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Frugivory by birds on *Schefflera morototoni* (Araliaceae) in a Cerrado-Amazon Forest transition area, eastern Mato Grosso, Brazil

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ABSTRACT

Schefflera morototoni fruits are important food source for neotropical frugivorous birds. The objectives of the present study were to record bird species that consumed fruits of *S. morototoni* in a forest in the transition Cerrado-Amazon Forest, Mato Grosso, Brazil and evaluate the potential of these bird species as seed dispersers of this plant species. During 31 observation hours, from November 1 to 5, 2011, 23 bird species were recorded consuming *S. morototoni* fruits. Out of these, 20 bird species were considered potential seed dispersers, as they swallow the fruits whole. The species consuming the greatest number of fruits were *Aburria cujubi* (24% of total consumed fruits), *Pteroglossus castanotis* (18%), *Tangara palmarum* (12%), *Patagioenas speciosa* (11%), *Ramphastos toco* (8%), and *Dacnis lineata* (5%). The species *T. palmarum* showed the highest visit frequency (VF = 1.51), followed by *P. castanotis* (VF = 0.80), and *D. lineata* (VF = 0.77). All bird species employed *picking* foraging method for removal of fruits and in 11 species (48%) this method was the only one used. Agonistic interactions represented 13% of the total number of visits. *Dacnis lineata* received the highest number of attacks and *P. castanotis* and *Pitangus sulphuratus* were the more aggressive species. The high bird richness and the great number of consumed fruits indicated that the fruits of *S. morototoni* may be an important food resource for birds in the Cerrado-Amazon Forest transition.

KEYWORDS: Avifauna, ecotone, seed dispersal.

Frugivoria por aves em *Schefflera morototoni* (Araliaceae) em área de transição Cerrado-Floresta Amazônica, leste de Mato Grosso, Brasil

RESUMO

Os frutos de *Schefflera morototoni* constituem importante fonte alimentar para aves frugívoras neotropicais. Os objetivos deste estudo foram registrar as espécies de aves que consumiram frutos de *S. morototoni* em uma floresta na transição Cerrado-Floresta Amazônica, Mato Grosso, Brasil e avaliar a potencialidade destas espécies de aves como dispersoras de sementes desta espécie de planta. Em 31 h de observações compreendidas entre os dias 01 e 05 de novembro de 2011, registramos 23 espécies de aves consumindo os frutos de *S. morototoni*. Destas, 20 foram consideradas potenciais dispersoras de sementes por engolirem os diásporos inteiros. As espécies que consumiram maior número de frutos foram *Aburria cujubi* (24% do total de frutos consumidos), *Pteroglossus castanotis* (18%), *Tangara palmarum* (12%), *Patagioenas speciosa* (11%), *Ramphastos toco* (8%) e *Dacnis lineata* (5%). A espécie *T. palmarum* apresentou maior frequência de visita (FV= 1,51), seguida por *P. castanotis* (FV= 0,80) e *D. lineata* (FV= 0,77). Todas as espécies de aves empregaram a tática de forrageamento *picking* para remoção dos frutos e 11 espécies (48%) utilizaram somente essa tática. Interações agonísticas representaram 13% do número total de visitas. *Dacnis lineata* foi a espécie que sofreu o maior número de agressões e *P. castanotis* e *Pitangus sulphuratus* as espécies mais agressoras. A alta riqueza de aves e o elevado número de frutos consumidos mostrou que os frutos de S. morototoni são recursos alimentares importantes para a avifauna na transição Cerrado-Floresta Amazônica.

PALAVRAS-CHAVE: Avifauna, dispersão de sementes, ecótono.

INTRODUCTION

Frugivory is an ecologically significant interaction between plants and animals, in which plants provide food and frugivorous animals disperse the seeds away from the parent plant, something that can reduce predation, competition, and contamination by pathogens. Furthermore, it increases the gene flow of the dispersed plant species and helps maintain natural community integrity (Snow 1981; Howe and Smallwood 1982).

Up to 90% of tree species in tropical forests produce zoochorous fruits (Howe and Smallwood 1982; Puig 2008). Birds stand out among vertebrate dispersers due to their abundance, mobility, and the frequency with which they eat fruits (Pizo and Galetti 2010). The neotropical frugivorous avifauna is represented both by families whose most species are highly dependent on fruits (≥ 75%) and by families with a smaller proportion of species dependent on fruits (< 25%) (Fadini and De Marco 2004).

The selection of fruits by birds is influenced by several plant attributes, including productivity, size, and color of the fruit, nutritional composition, presence of secondary chemical compounds, habitat structure, and vegetation composition (Staggemeier and Galetti 2007), as well as the bird's displacement distance to the foraging site (Levey *et al.* 1984). The evaluation of these attributes and their influence on the consumption of fruits allows an understanding of the processes of maintaining populations of fruiting plants and frugivorous birds.

Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae), popularly known as *mandiocão* or *morototó* in Brazil, is an evergreen, heliophilic tree species and it can reaching up to 35 m. It occurs from Mexico to South Brazil and Northeast Argentina, especially in open forest formations (Carvalho 2003). Fruit production is continuous with prolonged maturation, though annual fruit volume and maturity may be influenced by climatic factors (Franco and Ferreira 2002). Infructescences are abundant, green-purplish, and occur at the ends of branches, this provides contrast with the leaves and make it easier for the birds to locate those (Saracco *et al.* 2005). Fruits are fleshy drupes with an average width of 4-6 mm and average length 6-10 mm. They usually contain two flat seeds each up to 5 mm in length and with a < 1 mm-thick protein- and lipid-rich pulp covering (Snow 1971). They are considered an important food source for forest birds throughout the plants Central and South America range (Snow 1981; Sick 1997; Saracco et al. 2005; Parrini *et al*. 2013). Given the above, our objectives were: (i) to record the species of birds that consumed *Schefflera morototoni* fruits; and (ii) to evaluate the potential of these species as dispersers of seeds from this plant species in a Cerrado-Amazon Forest transition area in the state of Mato Grosso, Brazil.

MATERIALS AND METHODS

We conducted the study in a forest fragment in Fazenda Destino (12°51'S, 52°04'W), located some 30 km west of the town of Ribeirão Cascalheira, northeastern part of Mato Grosso state, Brazil. The region is characterized by semideciduous transitional forest at the Cerrado and Amazon Forest ecotone (Marimon *et al.* 2006). The climate is humid tropical: Aw type, according to Köppen's classification, and is characterized by two well-defined seasons, a dry (May to September) and a rainy season (October to April) (Silva *et al.* 2008). Average annual rainfall recorded at the Fazenda over the last thirteen years is 1,911 mm (data provided by Fazenda management). Altitude averages 330 m above sea level.

We observed two individuals *Schefflera morototoni* with an estimated height of 25-30 m during peak of fruit maturation. Trees were 1 km apart, both situated on the edge of a forest fragment, bordered by *Brachiaria* sp. (Poaceae) pasture. We conducted focal observations from 6:35 a.m. to 6:05 p.m., on five consecutive days, from 1 to 5 November, 2011. Observations were not continuous as rain occasionally interrupted the study. In total, we conducted 31 hours of focal observations at both individuals.

We evaluated the mode of consumption of fruit by birds, those that consumed fruit whole *in situ* or transported them from the site of the parent plant were considered potential seed dispersers (Howe and Smallwood 1982; Moermond and Denslow 1985). We recorded frugivory using an *ad libitum* methodology recommended by Pizo and Galetti (2010). We recorded all behaviors of individuals that consumed at least one fruit every visit. Birds that perched on the trees but did not consume any fruits were excluded from the analyses. From the arrival of an individual on the tree, we recorded: (i) the species of visiting bird, (ii) visit duration, (iii) the number of consumed fruits, (iv) how fruits were removed, (v) how birds processed fruits, and (vi) inter-intraspecific agonistic behaviors (when observed).

We used the terminology proposed by Moermond and Denslow (1985) for defining fruit-accessing behaviors: (i) *picking* – the bird catches the fruit landed, without extending its body or assuming a specific position, (ii) *reaching* – the bird extends its body below or above the perch to reach the fruit, (iii) *hanging* – the bird positions its whole body below the perch, with the ventral side upwards, and (iv) *hovering* – the bird catches the fruit during paused flight. We observed the avifauna and their feeding behaviors with the aid of binoculars (8×40 mm) roughly 20 m apart of plant.

Taxonomic classification and nomenclature of bird species follows the Comitê Brasileiro de Registros Ornitológicos (CBRO 2014). For the plant species we used the Lista de

Espécies da Flora do Brasil (2014). Classification of bird species diets followed Sick (1997), and Vieira *et al.* (2013).

We calculated the visit frequency (VF) for each bird species with at least one complete observation (bird was observed from its arrival on the plant until its departure) dividing the total number of visits of a particular bird species by total observation hours (Gondim 2001). We obtained the rate of consumption by each species by dividing the number of fruits consumed by each species by the total hours of observation (Pascotto 2006). We used Spearman's Correlation test to evaluate whether a correlation existed between number of fruits consumed and duration of visits. To verify whether fruit consumption differed among bird species we applied the nonparametric Kruskal-Wallis test (Zar 1999). We performed statistical analyzes with the software Paleontological Statistics (PAST), version 2.15 (Hammer *et al.* 2001).

RESULTS

We recorded 164 visits (5.29 ± 0.35 visits/hour) and the consumption of 2,426 fruits (78.25 ± 5.02 fruits/hour). We observed 23 bird species, belonging to five orders and 12 families, consuming *S. morototoni* fruits. Among them, 14 species belonged to the Order Passeriformes. The most strongly represented families in terms of number of species and visits were Thraupidae (6 species, 75 visits), Ramphastidae (4, 34), Picidae (2, 15), Tyrannidae (2, 14), and Icteridae (2, 2). Other families (Cracidae, Columbidae, Psittacidae, Tityridae, Contigidae, Turdidae, and Fringillidae) were represented by only one species each (Table 1).

Twenty bird species (87% of the total) were regarded as potential seed dispersers of *S. morototoni*, since they swallowed fruits whole enabling propagule dispersal away from the parent plant. Only *Forpus xanthopterygius* (Psittacidae), which crushed the seed, and *Tangara nigrocincta*, and *Tangara cyanicollis* (Thraupidae), which consumed only the pulp, were not considered dispersers of seeds. *Patagioenas speciosa* (Columbidae), *Melanerpes cruentatus* (Picidae), *Myiozetetes cayanensis* (Tyrannidae), *Ramphocelus carbo*, *Tangara palmarum*, *Tersina viridis*, *Dacnis lineata* (Thraupidae), and *Cacicus cela* (Icteridae) were observed consuming whole fruits and only the pulp. Therefore, we consider these species as potential dispersers, since they had at least one feeding bout involving the intake of whole seeds.

Fruit consumption significantly differed between bird species (Kruskal-Wallis $H_{(22, N = 164)} = 81.250$; $p < 0.001$). Those with the presenting a highest percentage of consumption were *Aburria cujubi* (Cracidae) (24% of total), *Pteroglossus castanotis* (Ramphastidae) (18%), *T. palmarum* (12%), *P. speciosa* (11%), *Ramphastos toco* (Ramphastidae) (8%), and *D. lineata* (5%). The species with the highest visit frequency was *T. palmarum* (VF = 1.51), which, in most cases, occurred in flocks of eight to 12 individuals. Other frequently visiting species were *P. castanotis* (VF = 0.80), followed by *D. lineata* (VF = 0.77), *M. cruentatus* (VF = 0.45), and *M. cayanensis* (VF = 0.29) (Table 1).

Species with a predominantly frugivorous diets accounted for 48% of consumption of *S. morototoni* fruits, followed by omnivorous (39%) and insectivorous (13%) species. The bird species which made only one visit were *F. xanthopterygius*, *Dryocopus lineatus* (Picidae), *T. nigrocincta*, *T. cyanicollis*, *C. cela*, *Icterus pyrrhopterus* (Icteridae), and *Euphonia rufiventris* (Fringillidae), and they accounted for 30% of the total.

We found a correlation between fruit consumption and duration of visit ($r = 0.878$; $p < 0.001$). Among the potential seed dispersing species, large frugivores, such as *A. cujubi*, *P. speciosa*, *R. toco*, and *Pteroglossus inscriptus* (Ramphastidae) accounted for 70% of the total consumption and had longer visits, whereas small frugivorous birds, such as *M. cruentatus*, *T. palmarum*, and *D. lineata*, accounted for shorter visits (less than four minutes), although these were more frequent. *Aburria cujubi*, *P. inscriptus*, *R. toco*, *Tityra semifasciata* (Tityridae), and *T. palmarum* defecated on plants while feeding. The same individual *A. cujubi* which defecated on the plant, as well as a *R. toco* individual, also regurgitated.

Pteroglossus castanotis and *Pitangus sulphuratus* (Tyrannidae) were the most aggressive species (n = 3 attacks), and *D. lineata* the most attacked species (n = 6). Interspecific agonistic encounters (n = 12) predominated over intraspecific encounters (n = 8). Intraspecific agonistic encounters were recorded for *A. cujubi*, *P. castanotis*, *P. sulphuratus* (n = 2), *M. cayanensis* (n = 2), *T. viridis*, and *D. lineata*, always involving only one individual. We observed the following interspecific agonistic encounters (aggressor species listed first): *Cotinga cayana* (Cotingidae) and *T. palmarum*, *P. speciosa* and *M. cruentatus*, *T. palmarum* and *D. lineata*, *T. palmarum* and *T. viridis*, *T. cyanicollis* and *D. lineata*, *C. cela* and *T. palmarum*, *M. cruentatus* and *T. palmarum*, *P. sulphuratus* and *M. cruentatus*, *M. cruentatus* and *T. palmarum*, *Turdus fumigatus* (Turdidae) and *D. lineata*, and *P. castanotis* and *D. lineata* (n = 2). We recorded a positive social interaction between two *T. palmarum* individuals that were foraging together, where one individual offered a fruit to another.

The foraging method most frequently used by birds for removing the fruits was *picking*, employed by all species and used as the sole means by 48% of them. Large frugivores which are highly dependent on fruits mainly used this method. *Pteroglossus castanotis*, *M. cayanensis*, *T. palmarum*, and *D. lineata* all used the catching method. The *hovering* method was mainly employed by insectivorous species, such as *T. semifasciata*, *P. sulphuratus*, and *M. cayanensis*, which employ similar tactics for catching insects in flight. The least frequently used method was *hanging*, but it was the most frequent method employed by *T. palmarum* and *P. castanotis*, species which also used other methods (Table 2).

Table 1. Bird species which consumed *Schefflera morototoni* (Araliaceae) fruits during 31 observation hours in a Cerrado-Amazon transition forest patch near the town of Ribeirão Cascalheira, Mato Grosso, Brazil. FRU = frugivorous; INS = insectivorous; OMN = omnivorous; PD = potential disperser; ND = not disperser. §Sick (1997); *Vieira *et al*. (2013).

Taxon	Number of visits	Duration of visits (seconds)	Diet	Number fruits consumed	Fruits/visit	Visit frequency	Potential dispersion
Cracidae							
Aburria cujubi (Pelzeln, 1858)	6	647 ± 628.8	FRU§	593	98.8 ± 82.6	0.19	PD
Columbidae							
Patagioenas speciosa (Gmelin, 1789)	4	413 ± 297	FRU§	273	68.2 ± 41.4	0.12	PD
Psittacidae							
Forpus xanthopterygius (Spix, 1824)	1	340	FRU*	4	4	0.03	ND
Ramphastidae							
Ramphastos toco Statius Muller, 1776	5	221 ± 55.4	FRU§	191	38.2 ± 18.9	0.16	PD
Pteroglossus inscriptus Swainson, 1822	2	451 ± 9.9	FRU*	65	32.5 ± 34.6	0.06	PD
Pteroglossus bitorquatus Vigors, 1826	2	381.5 ± 246.8	FRU§	36	18 ± 7.07	0.06	PD
Pteroglossus castanotis Gould, 1834	25	215.7 ± 270.9	FRU§	446	17.76 ± 13.86	0.80	PD
Picidae							
Melanerpes cruentatus (Boddaert, 1783)	14	121.2 ± 58	INS§	92	6.6 ± 3.9	0.45	PD
Dryocopus lineatus (Linnaeus, 1766)	1	445	INS*	47	47	0.03	PD
Tityridae							
Tityra semifasciata (Spix, 1825)	3	90.3 ± 48.8	INS§	16	5.33 ± 3.05	0.09	PD
Cotingidae							
Cotinga cayana (Linnaeus, 1766)	3	204.3 ± 98.6	FRU§	45	15 ± 1.73	0.09	PD
Tyrannidae							
Pitangus sulphuratus (Linnaeus, 1766)	5	142.2 ± 56.9	OMN*	37	7.4 ± 2.6	0.16	PD
Myiozetetes cayanensis (Linnaeus, 1766)	9	83.3 ± 36.7	OMN§	45	5 ± 2.6	0.29	PD
Turdidae							
Turdus fumigatus Lichtenstein, 1823	2	122 ± 36.8	OMN*	18	9 ± 1.41	0.06	PD
Thraupidae							
Ramphocelus carbo (Pallas, 1764)	2	156 ± 97.6	OMN*	14	7 ± 5.65	0.06	PD
Tangara palmarum (Wied, 1823)	47	107.3 ± 64.3	OMN*	293	6.34 ± 4.29	1.51	PD
Tangara nigrocincta (Bonaparte, 1838)	1	203	FRU§	12	12	0.03	ND
Tangara cyanicollis (d'Orbigny e Lafresnaye, 1837)	1	53	FRU§	3	3	0.03	ND
Tersina viridis (Illiger, 1811)	4	174 ± 120.1	OMN§	14	3.5 ±1.29	0.12	PD
Dacnis lineata (Gmelin, 1789)	24	118.4 ± 102.7	OMN§	137	5.7 ± 2.95	0.77	PD
Icteridae							
Cacicus cela (Linnaeus, 1758)	1	368	OMN§	33	33	0.03	PD
Icterus pyrrhopterus (Vieillot, 1819)	1	157	OMN§	9	9	0.03	PD
Fringillidae							
Euphonia rufiventris (Vieillot, 1819)	1	43	FRU§	3	3	0.03	PD

Table 2. Total number of *Schefflera morototoni* (Araliaceae) fruits consumed by birds at Ribeirão Cascalheira, Mato Grosso, Brazil (all fruit gaining methods combined).

Species	Picking	Reaching	Hanging	Hovering
Aburria cujubi	578	0	08	07
Patagioenas speciosa	273	0	0	0
Ramphastos toco	191	0	0	0
Pteroglossus inscriptus	65	0	0	0
Pteroglossus bitorquatus	36	0	0	0
Pteroglossus castanotis	415	11	14	06
Melanerpes cruentatus	84	05	03	0
Dryocopus lineatus	47	0	0	0
Forpus xanthopterygius	04	0	0	0
Tityra semifasciata	02	03	02	09
Cotinga cayana	41	0	04	0
Pitangus sulphuratus	10	05	0	22
Myiozetetes cayanensis	09	02	05	29
Turdus fumigatus	18	0	0	0
Cacicus cela	33	0	0	0
Icterus pyrrhopterus	07	02	0	0
Ramphocelus carbo	14	0	0	0
Tangara palmarum	203	40	44	06
Tangara nigrocincta	12	0	0	0
Tangara cyanicollis	02	0	0	01
Tersina viridis	10	02	0	02
Dacnis lineata	103	25	07	02
Euphonia rufiventris	03	0	0	0

DISCUSSION

Schefflera morototoni stands out among species the Araliaceae with regard to frugivory by birds, since it has nutritious and small fruits, which favor consumption both by small and large frugivores (Snow 1981). This indicates that *S. morototoni* is a generalist species with respect to its fruit dispersal of (Howe and Smallwood 1982), as it produces a large amount of small fruits consumed by specialist frugivores, such as *A. cujubi*, and generalist frugivores, such as *P. sulphuratus* and *T. fumigatus*. The production of attractive fruits to generalist frugivorous species is probably a strategy of the plant to favor the spread of its fruits in a variety of environments. This facilitates the colonization of new areas by frugivores that frequent preserved and altered areas (Manhães *et al*. 2003).

The fruits of *S. morototoni* are easy to remove and ingest, because there is no physical barrier that prevents or hinders their consumption by most birds. Fruits lacking capsules, such as *S. morototoni*, are more rapidly consumed by birds, and this makes visits shorter (Coates-Estrada and Estrada 1988). This reduces the possibility that the frugivore's foraging bout will be extensive, which decreases the changes of seeds being deposited close to their parent plant (Takahashi and Kamitani 2004).

Members of the Thraupidae are among the neotropical frugivorous birds most suited to seed dispersal (Sick 1997) and primarily act as dispersers of small fruits whose seeds are not easily removed from the pulp (Francisco and Galetti 2002). *Tangara palmarum* was the most frequently visiting species, and was third in terms of number of *S. morototoni* fruits consumed. Although Sick (1997) stated that some species of tanagers, as *T. palmarum*, are not good seed dispersers, due to their behavior of mashing the fruits and letting the seeds fall under the parent plant, this species was regarded as a potential seed disperser of *S. morototoni*. The behavior of swallowing the whole fruit was more frequent than discarding seeds. The results obtained for *T. nigrocincta* and *T. cyanicollis* are among the exceptions reported by Sick (1997), since these species were always observed discarding the seeds. On the other hand, species which discarded seeds, especially tanagers or species which dropped fruits, such as *D. lineatus*, can contribute to secondary dispersion.

Aburria cujubi showed higher consumption rate in relation to other species. On the other hand, it was the species with the longest visits, so that individuals of this species to defecate and regurgitate during foraging. However, we cannot neglect the importance of this species as a seed disperser, because this species was responsible for the largest amount of *S. morototoni* fruits consumed (24% of the total removed). Moreover, its seed dispersal efficacy was noted by Muñoz and Kattan (2007), who concluded that species of the Penelopinae subfamily play a significant role as seed dispersers, especially considering that seeds remain intact throughout the whole digestive tract of birds of this group.

The high number of specialist frugivores visiting *S. morototoni* was because of members of the Ramphastidae, since toucans, besides being primarily frugivorous (Galetti *et al*. 2000), are large appreciators of *S. morototoni* fruits (Sick 1997; Parrini *et al*. 2013). The Cotingidae family, represented in this study by *C. cayana*, is among the most efficient Neotropical bird families with regard to seed dispersal. According to Snow (1971), the seeds which are swallowed by species of this family do not suffer reduced viability. Indeed, they have higher germination rates.

The use of different methods to obtain fruits plays an important role in the frugivory and seed dispersal processes. This allows the removal of fruits from different portions of the same tree (Manhães *et al*. 2003). For instance, large birds that used the *picking* method were not effective at removing fruits of *S. morototoni* from the ends of the branches, whereas, birds such as *P. sulphuratus* and *T. palmarum* captured these fruits using the *hovering* method. Small birds, such as *D. lineata*, in turn, reached fruits at the tips of branches without hovering flight, a result of lower body mass.

Interspecific agonistic interactions represent a negative component in seed dispersal, since aggression can hinder fruit consumption by potential dispersers (Francisco and Galetti 2001). In this study, the frequency of agonistic interactions was low when compared to the total number of visits (13%), and is therefore not significant enough to negatively affect the process of seed dispersal of *S. morototoni*. *Dacnis lineata*, the most attacked species, was not considered as an efficient disperser, since most feeding bouts this species discarded seeds under the plant. In turn, *P. castanotis* and *P. sulphuratus*, the most aggressive species, were efficient dispersers. Thus, agonistic interactions between disperser birds do not reduce reproductive success of *S. morototoni*.

The number of bird species consuming *S. morototoni* fruits, both in this study and in that of Parrini *et al*. (2013), was high when compared with studies of other plant species using similar methodologies and sampling efforts greater that the current study (e.g. Francisco and Galetti 2001; 2002; Melo *et al.* 2003). The high richness of bird species with dispersal potential, different specific strategies for obtaining fruits and the high consumption of fruits suggest the existence of strong interactions between *S. morototoni* and the local frugivorous avifauna. Plants producing numerous, small, and nutritious fruits, such as *S. morototoni*, attract both large frugivorous birds, which have a high nutritional demand, and small frugivorous birds, which are able to swallow the whole fruits and, thus, disperse the seeds away from the parent plant (Snow 1981; Jordano *et al*. 2007).

CONCLUSIONS

In this study, we showed that *S. morototoni* is important food source for several bird species in the Cerrado-Amazon Forest transition region. In turn, the diversity of dispersal agents ensures the reproductive success this plant, as evidenced by the wide distribution of this species throughout Central America and South America.

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