Digestibility of Zoysia-type Grass by Japanese Deer

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Abstract Digestion trial was conducted on Japanese deer (Cervus nippon Temminck) to know the carrying capacity of Zoysia-type grassland in Nara Park. Three adult does of good temper were immobilized with succinylcholine chloride, weighed and moved into the feeding stall. These stall allowed quantitative control of feed intake and collection of fecal samples uncontaminated with urine or hair to study digestion coefficients for feed. Deer 1 (6 years old, 49 kg of body-weight) and Deer 2 (6 years old, 48 kg) were given Zoysia-type grass hay (Zoysia japonica Steudel) and Deer 3 (4 years old, 40 kg) was given alfalfa (2nd cutting) hay as a single component respectively. After the adjustment period of 5 days and the preliminary period of 10 days, total fecal samples were collected for 5 days and feed digestibility was studied. Average daily consumption of Zoysia-type grass was 13.8 g per kg bodyweight for Deer 1 and 18.8 g for Deer 2. That of alfalfa was 12.9 g for Deer 3. Apparent digestibility (%) of the proximate components and detergent fibers are as follows: dry matter in Zoysia-type grass, 65.0 for Deer 1, 62.5 for Deer 2; and that in alfalfa, 60.2 for Deer 3, crude protein, 74.0, 73.3; 65.3, ether extract, 61.7, 60.2; 48.8, crude fiber, 64.0, 62.6; 61.1, NFE, 65.4, 61.7; 60.8, NDF, 64.9, 66.5; 65.0, ADF, 64.4, 60.1; 60.0 and (NDF-ADF), 64.9, 72.6; 72.8 respectively. The digestible crude protein in Zoysia-type grass and alfalfa were 11.0% and 10.3% on dry basis. The total digestible nutrients for them were 64.0% and 58.4%. From the results of the experiment, it was supposed that Japanese deer could digest Zoysia-type grass, their favorite and common feed in natural conditions, very well and much more efficiently than alfalfa. The carrying capacity for Japanese deer of Zoysia-type grassland in Nara Park was estimated to be 12 to 14 head of adult deer per ha during the growing season of this plant from April to late September.


There grow more than one thousand Japanese deer (Cervus nippon Temminck) wild in Nara Park in a central part of the main island of Japan. Their main feeds have been Zoysia-type grass (Zoysia japonica Steudel) grown widely in this park. The acreage of the grassland is estimated to be 115 ha\(^1\). The deer are important wildlives and have long been kept from attacks by gutter dogs and rarely by hard hunters.

The number of deer has been fluctuating these ten years, which suggests that there are some environmental pressures on the carrying capacity of the grassland. Since Japanese deer in Nara Park is designated to be one of the Natural Treasures by Japanese government, the fluctuation of number of deer was remarked serious. Researchers have conducted many surveys and experiments to try to find the cause and to make an optimum population of deer in this park clear\(^2\).

The population dynamics and physical welfare of deer seem to depend principally upon their nutritional status. Therefore, Miyazaki et al.\textsuperscript{1,3,4,5} tried to estimate the carrying capacity of the grassland in Nara Park for deer by determining the annual production of nutrients from Zoysia-type grassland and digestibility by deer of high quality timothy hay containing almost equal chemical components to Zoysia-type grass. Total amount of nutrients was well estimated by multiplying the annual production of Zoysia-type grass in Nara Park by seasonal contents of the proximate components in this grass\textsuperscript{4,5}. However, it was hard to estimate the carrying capacity of the grassland appropriately, because of the large individual variation in digestibility between two deer used in that experiment. Dry matter digestion coefficient for timothy was 61.6\% for one deer and 47.6\% for the other, which seemed to be caused by the individual difference in the amounts of feed intake and fecal excretion\textsuperscript{3}.

At that time, there were some restrictions in capturing deer and in collecting Zoysia-type grass in Nara Park. Since tranquilizer gun was not permitted to cater the wildlife, two small young bucks were caught with a lasso and kept in the feeding stall for digestion trial. However, the animals moved about too actively and were too ill at ease to get the correct digestibility. Enough amount of Zoysia-type grass for digestion trial could not be collected from the grassland in Nara Park because of the regulation by the control act to keep the park beautiful. Therefore, digestion trial was conducted by using timothy hay as a single component for deer. Though this plant contained almost equal proximate components, it was not common feed for Japanese deer in natural conditions and seemed not to be suitable substitute for Zoysia-type grass.

Now it is easy to catch the adult deer of good temper from deer population in Nara Park, since tranquilizer gun is legally permitted to catch the wildlife there. It is possible to get enough Zoysia-type grass of equal quality to that in Nara Park from the green of the golf link near the park. The investigation reported here was undertaken to determine the digestibility of Zoysia-type grass, the favorite feed for deer, by adult does, dominant animals in deer population, captured by using a tranquilizer gun and kept comparatively quiet in the feeding stall.

**Experimental Procedure**

Three adult does of Japanese deer were used to determine the digestibility of Zoysia-type grass. They were immobilized with succinylchloride, weighed and moved into the feeding stall described in the previous paper\textsuperscript{3}. Age estimated by the method of OHTAISHI\textsuperscript{4} and body weight of the animals were as follows: Deer 1, 6 years old, 49\ kg; Deer 2, 6 years old, 48\ kg and Deer 3, 4 years old, 40\ kg. Deer 1 and Deer 2 were given Zoysia-type grass collected in Nara Country Golf Link late in May, as a single component. The grass was s\textsuperscript{un}-cured before feeding. Deer 3 was only given alfalfa (2nd cutting) hay.

The proximate components and detergent fiber contents (%) of Zoysia-type grass and alfalfa are shown in Table 1.
The digestion trial was conducted in three phases: (1) a 5-day adjustment period for feeding conditions, (2) a 10-day preliminary experimental period and (3) a 5-day fecal collection period (the experimental period). Since deer preferred Zoysia-type grass and alfalfa hay in the trough, average daily consumption of hay were 675g and 902g of Zoysia-type grass for Deer 1 and Deer 2, and 517g of alfalfa for Deer 3 during the experimental period. They were given hay once daily at nine in the morning. Trace mineralized salt block and water were available ad libitum. Fresh feces just after excretion were collected all the daytime to get the analytical fresh samples without any contamination with urine or hair and were weighed. In the night, though feces could not be collected freshly, feces dropped on the floor were gathered in the early morning and were weighed. By summing up the weights of feces in the daytime and the night, total weight was recorded daily for each animal. Analytical samples of feces were dried in a force-air oven at 60°C, ground through a 1mm screen in a Wiley mill.

Analysis of the proximate components of feeds and feces was conducted according to the usual method. Neutral (NDF) and acid detergent fiber (ADF) were determined according to the method of Goering and Van Soest.

Results and Discussion

Deer ingested considerably large amounts of Zoysia-type grass and alfalfa, which suggested that deer in Nara Park were not heavy consumers of browse but those of forbs and grasses. Average daily consumption of Zoysia-type grass was 13.8g per kg bodyweight for Deer 1 and 18.8g for Deer 2. That of alfalfa was 12.9g for Deer 3. Deer seem to prefer Zoysia-type grass, which have been dominant plant species in the park and main feed resources for deer. Although deer did not have any opportunities to access alfalfa hay in natural conditions, they ingested it well in the feeding stall. Acceptability of alfalfa hay seems to be rather good for Japanese deer.
Table 2. Apparent Digestibility of Proximate Components, Detergent Fibers and Digestible Nutrients of Zoysia-type Grass and Alfalfa by Japanese Deer

<table>
<thead>
<tr>
<th>Items</th>
<th>Zoysia-type Grass</th>
<th>Alfalfa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deer 1</td>
<td>Deer 2</td>
<td>Deer 3</td>
</tr>
<tr>
<td>Apparent digestibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>65.0</td>
<td>62.5</td>
<td>60.2</td>
</tr>
<tr>
<td>Crude protein</td>
<td>74.0</td>
<td>73.3</td>
<td>55.3</td>
</tr>
<tr>
<td>Ether extract</td>
<td>61.7</td>
<td>60.2</td>
<td>48.8</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>64.0</td>
<td>62.6</td>
<td>61.1</td>
</tr>
<tr>
<td>Nitrogen-free extract</td>
<td>65.4</td>
<td>61.7</td>
<td>60.8</td>
</tr>
<tr>
<td>NDF</td>
<td>64.9</td>
<td>66.5</td>
<td>65.0</td>
</tr>
<tr>
<td>ADF</td>
<td>64.4</td>
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<tr>
<td>NDF-ADF</td>
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<td>72.6</td>
<td>72.8</td>
</tr>
<tr>
<td>Digestible nutrients</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>DCP</td>
<td>11.0</td>
<td>10.9</td>
<td>10.3</td>
</tr>
<tr>
<td>TDN</td>
<td>65.3</td>
<td>62.9</td>
<td>58.4</td>
</tr>
</tbody>
</table>

Apparent digestibility of the proximate components and detergent fiber, and digestible nutrients of Zoysia-type grass and alfalfa are shown in Table 2.

Digestion coefficient for dry matter in Zoysia-type grass was 65.0% for Deer 1 and 62.5% for Deer 2, which was slightly higher than that of alfalfa (60.2% for Deer 3). Low digestibility of dry matter in Deer 2 seemed to be due to relatively low digestibility of crude fiber, induced by large intake of hay.

Alfalfa is known to be digested by cattle more than Zoysia-type grass is. However, dry matter digestion coefficient of alfalfa for deer was not so high as that of Zoysia-type grass. Alfalfa used in this experiment contained relatively high crude ash, which seemed to decrease apparent digestibility of dry matter. On the contrary, Zoysia-type grass used in this experiment was young and seemed easy to be digested. Furthermore, since this grass has long been main feed that Japanese deer could eat, deer in the park seem to be able to digest it well.

Crude protein digestion coefficient is considerably higher for Zoysia-type grass (74.0% and 73.3%) than for alfalfa (65.3%), though there was only a little difference in crude protein content between two kinds of hay (14.9% for Zoysia-type grass and 15.7% for alfalfa). Since digestion coefficient of crude protein by cattle was known to be 61% for Zoysia-type grass and 73-80% for alfalfa (2nd cutting)\textsuperscript{9}, it was remarked that deer digested crude protein of Zoysia-type grass more efficiently but digested that of alfalfa less efficiently than cattle did. MIYAZAKI et al.\textsuperscript{3} reported comparatively low digestibility of crude protein in timothy hay (67.8% and 58.1%) by Japanese deer living mainly on Zoysia-type grass. Besides, a large variation in apparent digestibility of nitrogen has been observed in elk (Cervus elaphus nelsoni) ingesting different kinds of forages\textsuperscript{8}.\textsuperscript{8}
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Usually, alfalfa (2nd cutting) is known to contain crude protein from 19.4% to 24.4% in dry matter\(^9\). However, alfalfa in this experiment contained crude protein only 15.7% in dry matter, which was considerably low for this kind of legume. Therefore, deer was given alfalfa of low quality in this experiment. On the contrary, Zoysia-type grass collected late in May were young and of high quality. They contained crude protein as much as 14.9% in dry matter, which was frequently observed in young grasses in their early growing stages and in young after-math grasses\(^9\).

Deer in Nara Park usually grazed lush after-math Zoysia-type grass of high quality since periodical changes in the proximate components were known to be small during their growing season from April to late September, which kept them in good nutritional conditions.

The digestibility of ether extract was remarkably higher for Zoysia-type grass than for alfalfa, indicating that deer seemed to be able to utilize crude fat in Zoysia-type grass more efficiently than that in alfalfa.

Apparent digestibility of crude fiber by deer was slightly higher in Zoysia-type grass (64.0% and 62.6%) than in alfalfa (61.1%). Crude fiber digestion coefficient of more than 60% for deer seemed to be higher than that for cattle ranging from 46% for low quality alfalfa (2nd cutting, blooming) to 55% for that of high quality (2nd cutting, pre-blooming)\(^9\). It means that deer seem to have superior capability to digest crude fiber more efficiently than cattle do. Since Fennessy et al.\(^11\) reported that red deer could digest hemicellulose and cellulose more efficiently than sheep did, digestive capability of wild deer seems to be superior to that of domesticated ruminants such as cattle and sheep. Davis\(^12\) reported that animals such as the eland and water buffalo which lived successfully on much coarse feed than cattle, had to have within their rumens, microorganisms that could more effectively attack the coarse feeds and convert them into usable energy sources and protein.

In the previous paper\(^3\), the authors reported that digestibility of crude fiber was considerably low in young buck moving about actively in the feeding stall (42.4% and 21.9% for timothy), because digesta seemed to be passed rapidly through the digestive system. Vangilder et al.\(^13\) also reported that low digestibility of leaves of woody species was induced by passage of digesta in digestive tract. However, adult does captured for this digestion trial were good-tempered and did not rush about wildly in the feeding stall, which seemed to contribute to such a high digestibility of crude fiber.

Digestibility of NFE in Zoysia-type grass by deer was 65.4% and 61.7%, which were slightly higher than that in alfalfa. However, it was pointed out that NFE was composed of many components of different digestibility by ruminants and was not homogenous\(^14\). Therefore, the authors determined the digestibility of NDF and ADF in Zoysia-type grass and alfalfa in this experiment.

Though NDF content was considerably higher in Zoysia-type grass (65.6% dry basis) than in alfalfa (55.3%), digestibility of this component was almost similar for both plants in this experiment. The authors supposed that deer in Nara Park are
good digester of Zoysia-type grass. Although digestibility of NDF in Zoysia-type grass was almost equal to that in alfalfa, individual difference was observed in digestion coefficient for ADF in Zoysia-type grass between two deer, which results in low digestibility of hemicellulose (NDF–ADF) in Deer 1 and its relatively high digestibility in Deer 2 and Deer 3. Digestion coefficient of 60% or more for ADF in Zoysia-type grass and alfalfa by Japanese deer is much more than in alfalfa by elk and white-tailed deer (49.8% and 34.8% respectively) reported by Mould and Robbins. It suggests that digestive ability of Japanese deer is high. It is also interesting that deer in Nara Park can digest hemicellulose in Zoysia-type grass well, which contains considerable amount of hemicellulose all over the growing season.

Digestible crude protein (dry basis) of Zoysia-type grass was calculated to be 11.0% for deer, which was higher than that for cattle (7.3%) reported in the standard tables of feed composition in Japan. DCP of Zoysia-type grass for Japanese deer was slightly higher than that of alfalfa in this experiment. Eissfeldt reported that digestibility of nitrogen in Roe deer (Capreolus capreolus L.) was 50% for general roughages but was more for forages selected by this animal itself and ranged from 60% to 90%. Therefore, Japanese deer in Nara Park seemed to digest more crude protein in Zoysia-type grass, the favorite feed for them, than in the other forages such as alfalfa in this experiment and timothy (DCP for deer, 8.2%-9.5% dry basis) in the previous experiment.

Syrjala-Quist reported that crude protein digestibility was lower in reindeer (69%) than in sheep (75%) when reindeer was given cocksfoot silage which was not common feed for this animal. In such a case, feed intake of reindeer reduced seriously and was 16 g per kg bodyweight, though intake of silage was 27 g for sheep. In this experiment, deer ingesting Zoysia-type grass seemed to be able to digest crude protein in their common feed.

Total digestible nutrients (dry basis) of Zoysia-type grass was 62.9-65.3% for Japanese deer which was remarkably higher than that for cattle (57.4%). Blankenship et al. reported in Texas that in vitro dry matter digestibility of 26 species of range plants by white-tailed deer (Odocoileus virginianus) was higher than by steers, and overall efficiency of the plants was in the order; white-tailed deer (52.5%), goats, sheep and steers (46.6%). Therefore, wild ruminants were supposed to be generally superior in digestive ability.

It was remarked that TDN content of Zoysia-type grass was higher than that of alfalfa for deer. Alfalfa (2nd cutting) was known to contain DCP from 14.2% to 19.4% dry basis and TDN from 53.6% to 62.4% for cattle. However, DCP content was very low and was only 10.3% for deer in this experiment. This finding seemed to be supported by the observation of Syrjala-Quist, who reported that the number of rumen microorganisms was fewer for reindeer ingesting grass silage which was not popular feed for this animal. It indicated that it took a long time for the wild-lives to adjust to the artificial feeding conditions.

Miyazaki et al. previously reported that digestibility of crude fiber was consid-
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erably low in Japanese deer from the experiment with timothy hay, but crude fiber of Zoysia-type grass was known to be easily digested by Japanese deer in this experiment. It suggested that digestion trial should be conducted by using the same feed as the wildlives ate to know their true digestive efficiency. Though the animals were fed substitute plant containing almost equal proximate components, there seemed to be some non-negligible species differences in digestibility. From the result of the digestion trial using Japanese deer and Zoysia-type grass, it is apparent that Zoysia-type grass is rich in digestible nutrients and can provide considerable amounts of nutrients for deer in Nara Park.

Now, the authors try to estimate the carrying capacity for deer of Zoysia-type grassland in Nara Park. According to the work by Wheaton and Brown, there was no difference in feed consumption per unit bodyweight between sexes and no seasonal difference in the digestibility of feed in white-tailed deer. Therefore, the authors suppose that there is no sexual and seasonal differences in digestibility in Japanese deer during the growing season of Zoysia-type grass.

There is no report describing the nutrient requirements for Japanese deer. Therefore, the authors arbitrarily decided average daily requirements of DCP and TDN for adult deer of 50 kg bodyweight as to be 0.15 kg and 1.50 kg respectively. Since the wildlives seem to move about actively, the figures for DCP and TDN are to be more than the maximum requirement for the domesticated ruminants on grazing.

Zoysia-type grassland in Nara Park was known to produce dry matter of 5-6 tons per ha. The average contents of DCP and TDN for Japanese deer were calculated to be 11.0% and 64.0% in dry matter in this experiment. Then, annual production of DCP and TDN of Zoysia-type grassland in this park seems to be 0.55-0.66 tons and 3.2-3.8 tons per ha. Those amounts of nutrients are presumed not to undergo any change during their growing season from April to late September. The carrying capacity estimated by TDN production in the grassland would be 12 to 14 deer per ha for half a year. Therefore, 1380 to 1610 head of adult deer could be fed in the grassland of 115 ha in Nara Park.

In this tentative calculation, one deer is estimated to ingest 2.3 kg of Zoysia-type grass (dry matter) per day as a single component to get enough energy to maintain itself and to move about vigorously in natural conditions. This amount of feed would be slightly over-estimated because deer are supposed not to be able to ingest such a large amount of dry matter. Furthermore, one-sixth of deer in the population were known to be fawns of less than one year old. They were far lighter than average adult deer and they required less nutrients for living and would ingest less feed than adult deer. Therefore, the carrying capacity of 12 to 14 head of deer would be under-estimated. Anyhow, it would be safe that the maximum amount of feed intake is taken into account.

Now the number of Japanese deer in Nara Park is reported to be 1075, which is far smaller than the above-mentioned number of the animals that Zoysia-type grass-
land could support during their growing season of about half a year. In addition to Zoysia-type grass, there are considerable amounts of miscellaneous grasses and legumes in woods in the park. Ricebran cracker and garbage that sightseeing tourists and residents in Nara city supply to deer should not be neglected as feed resources for the wildlives. Therefore, a large amount of nutrients would be saved for deer in the blasted Zoysia-type grass for wintering. However, since it has been observed that deer frequently eat buds and bark of miscellaneous trees in winter, the population dynamics of Japanese deer in Nara Park depend on the amount of nutrients available in the hard winter.

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References

ニホンシカによるシバの消化率について

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奈良公園のシバ草地に棲息する天然記念物ニホンシカの生活調査を決定するための調査の一環として, ニホンシカによるシバの消化率を測定した。麻酔剤を用いて, 3 頭の成雌シカを捕獲し, 養殖分離の可能な飼育室内に入れ, 5 日間の調査, ついて 10 日間の仮眠飼育ののち, 5 日間調査期間として, 全糞採取による消化試験を行なった。1号シカと2号シカにはシバ乾草, 3号シカにはアルファルファ（2 番刈り）乾草を 1 日 1 回給与した。その摂取量は 1 日, 体重1kg 当たり, 1号シカで平均13.8g, 2号シカで18.8g, 3号シカで12.9gであった。一般成分, NDF および ADF についての見かけの消化率（%）は, つぎのようであった。シバの乾物, 1号シカ, 65.0, 2号シカ, 62.5; アルファルファの乾物, 3号シカ, 60.2, 粗蛋白質, 74.0, 73.3; 65.3, 粗脂肪, 61.7, 60.2; 48.8, 粗れんが, 64.0, 62.6; 61.1, NFE, 65.4, 61.7; 60.8, NDF, 64.9, 66.5; 65.0, ADF, 64.4, 60.1; 60.0, へミセルロース（NDF–ADF）, 65.4, 72.6; 72.8。そして可消化粗蛋白質含量はシバとアルファルファで, それぞれ乾物当たり11.0％と10.3％,可消化養分総合は同じく, 64.0％と58.4％であった。その結果, 奈良公園に野生するニホンシカは, 常食しているシバを消化する能力についてきわめてすぐれており, 公園内のシバ草地の牧養力は, シバが生育する 4 月から 9 月末にかけての半年間は 1 ヘクタール当たり, 成動物として12〜14頭と推定された。

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