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A New Diet on the Menu: Yellow Baboon Foraging on Cassod Tree (*Senna siamea*), A Trypsin Inhibitor Legume

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ABSTRACT

Cassod (*Senna Siamea*) which belongs to the family Fabaceae is the fast-growing leguminous tree with prolific seed production. The tree contains trypsin inhibitor proteins which are potentially deleterious to monogastric animals. Feeding behaviour of yellow baboons has been extensively studied in the savannah environment of East Africa. However, none of the study has reported on yellow baboon foraging on *Senna siamea*, this is the first study reporting on its consumption by yellow baboons in East Africa. We used focal animal sampling to collect data on yellow baboons' consumption of *Senna siamea*. Finding from the study indicated that, seeds were the only food parts consumed by yellow baboons from *Senna siamea*; and they were consumed more in the late dry season and never in the wet season. Seeds were consumed either unprocessed or processed by removing the seed coat. Consumption of proceed seeds were done more by adult females and sub adult males (small bodied individuals) than adult males. It is considered that the climatic changes witnessed around the globe might have provided baboons with wider food choices options and adaptation. Therefore, more studies on baboons' dietary choices are important for the understanding of their complex ecological adaptations.

Keywords: baboons - selective omnivorous - dietary breadth – protease - fallback food - dry season diet - foraging strategy.

INTRODUCTION

Cassod (*Senna Siamea*) is the tree in the genus *Senna* which includes perennial plants belong to the family Fabaceae (Silva *et al*. 2008). The genus *Senna*, is composed with almost 250-300 species widely distributed throughout the world, particularly in tropical and sub- tropical regions of Africa, Asia, Europe and Latin America (Silva *et al*. 2008). The most common and highly utilized among *Senna spp*, is the *Senna siamea* also known as *Cassia siamea* which is the native to Southeast Asia, and has been introduced to Africa and South America (Silva *et al*. 2008, Hassan *et al*. 2015). It is an evergreen, medium-sized (10-12 m on average) leguminous tree with many-branches (Rojas-Sandoval *et al*. 2013), and considered to be invasive due to its fast growth and prolific seed production (CABI 2018). In human perspective, *Senna siamea* is well known for its effectiveness in managing constipation and as narcotic pain relievers (Sofowora, 1996), and for treating diabetes, malaria and microbial infections (Oladeji *et al*. 2021). In animals, its uses are known to only limited as fodder to livestock (Orwa *et al*. 2009). On other hand, *Senna siamea* contains anti-nutritional compounds such alkaloids, saponins, tannins, oxalates and phytate (Smith 2009, Orwa *et al*. 2009, Ingweye *et al*. 2010), and trypsin inhibitor (Altmann 2009). The effects of trypsin inhibitor are well known to humans, including severe vomiting and uncontrollable diarrhea (Altmann 2009, Oladeji *et al*. 2021). To animals, the severity of its toxicity is known

to egg laying birds, pregnant goats and cows, and it is considered to be deleterious to monogastric animals (Furlan *et al*. 2014, Gotardo *et al*. 2017, Oladeji *et al*. 2021). In African wilderness, *Senna siamea* is never known to be consumed by animals but it has been used in afforestation, soil reclamation projects and as potential agroforestry species for shade and hedges (Rojas-Sandoval *et al*. 2013, Ecocrop 2019).

Baboons of the genus *Papio* (*P. ursinus, P. cynocephalus, P. papio, P. anubis and P. hamadryas*) are considered to be among the widely distributed animals in Africa (Barton *et al*. 1993, Barton and Whiten 1994). They are all known as "savannah baboons", except hamadryas baboon (Norton *et al*. 1987, Bronikowski and Altmann 1996). Savannah baboons inhabit a wide range of habitats including grassland steppe, open woodland, gallery forests and a mosaic of savannah and woodland (Alberts *et al*. 2005, Ndagurwa 2013). Because of the habitat diversity, savannah baboons are acknowledged as selective monogastric omnivorous with diverse and seasonally variable diet (Barton *et al*. 1993). They are known to selectively feed on grass blades, leaves, fruits, flowers, seeds, roots, bulbs, tubers, corn, gum and bark of various plant species. Included in their diet are also vertebrates and invertebrate animals, and product thereof (Norton *et al*. 1987, Barton and Whiten 1994). However, diet composition may vary between population reflecting the constraints of local habitats, rather than species specific adaptations (Baron *et al*. 1993, Hill and Dunbar 2002, Marais *et al*. 2006). Many studies have documented on the foraging behaviour of savannah baboons (Norton *et al*. 1987, Rhine *et al*. 1989, Barton *et al*. 1992, Bentley-Condit *et al*. 2018). However, none have reported on their consumption of cassod tree (*Senna Siamea*) in the savannah environment or any other ecozone.

Feeding and foraging behaviour of baboons in Mikumi National Park (MINAPA) has been extensively studied since 1975. Among these studies, is that of Norton *et al*. (1987) indicating that, baboons consume about 10% (190 plant) of plant species occurring in MINAPA which are over 2000 plant species. However, the list is currently believed to have expanded to 223 consumed plant species (ABRU unpubl database). The current list includes plant species such as *Vachellia sieberiana* (formerly *Acacia sieberiana*) and cassod (*Senna siamea*) which were not part of baboon food reported by Norton and others (1987). This implies that, yellow baboons have multiple foraging options and choices, and their actual food and forage options can vary across time, between troops and even between individuals. Because of the climatic changes across the globe, savannah habitats could be changing, thus present different resources for baboon to forage. This infers that, information on the dietary breadth of the genus *Papio* in the savannah environment is still needed despite of the wide studies on their feeding and foraging strategies.

This paper therefore, is reporting on the first observation of yellow baboon consumption of Cassod tree (*Senna siamea*) a considered anti- nutritional and toxic food to monogastric animals. The paper is reporting on: (i) part of *Senna siamea* consumed by baboon (ii) processing of *Senna siamea* before consumption (iii) seasonal variation in consumption of *Senna siamea*, and lastly (iv) sexual variation in consumption of *Senna siamea* by baboons.

MATERIALS AND METHODS

Study site

This study was conducted in Mikumi National Park (MINAPA) in the core range of habituated troops of yellow baboons, known as the Viramba troops. Viramba range, roughly extends from the Mgoda River to the park main gate in north-south direction, and 2 km east of the power line to Mkata River in the east-west direction (Norton *et al*. 1987) (Fig 1). The area is traversed by Tanzania-Zambia (TAZAMA) pipeline, and the Tanzania-Zambia

(TANZAM) highway. The vegetation types in the area are grassland, wooded grassland and *Brachystegia* or *Combretum* dominated woodland (Fig 1). Encompasses in the areas are also patches of lowland, montane and riverine forests. Such vegetation creates an important feeding and foraging zone for yellow baboons (Norton *et al*. 1987, Rhine *et al*. 1989). Mikumi National Park has a unimodal pattern of rainfall (ABRU unpublished rainfall records). The wet season usually lasts from December to May and the dry season from June to November which also corresponds to the coolest time of the year with the average annual temperature being 25.5ºC.

This research work complied with ethical protocol for conducting research on wild animals approved by Tanzania Wildlife Research Institute, and adhered to the legal requirement for conducting research in National Parks, as provided by Tanzania National Parks Authorities (TANAPA).

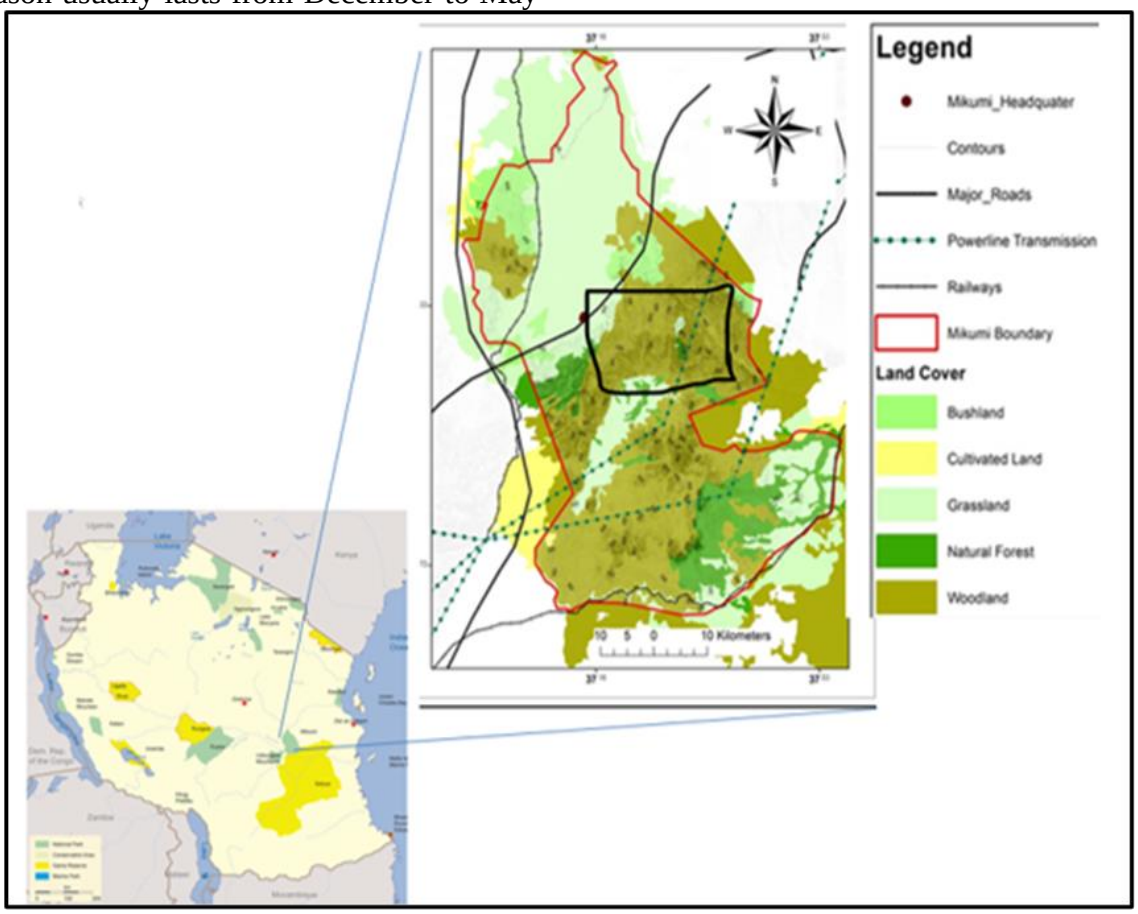

Figure 1: A map of study area, Mikumi National Park indicating the location of the study site, the Viramba troop range (black rectangle).

Data collection and Study animals

Data for foraging behaviour were collected using focal animal sampling technique; the most effective method for studying animal behaviour particularly for recording primate activities. Data were collected from adult males and females and sub adult male of two habituated troops of baboons. In total, the two troops had 61 individuals: 24 individuals in the first troop called V5 and 37 individuals in the second troop called V6. Animal were followed daily after locating the target troop at its sleeping site. A day was divided into four time periods of two and half hours each starting from 07:00 to 17:00. A maximum of 6 subjects were followed in a single period of the day. Each individual was followed for sixteen minutes, divided into 2 minutes intervals. Since data were collected from two different troops, data from a single troop

were followed for 4 consecutive days in a week then observations were switched to the other troop. Study subjects were randomly selected through rotary system, whereby names of adult female, male and sub adult males from the two troops were put in a container and a single name was randomly picked from the container and listed in a follow roster of a particular time period of a day. This was done to avoid bias that would have been caused by oversampling of most visible individuals.

One-zero technique was used for recording data on foraging behaviour. This technique was used because it allows the accurate recording of the occurrence or non-occurrence of multiple behaviours which vary considerably in frequency of behavioural bouts and typical durations. Species, part consumed and number of processing involved were recorded. Other information such as age-sex class of focal subject, date of data collection (in Julian calendar), seasonal quarter, time, location (GPS), habitat type and weather condition were recorded prior to focal animals follow. Most plant species could be identified in the field but were usually cross checked with the list of plant species by Norton and others (1987). All unidentified plant species fed by baboons were collected for future identification back in the office with the assistance from Mikumi herbarium and Animal Behaviour Research Unit (ABRU) plant guides.

Data analysis

Data analyses were carried out using Generalized Estimating Equations (GEE), to assess the variation in consumption of cassod between age-sex classes within a feeding follow. GEE analysed the proportion of intervals within a follow in which cassod consumption was recorded. Specific word equation used to test for the prediction on age-sex class variation is indicated below:

Cassod consumption =age-sex class +subject ID

Where: *age-Sex class* was treated as a fixed categorical explanatory variable and *subject ID* as random explanatory variable.

Response variable was assumed to be a binomial distribution with trial size of 8 and logistic model was used as a logit link function. A critical significance level of 0.05 was used to interpret results. “Test of Model Effects” was used to assess overall significance, while “Parameter Estimates” were used to assess where the differences lie between categorical explanatory variables. Wherever indicated, Error bars represent the standard error of the mean, unless explained otherwise.

RESULTS

Feeding records of yellow baboons

A total of 3838 follows were conducted in 270 observational days, over which adult females were followed in aa total of 2307 focal follows (Table 1). Adult females comprised more follows than both adult and subadult males because of their overall composition in a troop. Of the 3838 follows, baboons were recorded as feeding at least once in a total of 3074 follows, which is over 80% of all follows. During the whole study time baboons were recorded foraging on 93 plant species of different forms. Out of plant species consumed 31plants (33%) were trees including Cassod tree (*Senna siamea*). Foraging from Cassod tree by baboons was less frequent, account for 0.6% of overall feeding follows (3074) (Table 1).

Moreover, much as adult males had slightly higher proportion of consuming cassod (*Senna siamea*) than adult females and sub adult males (Table 1); further analysis on the amount of cassod consumption within follow (i.e., number of intervals per follow) indicated that there was no significant difference in the consumption of cassod (*Senna siamea*) between age sex classes (Wald X^2_2= 5.344, N= 101, P=0.229).

Table 1: Number of observations in which baboons were recorded feeding from *Senna siamea* based on overall follows and proportion of feeding follows by age-sex classes

Age-sex class	Number of focal animals follows			Proportion feeding	
	Overall follows	Feeding follows	Feeding on Cassod	Feeding follows	Cassod feeding
Adult males	756	557	5	73.7	0.9
Adult females	2307	1862	11	80.7	0.6
Subadult males	775	655	3	84.5	0.5
Total follow	**3838**	**3074**	**19**	**80.1**	**0.6**

Part consumed

Cassod tree (*Senna siamea*) produces four plant parts that are potential food for baboon; leaves, pods, flowers and seeds. However, baboons were recorded foraging on seeds only. The mean number of follows in which baboons were recorded foraging on Cassod seed for the entire study period regardless of age sex class was 13.05 follows (n=19; SD= 4.672; range 3-11 follows); and mean number of intervals baboons were recorded foraging on Cassod seeds at least once was 11.07 intervals (n=101; SD= 0.697; range 23-49).

Proportionally, adult females foraged on seeds in more follows (Fig 2a), and more intervals per follow than both adult males and subadult males (Fig 2b). However, this variation was not statistically significant ($F_{2,17}$ = 1.808, DF=2, P=0.194.

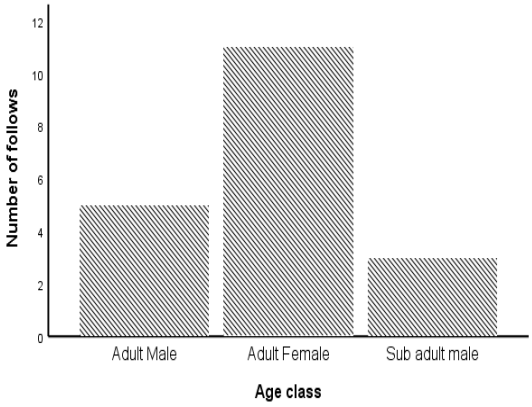

Figure 2a: Age-sex classes variation in consumption of cassod seed per number of follows.

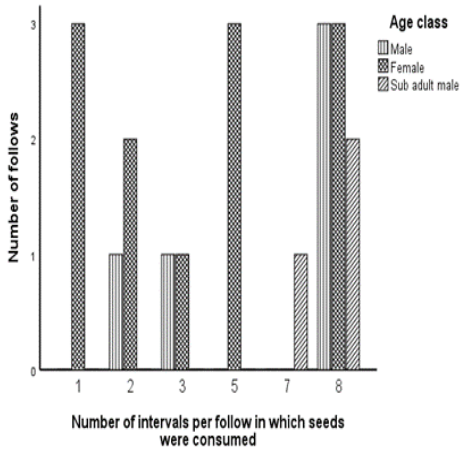

Figure 2b: Age-sex classes variation in consumption of cassod seed per number of intervals within a follow.

Processing of Cassod seeds before consumption

In almost all incidences where baboons were recorded feeding on seeds of cassod tree, they were either processing the seeds once by removing the seed coat or not processing the seeds at all before consumption. However, more often seeds were consumed unprocessed (Fig 3a). Further assessment indicated that seed processing was significantly different between age-sex classes (Wald X^2_2= 8.134, N= 101, P=0.017). Adult males rarely process the seeds before consumption unlike subadult males and adult females (Fig 3b).

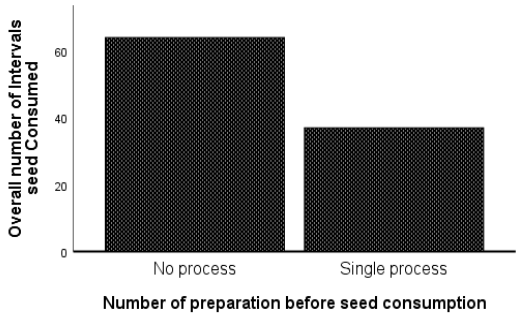

Figure 3a: Treatment of Cassod seeds before consumption by overall number of feeding intervals.

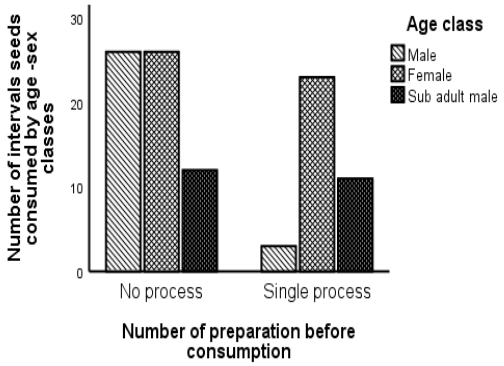

Figure 3b: Age-sex classes variation in treatment of Cassod seeds before consumption by age-sex class specific number of feeding interval.

Seasonal variation in consumption of Cassod seeds

For the entire study period (270 days), baboons consumed seeds of *Senna siamea* in dry season only. In MINAPA dry season is encompassed with early dry season (June-August) and late dry season (September-November). The consumption of cassod seeds by baboons were mostly during late dry season than in early dry season (Fig 4a). Moreover, adult females were recorded feeding on cassod seeds in fewer intervals per follow in early dry season than both adult and subadult males. However, the trend was reversed in late dry season where adult females were recorded feeding on the seeds in more intervals per follow than both adult and subadult males (Fig 4b).

Moreover, the variation in consumption of *Senna siamea* seeds was also observed between the time periods of the day. Seed were consumed more between early afternoon to midafternoon (12:00pm-1400pm) and less between late afternoon to evening (15:00pm-17:00pm).

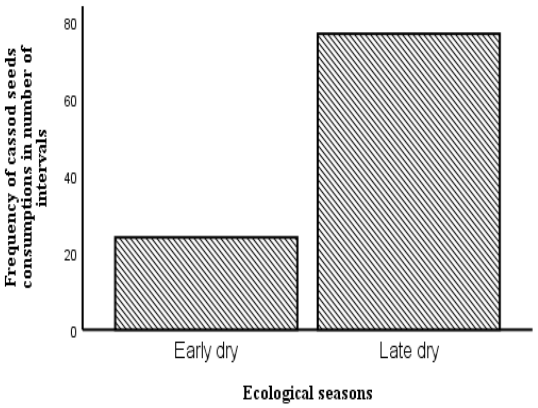

Figure 4a: Within season variation in consumption of Cassod seeds by overall number of feeding intervals.

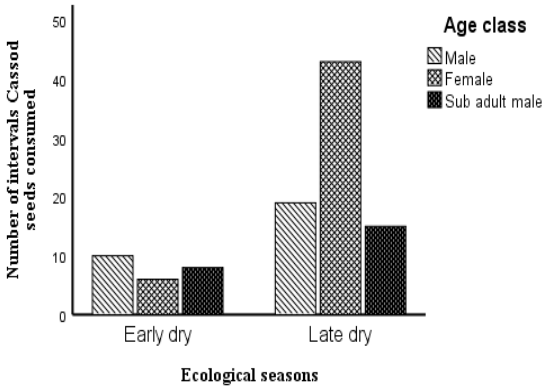

Figure 4b: Within season variation in consumption of Cassod seeds by age-sex classes.

However, adult female had more records of feeding intervals per follow in both time periods than adult and subadult males (Fig 5). Moreover, while adult female and subadult males had similar records feeding intervals per follow in early morning, subadult males were not observed foraging on cassod seeds in the evening (Fig 5).

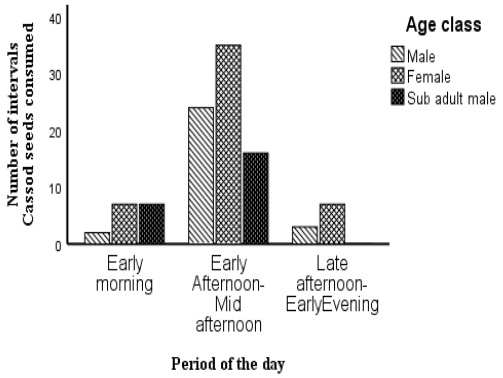

Figure 5: Variation in the frequency of consumption of cassod seeds by number of intervals in various periods of the day by age-sex classes.

DISCUSSION

Baboons were recorded feeding on *Senna* in very few feedings follows (20 feeding follows, less than 1% of all feeding follow-Table 1), and fewer intervals within follow. This is the first-time baboons are reported to feed on *Senna siamea*; findings will be discussed in reference to other studies in which yellow baboons have been reported to forage on other trypsin inhibitor plants. In that regard, two reasons may account for the current record of baboons feeding on *Senna siamea* in Mikumi National Park. Firstly, is the limited occurrence of cassod trees in MINAPA, most cassod trees (*Senna siamea*) occurs in the Southern part of the park, down the hill near water sources and at the tented camp near the gate. Because of their structure, they have been mainly used by baboons as sleeping site, so baboons were recorded feeding on cassod seeds only in the days they slept in it (the Cassod tree was sleeping site 265). Since yellow baboons can have a number of sleeping sites within their home range, frequent use of single sleeping site is rare, so this may explain the few records of feeding on *Senna siamea*. Before the year 2000, baboons of the study troop (Viramba troop) never used the southern part of their home range, they mainly concentrated in the Northern section of the park. This may explain why feeding studies conducted before 2000, such as Norton and others (1987), never recorded baboon feeding on Cassod seeds. In 2007, Viramba troop shifted the use of their home range from Northern part to Southern part where *Senna siamea* occurs. This shift is anticipated to have been influenced by the eruption of *Vachellia sieberiana* (formerly, *Acacia sieberiana*) in the south part (Norton per comm) hence provide new food choices for Viramba troop. Secondly, seasonal change; changes in seasons may lead into production of new food parts by plant species. In MINAPA, *Senna siamea*, produce more seeds in dry season especially late dry season which last for three months, from September to November, and it at this time when baboons consumed the seeds of cassod tree the most (Fig 3). The short time the late dry season exist in MINAPA can also account for the fewer records on baboon observed foraging on cassod tree. Impact of seasonal change on the use of habitat and diet of primates have also been reported by Altmann (2009) on yellow baboons in Amboseli Kenya. Altmann (2009) reported that, primate may shift their use of habitat and change into different diet as response to seasonality change of their habitat.

From the cassod tree (*Senna siamea*), baboons foraged on seeds only and completely avoided other plant parts like pods, flower and leaves. Based on their feeding behaviour on other leguminous plants like *Cassia memosaidea*, *Vachellia sieberiana* and *Vachellia tortilis*, leaves, pods and flowers from *Senna siamea* could have been their potential foods. Avoidance of these parts, and feed on seeds only could probably due to high toxic contents of these parts. The leaves, flowers and pods of *Senna siamea* has been described to contain anti-nutritional compounds such anthraquinones, alkaloids, phylobatannins, saponins, tannins, oxalates and phytate which cause digestive distress when consumed by monogastric animals like baboons (Smith 2009; Orwa *et al*. 2009, Ingweye *et al*. 2010). Similar finding on strategic feeding by yellow baboons through avoidance of some parts of

leguminous plants has also been documented from Amboseli in Kenya by Altmann and others (1987) and Altmann (1998). In their report, Altmann and others (1987) and Altmann (1998) documented that, yellow baboons strategically fed on pods of *Vachellia tortilis* and avoided other parts. In Amboseli, it is believed that, this was done probably to reduce the effect of trypsin inhibitor from seeds of *Vachellia*, the same can be applied in MINAPA to reduce the effect of trypsin inhibitors in the pods of Senna *siamea*. Throughout the study period, baboons were recorded feeding on cassod seeds from a single tree which they used as their sleeping site (sleeping site 265). Altmann (1998), documented on similar finding on the selective feeding by yellow baboons in Amboseli, where baboons were reported to selectively feed on specific trees and avoiding other with the same products. This selection is suspected to indicate lack of multi adaptative trait of primate toward trypsin inhibitor (Altmann 1998, Bentley-Condit 2009).

Most primate species are selective foragers, baboons for instance they typically feed selectively on food high in energy (Kamilar and Pokempner 2008) and protein (Barton and Whiten 1994) and less in fiber (Norton *et al*. 1987). The nutritional content of the food in turn, influence the behaviour and strategy with which the primate forage on that particular food. In this study it was observed that, seeds of cassod tree (*Senna siamea*) were either consumed once acquired (no processing) or processed once before consumption by removing the seed coat. Similar behaviour has been also reported by Altmann (1998) on baboon feeding on seeds of *Vachellia tortilis* (another trypsin inhibitor plant). It is anticipated that, feeding on cassod seeds without processing, increase protein intake of baboon by digesting protein contained in the seed coat (Altmann, 1998). Because, trypsin inhibitor is a protein, and if kept long enough along the digestive track of primates their molecule may split and allow primates to acquire more amino acid and less toxin (Altmann, 1998). This may also explain why adult males because of their high retention rate due to large body size, were most often consumed the seeds without processing. Seed processing was done by joint action of tongue and incisors to remove the seed coat. Similar processing has been described by Altmann (1998) when baboons were feeding on seeds on *Vachellia tortilis* in Amboseli, "the seed coats were removed from the seeds and discarded" (Altmann,1998). It is believed that by processing the seeds of Vachellia once, baboons reduce their trypsin inhibitor intake by more than 90%, and enrich the protein and carbohydrate intake by more than 80% and reduce the fiber intake (from whole pod) by 7% (Altmann 1998). Although concentration of trypsin inhibitor between *Vachellia spp* and *Senna siamea* may vary; the fact that the process reduces the intake of trypsin inhibitor and increase the intake of carbohydrate, similar reasons may explain why yellow baboons in MINAPA processed the seeds of *Senna siamea* before consumption. High carbohydrate and less fiber contents of naked seeds may better explain the observation that adult females and sub adult males were the once mostly processed the cassod seeds before consumption. This is probably due to their high demand of readily available energy influenced by their smaller body sizes (Kamilar and Pokempner 2008).

In this study, seeds of *Senna siamea* were consumed only during dry season between June to November, this indicates typical seasonal consumption. This implies that, seeds of *Senna siamea* were consume by baboons as a "fallback food" responding to seasonality change of their habitat in MINAPA. Changing of diet as feeding strategy on response to seasonal changes in the habitat is a common behaviour of different other animals including ungulates and other species of primates. Unlike some ungulates who response to this change by becoming seasonal migrants (Barton *et al*. 1992, Alberts *et al*. 2005, Hongo *et al*. 2018). Baboons, respond to decline of food availability in dry season by resorting to

fallback foods for extended period of time (Altmann, 1998). *Senna siamea* is less nutritious and contain toxic secondary compounds, its consumption by yellow baboons in dry season in MINAPA could be baboons' response to extended periods of drought and shift in home range. Resorting to fallback foods and reduction of choices of food items as response to extended periods of drought by primates has been reported in feeding observations of other primates (Altmann 1998, Bearder *et al.* 2006). This conforms with the definition of fallback food as "food eaten by animals at times, typically seasonal, when the arrays of foods available to them would result in diets of appreciably lower quality, much less nutritious and more deleterious to harvest and consume than the foods that the animals eat at other times of the year" (Altmann 1998, Pochron 2000, Hill and Dunbar 2002).

Cassod seeds were mostly consumed in the afternoon than in the morning and late in the evening (Fig 5). Consumption of cassod seeds in the afternoon from specific cassod tree which is allocated near water source (Korongo), is believed to have been purposely cynclonized by yellow baboons with time for drinking, although the study did not analyse data to support this. Study on the efficiency of trypsin inhibitor by Sabreena and others (2016) has indicated that, efficiency of trypsin inhibitors increased with increase in temperature. In that regard, consumption of cassod seeds in the afternoon during dry season subject baboons to more risks. However, strategic foraging of cassod seeds under the shed, where the temperature was presumed to be low believed to have profound effect in reducing the toxicity of the seeds hence affect the efficiency of trypsin inhibitor.

CONCLUSION

According to Bentley- Condit (2009), data on dietary choices of baboons are available for 19 populations from ten African countries. However, none of these have document on yellow baboon consuming *Senna siamea*, an exotic trypsin inhibitor plant in the savannah ecozone. This study provides empirical evidence on how and when yellow baboons forage of *Senna siamea* in MINAPA. The findings have indicated that, age, body size and/or sex has no influence on part of *Senna siamea* consumed by baboons. The study however, indicated that body size has significant influence on how the seeds were consumed by baboons. It is considered that probably, climatic changes that have been witnessed recently in the savannah ecozone might have provided baboons with new adaptations, hence wider options for food choices. This validates the need on the continuing studies on the baboons' dietary choices and breadth despite of monumental researches on this subject in the savannah habitat.

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