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Research article

A Study of the Feed Management Practices of Private Elephant Camps in Chiang Mai Province, Thailand

Sangtiwa Suriyong[1], Korawan Sringarm[2], Nattasak Krittigamas[1] and Pakkanut Bansiddhi[3,4,*]

[1]Department of Plant and Soil Sciences, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand
[2]Department of Animal and Aquatic Sciences, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand
[3]Department of Companion Animals and Wildlife Clinics, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100, Thailand

[4]Center of Elephant and Wildlife Health, Chiang Mai University Animal Hospital, Chiang Mai, Thailand

Abstract

Captive elephant must be properly fed to meet their nutritional demands, and to support optimal growth and development to achieve their providing conservation through tourism. This research aimed to study the feed management practices of private elephant camps in Chiang Mai province. An archival review and in depth interviews of key informants involving elephant camps owners or managers located in Chiang Mai were conducted. The interview showed that the main roughage of most camps was hybrid Napier grass, and in one camp, it was sweet corn plant residue. Most of the large-scale camps (more than 30 elephants), the meals were fed by the worker/keeper in the camp area. Elephants' dietary requirements were addressed under the supervision of veterinarians. The roughage were delivered by collectors both in large-scale camps coincided with a small-scale camp in which a middleman played an important role in gathering, harvesting, transporting and some feeding the roughage to the elephants raised in the camps. The elephant was fed 10 percent of their weight or about 100-120 kg roughage per individual. In most of the camp, roughage was divided into four to five meals per day. In small-scale camp, the elephants not only fed by roughage delivery, but also eat while traveling the hiking trails using elephants in greeting activities for eco-tourists. The camp also bought bananas and sugar cane from local farmers to sell to visitors for the purpose of feeding the elephants. However, a COVID-19 outbreak that occurred during the research period prevented the elephant camp from earning money from the tourism sector, which reduced the amount of feed available.

Keywords: Asian elephants, Elephant camps, Feed management, Nutrition, Roughages.

Corresponding author: : Dr. Pakkanut Bansiddhi, Department of Companion Animals and Wildlife Clinics, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100, Thailand. Tel.: +66 5394 8015, Fax: +66 5394 8015, Email: pakkanut.b@cmu.ac.th.

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INTRODUCTION

Asian elephants (*Elephas maximus*) are classified into the order Proboscidea, family Elephantidae and genus *Elephas*. The subspecies can be classified to three groups: Sri Lankan, Sumatran and Indian elephants. In Thailand and Southeast Asia as well as Borneo, most elephant are Indian elephant (*Elephas maximus indicus*). Asian elephants were raised by humans about 4000–5000 years ago and become associated with various fields and functions (Tennent, 1861; Carrington, 1958; Lahiri-Choudhury, 1991; Fleischer et al., 2001). However, the Asiatic elephant is one of the most famous endangered species by according to International Union for Conservation of Nature, and their report showed that the population has declined by at least 50% in the last three generations (Williams et al., 2020). In addition, it is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Today, they are not only global and cultural resources worthy of conservation, but also an important tourism resource of Thailand. Since 1989, when the logging was banned, most logging elephants have been used in the tourism industry. Elephant tourism in Thailand has developed and become an important socioeconomic factor. This has increased so much that elephant tourism can be considered one of the country's most important incomes (Bansiddhi et al., 2019). In 2020, the population of raised elephants in Thailand was made up of only approximately 3771–3971 individuals. According to data sources from the National Institute of Elephant Research and Health Service, in 2017, there were about 2700 elephants working in 223 tourism venues throughout the country (Bansiddhi et al., 2019).

Elephants are herbivores but not ruminants. Therefore, their digestion is inefficient. The weight of the elephant's stomach contents or extrapolation from feeding time and rate has been used to estimate their daily feed intake. A previous study reported that daily dry matter consumption for wild adult Asian elephants was calculated to be 1.5–1.9% of body weight (Sukumar, 1989). The animals weigh up to 3000–4000 kg and must consume 80 litres of water and 10% of their body weight in fodder each day, and only 40% of what they eat can be digested (Tipprasert, 2002; The National Elephant Institute, 2022). Feed passes through the digestive system about twice as quickly as ruminants, such as goats, sheep, cattle, and buffalo. As a result, elephants must constantly devour feed and can eat a wide variety of feeds. Likewise, the elephant excretes a lot of waste when it consumes a lot of feed. They urinate between 17 and 20 times per day (Santiapillai and Suprahman, 1986). Typically, elephants spend between 12 and 18 h of their daily calories on feed. Most of an elephant's diet consists of plants, particularly grass. They typically consume roughly 200–600 kg of plants a day (The National Elephant Institute, 2022). Vancuylenberg (1977) mentioned that roughage is a main feed of wild elephant. The feed of Asian elephants in Thailand is also classified into 5 types: grass, bamboo, creeper/vine, trees/palms/shrubs, and cultivated field crops such as paddy rice, sugar cane and banana (Sukmasuang, 2013).

In 2018, there were over 892 captive elephants in 82 small to large-scale camps in Chiang Mai, mostly located in Mae Tang and Mae Wang districts. Finding enough feed sources for the elephants' needs is consequently

important in the case of private elephant rearing. To study the management of elephant feed in Chiang Mai's elephant camps, Thailand, this research was undertaken through an interview survey and monitored the dietary requirements of elephants, which included different kinds of roughage feed. Then some raw material were analysed for their nutritive values. A survey was taken to establish the feeding practices used in large and small-scales tourist elephant camps.

MATERIALS AND METHODS

Study area and scale of private camp

The information of feed management and main roughage samples were investigated from July 2020 to January 2021. The study was carried out at eight private elephant camps in Chiang Mai, Thailand. The collections were selected according to the suitability of the elephant numbers in the camp, which mainly corresponded with the maintenance and feed requirements of the elephants. Generally, the proportion of camps in Thailand was indicated to follow standard criteria for organizing elephant camp activities for tourism (Department of Tourism, 2019). Then, data were collected from two scales of camp to represent the management of different elephant camp magnitudes in Chiang Mai province by following:

1) Large-scale elephant camps (>30 elephants) 4 sites: 3 sites in Maetang district (LM1, LM2 and LM3) and 1 site in Hang Dong district (LH1)

2) Small-scale elephant camps (2–15 individuals) 4 sites: 3 sites in Maetang district (SM1, SM2 and SM3) and 1 site in Maerim district (SM4)

Evaluation of feeding management

An interview survey was undertaken at eight elephant camps in Chiang Mai (large-scale camps: LM1, LM2, LM3, LH1, and small-scale camps: SM1, SM2, SM3, SM4). The respondents were met personally and interviewed using semi-structured questionnaires. The research data were collected through interviews with elephant camps managers and elephant caregivers. In-depth interviews were conducted after studying and comprehending statistical data and conducting research on elephant feed management, with an emphasis on integrated organizations to identify analysis issues and conduct interviews on related subjects. The question centered on elephants' feed preferences, feed supply management, source of raw materials used annually and cost and logistics of transporting raw materials. Additionally, topics related to remedies for feed shortage during the dry season and difficulties with elephant health were discussed. The information gathered during the interview was then organized and categorised. During our visits to each camp, sample of major forage roughage in the form of stem cutting and stocked for the elephants were collected from October to November, 2021.

Nutrient analyses

The roughage stem and leaf were chopped into small pieces. The samples were determined by oven drying and then ground. After that, it was time to analyze the chemical composition and nutritional value of the

feed. The chemical contents of these feedstuffs were examined according to Souphannavong et al. (2001), including oven-drying at 95–100°C for five hours to assess the dry matter (DM) (method 934.01). Ash was measured after samples were completely burned for two hours at 600°C in a muffle furnace (method 942.05). Using the macro-Kjeldahl method (method 2001.11), Crude protein (CP) was calculated as nitrogen x 6.25. Crude fat (EE) was extracted using the Soxhlet technique with dichloromethane as the solvent for 16 hours (method 920.39). Crude fiber (CF) was determined following method 962.09. The detergent fibre was analysed for neutral detergent fibre (NDF) (Van Soest et al., 1991) and acid detergent fibre (ADF) (Van Soest et al., 1991).

RESULTS

Feed management of large-scale elephant camps

The fourth huge elephant camp was spread out across various districts, with three in Maetang (LM1-LM3) and one in Hang Dong district (LH1) (Table 1). In practice, veterinary staff or veterinarians encountered feeding control for a sizable elephant camp (standing elephants of more than 30 individuals). Normally, individual elephants stayed with their mahout (elephant keeper), except when delivering a newborn; when the mahout would look after both. The majority of the place took care of more than 50 elephants in each camp and responded to feed handlers' supply for all of them. The elephants' feed requirements were overseen by veterinary advice.

Table 1 Comparison of the large-scale elephant camps in Chiang Mai, types of feed served and feeding rates.

	Large-scale elephant camp			
	LM1*	**LM2**	**LM3**	**LH1**
Elephant number	59	67	45	70
Main feed roughage	Sweet corn residue	Napier grass	Napier grass	Napier grass
Secondary roughage	Napier grass	Sweet corn residue	Sweet corn residue	Sweet corn residue
Roughage amount/individual	8 bundles/day or 100 kg/individual	Big elephant: 10-13 bundles/day, Young elephant: 7 bundles/day	Female elephant: 10-15 bundles/day, Male elephants: 20 bundles/day (about 7 kg/bundle)	10-15 bundles/ day /reduced to 10-15 bundles/day if elephant had no activity
Feeding time	4-5 meals a day, Fixed time	4-5 meals a day, Fixed time	4-5 meals a day, No fixed time limit	4-5 meals a day, Fixed time
Concentrated feed Pellet (In case of working in intensive activities, nursing mother and old elephant)	Elephant feed pellet brand "Erawan" 2 kg/individual/day	Elephant feed pellet brand "Erawan" 2 kg/individual/day	Rabbit feed pellet Brand "Randolph"	Horse feed pellet
Other feed	Banana and Sugar cane	Banana, Sugar cane, Banana stalk and Tamarind	Banana and Sugar cane	Banana and Sugar cane

* Large-scale elephant camps (>30 elephants) where 3 sites in Maetang district (LM1, LM2 and LM3); 1 site in Hang Dong district (LH1)

For preferred feed for elephants, most camps provided 2 different types of roughage. Three out of four were fed Napier grass cv. Pak Chong 1 (*Pennisetum purpureum* x *Pennisetum glaucum* 'Pak Chong 1') (Figure 1) or Bana grass (a hybrid *P. purpureum x P. americanum*), and the rest used solely or mostly on sweet corn plant residue (Figure 2). Young elephants were fed 7–8 bundles of fresh cut forage per day, while adult elephants were fed 10–13 bundles per day. Each bundle of forage weighed between 12 and 15 kg. According to the interviewee, the fodder weight per animal each day was approximately 100 kg. Whole amounts of grass were given 4–5 times per day, on average. The details were as follows: morning (feed before work) from 05.00–06.00, late morning at 9:00, noon at 12.00 (getting new grass), afternoon at 15.00 and dinner at 19.00 (big meal by giving as much as possible). Some camps' routines were not set for precise timekeeping but were nevertheless provide throughout the day. Some supplements, such as bananas and sugar cane, were purchased from local farmers for tourists to feed to the elephants. However, during the research period, there was an outbreak of the COVID-19 virus, which caused the elephant camp to lose revenue from the tourism industry, thus, the amount of feed given to each elephant was reduced. When grass became scarce, corn plant residue served as alternate feed, and when there was ultimately no supply of feed during the dry season, banana trunk was acquired as a substitute feed. Furthermore, elephants were given tamarind to eat when they were bloated or needed to take medicine. Small amounts of sugar cane and banana (Figure 3) were distributed to consume less feed that is high in calories.

Figure 1 Napier grass "Pak Chong 1" stocked and used as main roughage for elephant.

Figure 2 Sweet corn plant residue stocked and used as main/ minor roughage for elephant.

Figure 3 Basket of sugar cane and bananas served for tourist to feed elephants

Concentrated feed serves as a source of energy. The only type used for elephants was the trademark "Erawan". However, the supply must be obtained in large quantities, and if the consumer cannot use the product within 3 months, the pellets become mouldy and damaged. When some camps were unable to locate the pellet, feed for horses was used instead, because it is high in energy and easily accessible. The elephants were fed when they seemed thinner, when nursing mother appeared sleepy and consumed less grass, or when they were used in intensive working activities; the pellets were given at a rate of roughly 2 kg per day.

For feed supply chain management in large-scale camps, a portion of the roughage year round is produced in the camp's own region. As a result, the quantity produced was determined by plot size, as well as whether a large portion of the elephant camp's staple feed had to be purchased and picked up

from a roughage collector who served as an intermediary. The middleman played an important role in harvesting and collecting any roughage from a farmer's Napier or Bana grass field. Every morning (4:00–5:00 am), middleman who wished to buy sweet corn residue made appointments with farmers, who then traveled to those plots and delivered the corn residue to the camp between 11.00–12.00 am every day. They used their own effort to cut and hold a bundle of grass using bamboo sticks, which weighed between 12 and 15 kg. Then, using stall truck, it was transported directly feed the elephants or to stockpile it for future meals. For instance, a camp that housed 67 individual elephants requested the services of 3 middlemen daily for each truck whose container weighted between 2500 and 3000 kg, or more than 200 bundles. Each man may have his own contract and be both a farmer and a middleman. Nevertheless, the man who actually does the work is usually familiar with the owners of elephant camps, who were ensured that the fodder would be supplied each day without official contract, and the grass quality was certified. However, one camp's staple feed differed from others in that they fed the elephants sweet corn residue. The intermediary must next get in touch with the farmer who grows sweet corn for the can business, and the corn plant residue was harvested while it was still fresh after the ear was removed. In contrast, the camp that relied on sweet corn residue as its primary source had to find a secondary source, such as Napier grass, during the sweet corn residue shortage. As a result, their middleman made every attempt to discover the source of the roughage, especially during the dry season, when feeding problems were uncommon.

According to this study, a large-scale camp in Hang Dong district reduced the need for a middleman. When farmers in the surrounding region of the camp registered to plant Napier grass and sell it to the camp, which was responsible for harvesting (hiring for cut and bundle) and transporting it, there were no feed scarcity issues. Some problems also occurred when farmers did not arrange to sell Napier grass to one another and when some grass-planted places had a challenging terrain, making it difficult to cut and transport. When there are feed shortages, it may be essential to spend money traveling a great distance to acquire sweet corn residue.

For health issues of elephant in the camp, this study found some body injuries resulting from minor accidents. The same elephant frequently get gastrointestinal conditions, which were particularly prevalent in the winter and at the beginning of the year. Constipation with flatulence (bloat) was a common gastrointestinal condition found in geriatric elephants and in elephants that overeat and/or consume less water, especially in winter season, where old grass has a high fibre content. To prevent flatulence, the feed was switched from Napier grass to corn residue, and its stalk's length was decreased by cutting it into smaller pieces so that the elephant could chew it more easily. Sometimes, feed-induced diarrhea can contaminate mud and soil when it came into direct contact with unclean regions. In addition, fertilizer application in grass fields has been hypothesised to be the cause of diarrhea in the camps.

Feed management of small-scale elephant camps

For the feed management of the small-scale elephant camp (2–15 individuals), elephants were used in eco-tourism reception activities. The purpose of the excursion is to give tourists the opportunity to engage directly

in activities with elephants, such as water play and mud fermentation. Tourist-organized activities involve walking elephants and feeding them various forages as they make their way to the forest. As a result, elephants eat while on the daylong walk from 10:00 am to 3:00 pm. It appeared to be a day trip. This allows elephants to eat a variety of feeds in the forest. The elephant camp saves money on roughage because they do not have to look for feed during the day. Once the elephants have reached the shelter, forage preparation is also made available to them. Napier grass cv. Pak Chong1 is also the primary stable roughage (Table 2). The camp has two sources of feed: it grows naturally on camp-owned property, and during times of scarcity, it is replaced with sweet corn residue. Bananas and sugar cane were fed to the elephants by tourists.

A small-scale elephant camp (SM1), consisting of 11 individuals, also depended on middlemen for the supply of Napier grass or sweet corn residue of 1 vehicle as an additional truck every day. Napier grass weighs between 1500 and 2000 kg and costs 2000 Baht. Ten to twelve bundles of grass were fed per individual each day. The mahout was in charge of feeding the animal in the morning and evening. Lunch was added if the elephant was still in the camp, and served indefinitely or until the animal is satisfied. During the COVID-19 outbreak, tourism activity was slow, and there were fewer tourists. It was necessary to cut costs by reducing the amount of grass per elephant. Alternatively, during the COVID-19 virus pandemic, camps without a grass plot tried to find an area to cultivate grass in their own regions to feed the elephants to save money, and they sometime limited the amount of feed given to elephants to 8–9 bundles per head each day.

For pellet feeding, the small-scale camps used both horse feed and elephant feed in pellet form under the "Erawan" brand, especially for young elephants who had recently given birth. Currently, the Friends of the Asian Elephant Foundation and Thai Elephant Alliance Association provide funding to elephant camps to aid with various costs that arise in the camps during the period when there is no revenue from visitors.

However, other camps with lesser number of elephants used their own self-cultivated feed without a middleman. If the feed supply was insufficient, they would constantly beg and borrow from neighbors who had overgrown plots by gathering fodder that naturally grows in forests. The limitation of funds prevented the procurement of extra fodder, particularly during the COVID-19 pandemic.

Health issues and small injuries also occur in captive elephants in small-scale camps. An interviewee noted that the winter and the late rainy-early winter are the times of year when flatulence typically happens. However, such signs were quite uncommon in small-scale camps in this research.

The interviewee from one camp also reported that tooth decay was brought on by the elephant's consumption of sugar cane. Elephants lose their last set of teeth at age 45 according to information provided by the camp's owner.

Table 2 Comparison of the small-scale elephant camps in Chiang Mai, types of feed served and feeding rates.

	Small-scale elephant camp			
	SM1*	**SM2**	**SM3**	**SM4**
Elephant number	11	3	10	4
Main feed roughage	Napier grass	Napier grass	Napier grass	Napier grass
Secondary roughage	Sweet corn residue	Grass from the forest	Sweet corn residue in October	Sweet corn residue
Roughage amount/individual	8 bundles/day or approximately 100 kg/individual	300 kg/day or 150 kg/individual	12 bundles/day, Decreased to 8-9 bundles/day during COVID-19 pandemic	8 bundles/day or approximately 100 kg/individual
Feeding time	4-5 meals a day, Fixed time	No fixed time limit	4-5 meals a day, No fixed time limit	4-5 meals a day, Fixed time
Concentrated feed Pellet (In case of working in intensive activities, nursing mother and old elephant)	Elephant feed pellet brand "Erawan", Horse feed pellet	Elephant feed pellet brand "Erawan" from donation	Elephant feed pellet brand "Erawan" from donation	Elephant feed pellet brand "Erawan", Horse feed pellet
Other feed	Tree and herb in the forest, Banana stalk, Banana and Sugar cane	Grass from the forest, Banana stalk, Banana and Sugar cane	Tree and herb in the forest, Banana and Sugar cane	Tree and herb in the forest, Banana stalk, Banana and Sugar cane

* Small-scale elephant camps (2–15 individuals) where 3 sites in Maetang district (SM1, SM2 and SM3); 1 sites in Maerim district (SM4)

Nutritional value of sample roughage

The means of apparent nutrients digestibility (%) are presented in Table 3. The analytical results showed that the highest crude protein (CP) content was found in sweet corn residue (9.52%), which was low in fat content (3.52%). In addition, grass samples had a very wide range of CP between 4.16 and 7.33%, and fat was 4.11–5.5%. The values found in the present study showed a high variability in the fibre content (28.26–34.78%) and degradability parameters, reflecting a wide range of neutral detergent fibre (NDF) quality in each grass sample. Grass had a very wide range of NDF digestibility (74.83-83.20%). The acid detergent fibre (ADF) content of the grass sample was 41.72–52.05%, which was significantly higher than that of the other samples.

Table 3 Nutritional values of major roughage sample from various elephant camps in Chiang Mai.

Elephant Camp	Feed type	Moisture (%)	Dry matter (%)	Ash (%dw)	Crude protein (%dw)	Crude fat (%dw)	Fibre content (%dw)	NDF (%)	ADF (%)
LM1*	Napier grass Pak Chong 1	86.82	13.18	10.32	4.76	5.50	31.63	81.37	41.72
LM2	Sweet corn residue	90.49	9.51	9.41	9.52	3.82	31.95	73.19	37.83
LM3	Napier grass Pak Chong 1	86.21	13.79	10.29	4.26	4.28	34.78	81.51	50.19
LH1	Hybrid Napier Bana grass	92.20	7.80	10.88	7.33	4.11	30.27	75.13	49.05
SM1	Napier grass Pak Chong 1	88.12	11.88	10.97	4.52	4.49	29.91	83.20	51.17
SM2	Napier grass Pak Chong 1	87.58	12.42	10.76	4.16	4.27	28.26	74.83	52.05

dw = Dry weight

Data for the nutritional values represent the mean of triplicates.

* Large-scale elephant camps (>30 elephants) where 3 sites in Maetang district (LM1, LM2 and LM3) and 1 site in Hang Dong district (LH1); Small-scale elephant camps (2–15 individuals) where 3 sites in Maetang district (SM1, SM2)

DISCUSSION

Feeding an elephant alludes to the feed requirements of a horse. Elephant dietary supplies are based on a horse's dietary requirements. The feed quantity of elephants was based on the various types and needs of each elephant. Generally, feed intake was estimated and actual weight and body condition scores, representing 8-10% of the elephant's body weight and nutritional analysis data, were also used as reference for the proportion of dry matter intake. The proportion of forage in the diet represented 41 to 62% of the dry matter intake.

The quality of hybrid Napier grass, both cv. Pak Chong1 and Bana were the favorite varieties used in local camps in Chiang Mai. According to their diet, they were divided into two groups: concentrated feed, which contains less than 18% of the fibre typically found in fortified pellets, and roughage, which contains a variety of grasses. Roughage is naturally fed using the roughage-feeding concept between 16 and 20 hours each day. Typically, they continue to go along the forest path while hiking and grazing on various feed plants and tree branches along roadside. As a result, it should be possible to provide grass for elephants to eat virtually continuously throughout the day so that their intestinal motility may function regularly. According to this study, private elephant camps, typically divide feeding into four meals, morning (before work), lunch (during work), evening, and night time, to avoid interfering with tourist working hours. The mahouts who care for the elephants must work together closely to make these donations possible. The grasses most commonly used to feed elephants are those large trunks similar to cane, such as Bana grass and Napier Pak Chong1 grass. The benefits of these two types of grass include low cost, perennial forage crop with a high growth rate, high productivity and good nutrition (Wadi et al., 2004). However, the protein level of the grass samples from the private elephant camps was less than twice that of the 70-day-old sweet corn residue. Previous research confirmed that cutting interval of king Napier grass had a significant effect on the content of the chemical components. This indicates that extending the cutting interval (i.e., moving up the maturity age) considerably boosts dry matter and nutrient yields. It also raises the percentage of crude fibre, acid detergent fibre (ADF), neutral detergent fibre (NDF), and acid detergent lignin (ADL) in the plant, which are indicators of nutrient content. However, as the cutting interval increases, the percentages of crude protein and ash are noticeably reduced (Lounglawan et al. 2014). In addition, according to Jauhar and Hanna (1998), napier grass is a short-day plant with a critical light period of 12–13 hours (Pl@ntuse, 2022) that begins flowering in Thailand around September–October. As plants mature, they produce more fibre (Buxton and Redfearn, 1997).

A survey of captive elephant health status in Thailand by the Thai Elephant Conservation Center (TECC) in Lampang province identified a number of management-related problems. Gastro-intestinal problems were the most common cases (24%) with the most serious and the major cause of death. Gastro-intestinal problems were associated with feeding. Elephant food was often contaminated with the insecticide and fertilizer. If elephants are fed with such contaminated food, fermented food, or too much food, they developed dyspepsia and constipation (Angkawanish et al., 2009). Mahasavangkul (2022)

reported that constipation is mostly caused by eating feeds high in fibre that become tangled together until they are compressed into a lump, for example, eating leaves or a banana stalk without cutting into pieces. Previous study showed that nutritive value and digestibility of banana stem are low (CP 3.1% and CF 42.9%). The results show that pure fresh and fermented banana stems have low digestibility. However, their digestibility increased by 50% when mixed with concentrated feed (Arjin et al., 2021). Constipation is frequently associated with flatulence (bloat), which is caused by consuming excessive amounts of certain feeds, such as paddies, pellet, grain legumes, corn, old grass, and coconuts. The elephant, filled with anxiety, sits up, spreads his stomach, refuses to eat, and groans in pain. Furthermore, eating nitrate-rich feed is one of the causes of herbivore sluggishness. As a result, a private camp in this survey decided to feed its elephants freshly cut corn or sweet corn residue to avoid constipation. However, middleman is in close contact with farmers, who grow sweet corn, which must be planted continuously throughout the season, and the camp needs to respond for the feed cost expenses year-round. However, elephant camps that continue to feed on Napier grass also take precautions in their feeding practices, especially for old elephants and those with a history of flatulence. To lessen the length of the fibres consumed by elephants, they may consider chopping the feed into smaller pieces to reduce the amount of fibre. As a result, they may accumulate less fibre. The veterinarian who participated in the interview also mentioned that elephants tend to drink less water in the winter; therefore, stimulants that encourage frequent water intake were required.

Romain et al. (2014) found that the composition of elephants' diets at the Thai Elephant Conservation Center, Lampang province, was composed of forage in the diet ranged from 41 to 62% of the dry matter intake, while varied between 68 and 72% in the other collections. Commercial pellets made up between 8.5 and 24% of the diet, while in one collection, hulled rice made up as much as 25% of the dry matter intake. Smaller quantities of sugar cane, maize cobs, and fruits, such as bananas, were consumed. In addition, elephants were fed Bana grass (a hybrid of *Pennisetum purpureum* and *Pennisetum americanum*), Para grass (*Brachiaria mutica*), and Pangola grass (*Digitaria eriantha*) hay. This study showed that rearing in a large-scale elephant camp required some changes in the forage patterns and diversity. In addition, most elephants in large-scale camp were at risk of flatulence due to being raised inland and limited movement and exercise. They might be tied up in the forest until they are free of work, or have only a natural feed source when it is delivered by the mahouts. The elephants in small-scale camps were engaged in both exercise and digestion activities while traveling. Elephants and visitors worked by going on walks through the forest, allowing them to pick up twigs or grasses to eat anytime they pleased. As a result, there was less flatulence.

A similar hybrid Napier between Bana and Pak Chong 1 provided good efficiency such as adequate protein and low fibre to feed the elephants. The grass's quality, particularly the Napier grass age and range of fertiliser application, was ideally focused by the camps. The grass should be trimmed at the right period, which is ideally no later than 70 days after it has attained maturity. The intermediary can do this as well. Having staff carefully measure the age of the grass and take care of it has an impact on the long-term health of elephants. Usually, a healthy patch of Napier grass should not appear too young or too aged. Naturally, it thrives in regions with mean annual temperatures

between 21 and 40°C (Moore et al., 2006). The wet season had an evenly distributed rainfall, which results in leaf and stem growth of Napier grass (Tudsri et al., 2002) and rapid growth in the rainy season. As a result, the grass has good growth characteristics from late September to early October, providing the elephants with tasty feed without restricting the amount of feed they eat. Elephant can feel sick after eating a lot of feed. When flatulence or bloating happens, it can result in a loss of life, as well as economic value, because elephants are currently a protected species. In addition, cost efficiency of fertiliser application should be evaluated for reasonable of animal feed or biogas material aspects. High nitrate levels have been found in forage and tainted water, which are the main sources of nitrite exposure in animals (Cockburn et al., 2013). In northern Thailand, the grass has a reduced yield due to low temperatures at the end of year. There was a dry spell from December to March that would have further inhibited regrowth. Farmers occasionally prefer to wait to obtain great yields and heavy weights, but when the time comes, grass is not suitable for feeding elephants. The results also showed that harvesting and bundling of Napier grass were done without weighing; as a result, the weight of the grass varied seasonally and did not accurately reflect individual needs. In this investigation, a large-scale elephant camp in Hang Dong (LH1) had a truck scale at their own camp site for daily grass weighing demonstrated satisfactory operating and functioning.

In conclusion, the quality and quantity of staple roughage diet play an important role in elephant health. Elephants should be fed enough feed, which can be estimated from their body weight to maintain their body condition. Elephant camps should provide elephants with a variety of roughage and supplements throughout the day, which can also be achieved by increasing foraging opportunities in the nearby forest. Elephant camps should be aware of aging elephants by avoiding dry and old age grass and providing enough water. Feed production should be monitored closely including the age of grass, sanitation, and fertiliser application to prevent gastrointestinal problems in elephants. Therefore, farmers, collectors, mahouts, and camp proprietors should all gain knowledge and comprehension about forage and animal nutrition.

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AUTHOR CONTRIBUTIONS

Sangtiwa Suriyong: conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and tables, authored and reviewed drafts of the paper, approved the final draft.

Korawan Sringarm: conceived and planned the experiments, carried out the experiments, verified the analytical methods.

Nattasak Krittigamas: conceived the study, were in charge of overall direction and planning, provided critical feedback.

Pakkanut Bansiddhi: authored or reviewed drafts of the paper, approved the final draft.

CONFLICT OF INTEREST

The authors declare that they hold no conflicting interests with regards to the publishing of this manuscript.

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