (Pratt & Beehler, 2015), such as glucose, fructose, and sucrose (Beauchamp & Jiang, 2015). In order to assess the influence of sweetness level to feed intake by the birds, therefore the sweetness level was determined using sweetness index and tested with hand held refractometer. According to Beckles (2012), the sweetness index was calculated based on the content and sweetness properties of individual carbohydrates by multiplying the sweetness coefficient of each sugar. In this sweetness estimation approach, the contribution of each carbohydrate was calculated, based on the fact that fructose and sucrose were sweeter than glucose (Rosales et al., 2011). A sweetness index was used to assess sweetness as sucrose equivalent (Suceq). Based on these results, siwalan sugar showed the highest sweetness index (91.42 Suceq) followed by aren (79.43 Suceq), coconut (78.05 Suceq), and nipah sugar (76.61 Suceq) respectively (Table 1.). It seems that the highest sweetness index for siwalan sugar is due to the high sucrose content. The sucrose content of 4 types of the palm sugar can be seen in Table 1. However, based on tested sweetness level using hand held refractometer, this study found that siwalan sugar solution diet has lower value degree Brix (14.5º) compared than nipah sugar (15.0°), but it has a higher value degree Brix compared than coconut sugar (14.0º) and aren sugar (13.5º).This is contrary to the general principle that the value of degree Brix is used to determine the sucrose content. The existence of this discrepancy may be caused by the presence of other chemical content in Nipah sugar, such as higher in mineral content which gives the effect of greater light reflection (Pontoh, 2013). It seems that higher in mineral content can increase solution density, and thus cause light to refract (bend) more as it passes through a watery medium. Ash content in nipah sugar was the highest compared than the other palm sugars (Table 3.). Ash content represents the amount of total minerals present within a food (Afify et al., 2017). Non-sugar substances such as insoluble solid might concentrate on the molasses which contributed to the higher ash content (Payet et al., 2005). According to Rane et al. (2016), the Brix method does not measure sucrose specifically, but can also measure other solutes such as glucose, fructose, vitamins, minerals, amino acids, and proteins. Therefore, the sucrose content cannot be predicted by simply measuring the Briks value.

The highest sweetness index in the siwalan sugar solution diet can be a signal for the birds that the sugar contains high sucrose and energy. This study showed that the feed intake of siwalan sugar (33.83±10.83gram) was significantly higher over the other palm sugars. While the feed intake of coconut, nipah, and aren sugar were not significantly different (Table 2.). According to Wilson and Downs (2011), lorikeets *T. haematodus* are very active birds, so they require a large amount of a higher level of energy to maintain high metabolic rates. The lorikeets must consume a large volume of food to meet their energy requirements, since their food content high moisture (Gelis, 2016).

Furthermore, this study found that if three grams baby biscuits added to the palm sugar solution diets, the feed intake of nipah sugar was significantly higher (51.78±10.00 g) than the siwalan (41.75±10.26 g), and the other palm sugars (Table 2.). According to Prijono and Rachmatika (2019), siwalan sugar solution diet added with baby biscuit have higher energy content than siwalan sugar solution diet without baby biscuit. Therefore the birds were fed diets with high energy content, reduce the amount of feed intake. Kalmar et al. (2009) stated that lorikeets will adjust their "nectar" intake based on the energy density of the nectar to reach energy maintenance.

Table 1. Degree Brix, Sweetness Index and Sugar Composition of palm sugars from four types of palm tree

Parameter	Type of Palm Sugars			
	Aren Sugar	Coconut Sugar	Siwalan Sugar	Nipah Sugar
Degree Brix	13.50	14.00	14.50	15.00
Sweetness Index	79.43	78.05	91.42	76.61
Sucrose %	68.10	61.80	89.50	64.50
Fruktose %	4.24	6.67	0.26	5.31
Glucose %	3.27	6.36	1.58	3.94

Table 2. Feed intake of palm sugar solution (gram) without and with the addition of commercial baby biscuits in coconut lorikeet (*T. haematodus)*

Treatment	Feed intake of palm sugar solution (gram)			
	Aren Sugar	Coconut Sugar	Siwalan Sugar	Nipah Sugar
Without baby biscuit	21.93±5.87[a]	26.25±9.88[a]	33.83±10.83[b]	25.48±7.54 [a]
With added baby biscuit	47.3±14.15 [cd]	43.4±11.31[c]	41.75±10.26[c]	51.78±10.00 [d]
Total Consumption	69.23±11.55	69.65±6.13	75.58±5.70	77.27±5.05

[abc]Values within a row with different superscript indicate a significantly different result ($P < 0.05$) based on Duncan Test

Table 3. Nutrient composition of palm sugar (% dry matter)

Nutrient Componen	Aren Sugar	Coconut Sugar	Siwalan Sugar	Nipah Sugar
Dry Matter (%)	6.90	4.64	6.42	7.72
Fat (%)	0.49	0.76	0.10	0.70
Protein (%)	1.79	1.61	0.17	1.70
Ash (%)	1.21	3.59	0.09	3.76
Carbohydrate (%)	89.61	89.40	93.22	86.12
Gross Energy (Kcal/100g)	370.01	370.88	374.46	357.58

Amino acid composition

Nectar in the wild besides being a source of carbohydrates, also contains essential amino acids even though the protein content is low (Nicolson &Thornburgh, 2007). Birds consume nectars in large volumes in a day due to nectars are by nature low in protein (Gelis, 2011). Lorikeets are reported need lower protein in their diets than those of similar-sized granivorous parrots (Frankel & Avram, 2001).

Sugars are important energy sources, and amino acids are essential for protein synthesis (Toshima & Tanimura, 2012). Animals obtain essential amino acids by the consumption of plant or animal proteins. Proteins are digested into amino acid units, which are absorbed and then used to produce new proteins, generate ATP, make other amino acids are used as signals between cells. Protein intake is actively regulated around a nutritional optimum that is determined by age, physiological state and reproductive capacity, because the need for amino acids continues throughout an animal's lifespan (Simpson & Raubenheimer, 2012).

Palm sugars used in this study have high energy, low protein (Table 3.), and contain amino acids (Table 4.). Although siwalan sugar has the lowest protein content compared to the other palm sugars, but the feed intake and the content of lysine amino acid was the highest. Since a large volume of food eaten and the rapid passage time in the gut, the food may meet. requirements for the birds (Gelis, 2016).

Table 4. Amino acid composition(mg/kg) of four types of palm sugars

Amino Acids	Aren Sugar	Coconut Sugar	Siwalan Sugar	Nipah Sugar
Essential Amino Acids				
Phenylalanine	ND	ND	ND	ND
Isoleucine	ND	ND	ND	ND
Valine	ND	267.96	307.37	445.24
Arginine	927.33	ND	ND	ND
Glycine	603.11	733.16	859.84	1153.82
Lysine	278.37	257.76	366.09	ND
Leucine	ND	ND	ND	ND
Proline	ND	242.07	366.23	554.27
Threonine	395.30	387.78	601.25	620.92
Histidine	ND	ND	614.76	678.58
Methionine	4.58	72.66	ND	51.44
Tryptophan	ND	ND	ND	ND
Non Essential Amino Acids				
Serine	851.34	<830.17	1656.11	1933.01
Glutamic acid	3997.31	3309.88	ND	4157.12
Alanine	410.70	475.75	556.76	675.39
Aspartic acid	1726.75	753.49	608.85	1479.89
Tyrosine	9006.45	ND	301.84	ND

Animals regulate their protein intake by altering quantities of food eaten (Simpson et al., 2004) or by consuming a mixture of foods with the correct balance of protein and other macro nutrients (Simpson & Raubenheimer, 2012). There is still largely unknown about the regulation of protein intake is accomplished by the body's ability to detect the need for essential amino acids (Morrison et al., 2012). According to Koutsos et al. (2001), if there is an imbalance of amino acids, it will cause anorexia or lack of appetite so that feed consumption will be low. It seems that siwalan sugar has enough balance amino acids to fulfil the bird needs since the siwalan sugar solution diet showed the highest feed intake. According to Ferket and Gernat (2006), the first priority for the birds is to consume feed to satisfy their energy requirement. The second priority is to consume feed to satisfy daily amino acid intake requirements. Under free-choice feeding conditions where different dietary sources are available, birds will modulate their feed intake to satisfy both energy and daily amino acid needs.

Birds require 12 essential amino acids: phenylalanine, valine, tryptophan, methionine, arginine, threonine, histidine, isoleucine, lysine, leucine, glycine, and proline (Matson & Koutsos, 2006). However, from the results of amino acid analysis, not all essential amino acids were detected in palm sugars. In general, the four palm sugars that were given as lorikeet's diet did not contain several essential amino acids such as phenylalanine, isoleucine, leucine, and tryptophan.

The composition of amino acids of 4 types of palm sugars can be seen in Table 4. It shows that nipah sugar contains higher level of several essential amino acids compare than the others palm sugars such as valin (445.24 mg/kg), glycine (1153.82 mg/kg), proline (554.27 mg/kg), threonine (620.92 mg/kg), histidine (68.58 mg/kg), and methionine (51.44 mg/kg). However, this study showed that siwalan sugar contains the highest essential amino acid lysine. Lysine may be the single most important amino acid that affects the protein nutrition of captive birds since the birds unable to synthesize lysine and thus completely dependent on the diet to supply it (Grau and Roudybush, 1986). Yin et al. (2017) stated that the lysine level in the diet will adjust feed intake, it can modify the secretion of satiety hormones (leptin and cholecystokinin). According to Namroud et al. (2008), amino acid metabolite levels have been reported to serve as signals to regulate feed intake through an appetite-controlling mechanism., In this study showed that the lorikeets were fed palm sugar solution diet still look healthy and have shined, brightly coloured and smooth plumage the same as reported by Prijono and Rachmatika (2019). It seems that the amino acids content in the palm sugar solution diets were able to meet the amino acid requirement by the birds, especially lysin in siwalan sugar. Grau and Roudybush (1986) stated that if the birds were fed diets with the lowest lysine level, the feather growth of survivos was poor. According to Pratt and Beehler (2015) wild lorikeets obtain their protein from pollen found in flowering plants such as eucalyptus, while Van Tets and Hulbert (1999) reported that the eucalyptus pollen contain adequate levels of all amino acids except methionine. The result of this study also showed that the birds prefer siwalan sugar solution diets instead of this sugar was no detected methionine.

In the wild, he main protein source in lorikeet diets is pollen (Smith & Lill, 2008). Supplementing their nectar diet with pollen (Fleming & Moore, 2012) insects or spiders is therefore important, especially during seasons when the birds are moulting or breeding (Nicolson & Fleming, 2014). In order to meet the protein requirement for the birds, therefore the palm sugar solution as the primary diet should be added with other food as a protein source. Prijono and Rachmatika (2019) suggested that the commercial baby biscuit was chosen as an alternative for protein food since this biscuit has a sweet taste, contain 9% protein, rich in vitamin and minerals, and also favoured by the birds. This study showed that the feed intake of palm sugars added with commercial baby biscuit was also high especially in nipah sugar. Therefore, although the birds favoured the siwalan sugar solution diet, we suggested that the birds should be fed with siwalan sugar mixed with the other palm sugars such as aren sugar with high arginine content and nipah sugar with high valin, glycine, proline, threonine, histidine and methionine content, also with the other foods as sources of essential amino acids to meet the needs of essential amino acids. This study provides the new information regarding the sweetness level of palm sugar and amino acid composition in the diet that can affect feed intake of *T. haematodus*. Therefore, this information will help to make a formulation of appropriate diet that meets the nutrient requirements especially amino acid for the birds. Fulfill the nutritional requirements plays a huge role in maintaining the birds' health and their reproductive potential to support the conservation effort for the birds.

CONCLUSION

Palm sugar has a variation on sweetness level and contain a diverse amino acid profile. It seems that the sweetness level and amino acid composition in the palm sugar may affect the feed intake by coconut lorikeets (*T. haematodus*). The feed intake of siwalan sugar solution diet was the highest over the other palm sugar solutions. Siwalan sugar has high sweetness level, sucrose content and essential amino acid lysine.

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