DIGESTION TRIALS WITH THE COLLARED PECCARY,

TAYASSU TAJACU (L).

by

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ABSTRACT

Two female collared peccaries were tamed and accustomed to living in metabolism crates for five days. The metabolism crates, intended for use with sheep, were altered so the peccaries would have access to food and water, and so feces and urine from these animals could be collected.

Three different diets, including a commercial swine diet, a purified diet, and a natural one--prickly pear (*Opuntia engelmannii*)--were fed to the peccaries. Each diet was fed for at least two weeks prior to two five day digestion trials.

Digestibility coefficients for fiber, crude protein, ether extract and digestible energy were determined and compared for all diets. Fiber digestibility was highest (26 percent) on the commercial supplement. Protein digestibility was highest on the purified diet (84 percent). Digestible energy values were similar on all diets.

In Vitro Dry Matter Disappearance of the commercial diet, using gastric contents from another peccary, was 73 percent. Dry matter disappearance of cellulose was negligible.

This study indicates the feasibility of using metabolism crates with nondomestic animals. Acceptance of a purified diet may help in defining the peccary's nutritional requirements, and aid in critical investigation of other physiological processes associated with animals who may possess microbial fermentation in anterior portions of their digestive tracts.

INTRODUCTION

In The Journey Home by Edward Abbey, javelina are described as ". . . whimsical little beasts with bristling coats and oversize heads half as big as their bodies . . . little pork, nothing but hide, hair, blood, muscles, nerves and gristle . . . wild beasts of pure drive, rudimentary brains, raw, concentrated vigor. A simple personality but vital, vivid" (1977, p. 65).

Javelina are vivid, especially to those who inhabit the desert of the southwestern United States. With their small, somewhat pig-like bodies, they can be seen wandering throughout the harsh environment they choose as their home.

The javelina is a peccary, member of the family Tayassuidae within the order Artiodactyla. They are native to the New World, with three species currently known to exist. These are the collared peccary (*Tayassu tajacu*), the white lipped peccary (*Cataganous wagneri*), and the chacoan peccary (*Tayassu pecarii*). The collared peccary is the only one in the United States, with a distribution limited to southwestern Texas, southern New Mexico and southern Arizona. The white lipped peccary and the chacoan are more tropically oriented and inhabit the southern most end of the peccary range, including Southern Mexico, Central America and South America into Peru and Argentina.

The peccary is primarily a vegetarian consuming great varieties of green plants including young grasses and weeds, reproductive structures (gourds, acorns, beans) and the roots of plants such as agave

(*Agave palmeri* and *Agave schottii*) and buffalo gourd (*Curcurbita foetidissima*). Prickly pear (*Opuntia*, sp.) is said to be the preferred food of most collared peccaries (Knipe, 1957; Eddy, 1959). It is especially important in times of drought when little else is available.

Over the past several years sport hunting of peccaries in Arizona has increased in popularity. This in turn has prompted an increase in concern over management practices within the state. There has also been a growing scholarly interest in the nutrition of the collared peccary and the digestive processes which occur within the ruminant-like stomach. Also, there tends to be an increase in the aesthetic value of the peccary with the growth of ecological awareness prompted by the fact that the collared peccary is found only in the southwestern deserts of the United States.

More information on the animals habits and biological functionings are necessary. Management practices could be improved if dietary and nutritional requirements are known. The introduction of animals into new areas would be futile if digestive processes are not understood more fully, and in turn, geographical areas could be more accurately evaluated as to their carrying capacity and environmental suitability for the peccary.

It is difficult, if not impossible, to study the digestibility of various foods of the collared peccary in a natural environment. There is also a question as to which methods routinely used for studying diet utilization in domestic animals can be adapted for use with peccaries. This experiment was conducted to determine whether or not peccaries could be used in studies requiring a high degree of confinement (metabolism crates) and to determine the digestibility of commercial, purified and natural diets.

REVIEW OF LITERATURE

Few detailed studies involving peccaries have concerned digestion, although there have been several which complement this area. Various studies in the past have yielded information regarding seasonal movements, social activity and natural foods chosen by the peccary. Other studies have dealt with parasites, reproductive hormones, thermal regulation, and composition of milk in lactating females.

Langer (1974, 1977, 1978) and Stewart (1964) have concerned themselves with anatomy of the digestive tract and stomach while Eddy (1959) has studied the natural foods of the peccary. Knipe (1957), Prins (from Langer, 1977) and Hayer (1961) broach the subject of nutrition, but Dyson (1969) is the only one to have shown any type of thoroughness in the matter.

Anatomy of the Digestive Tract

Stewart (1964) outlines some of the important aspects of the alimentary tract in the collared peccary. The esophagus consists of striated muscle intermingled with smooth fibers near the stomach. The stomach is divided into several chambers with folds and pillars which slow down the movement of digesta through the stomach. Initially, this organ is lined with mostly stratified squamous epithelium with roughly 1/4 of the blind sac and central cavern being cardiac columnar epithelium. The lower glandular portion of the stomach is lined with gastric epithelium and the area near the pylorous with pyloric epithelium. The non-glandular portion of the stomach (i.e., the blind sacs and central cavern) shows heavy musculature.

The small intestine is approximately 13 to 14 times the length of the body (Stewart, 1964). The peccary does possess a vermiform appendix as a finger-like projection at the end of the cecum. The cecum is not overly enlarged as in some monogastric herbivores. Stewart attributes the similarity between the peccary stomach and that of ruminating mammals to either primitiveness or phylogenetic degeneration.

Langer (1974, 1977, 1978) further described the peccary stomach with special emphasis on its significance. This author points out that the peccary stomach is a result of neither degeneration nor primitiveness but, is as it should be, due to the fact that it rose independently from stomachs of the other Artiodactyla.

Further investigation revealed there is a decrease in the glandular stomach area from birth to adult (Langer, 1977). This is accompanied by an increase in squamous epithelium as a percentage of the whole gastric surface. The blind sac area amounts to about 85 percent of the total stomach capacity. This, in itself, is of adaptational significance since the peccary spends much of its time resting in the shade at which time no food is taken in. Also, due to "the reduced pinnation and altered orientation of the elevator muscles probably restrict(ing) the amount of masticating torque" (Herring, 1975, p. 88) it would be beneficial for the animal to possess the heavy musculature and microbial digestion in order to accommodate food where particle size is large and of a fibrous nature.

The folds of the gastric compartment slow the rate of passage but probably do not cause polarized flow in which the gastric contents pass successively from one compartment to the next. Some food may even bypass the blind sac area. No sorting mechanism due to particle size or density was observed in the blind sac area of the peccary (Langer, 1977).

In this same study, Langer observed a strong bacterial infiltration on the upper cell layers of the stratum corneum in the dorsal part of the upper blind sac and ventral part of the gastric pouch (or central cavern). He also noted that the cornification of cells near the beginning of the glandular stomach was greatest in an animal which had access to some straw as compared to animals which had been on a diet of commercial supplement. Epithelial thickness, especially in the gastric pouch and blind sac areas where digesta are stored, was found to be almost identical with epithelial thickness measured by Lauwers in rumen, reticulum and omasum of cattle (in Langer, 1977).

In another study, Langer (1978) compares criterion necessary for ruminant digestion to those indicative of ruminant-like digestion and concludes the peccary shows inclinations towards the later.

Due to trophic, behavioral and anatomical differentiations the peccary is placed between herbivores with fore-stomach digestion of cellulose and those with cecal digestion. Langer (1978) prefers them to be placed nearer to herbivores with predominant microbial cellulose digestion occurring in the fore-stomach.

Nutritional Studies

Eddy (1959) studied the natural foods of the collared peccary through field observation, fecal analysis, and examination of gut contents from hunter kills. He reports that prickly pear pads (*Opuntia*, spp.) and agave root (*Agave*, spp.) are the major food items of the collared peccary throughout the year. To supplement these items, seasonal foods such as acorns (*Quercus*, spp.), jojoba fruits (*Simmondsia chinensis*), saguaro cactus fruits (*Carnegiea gigantea*), mesquite beans (*Prosopis juliflora*), palo verde beans (*Cercidium* spp.) and many annual forbs are consumed. These foods are available to the peccary depending upon which elevation and vegetational zone the animals inhabit.

Knipe (1957) reports that the collared peccary seeks water less often than any other big game animal except desert bighorn sheep. He also states that the need for water depends upon the succulence of their diet.

Phelps (1971) concluded that peccaries are unable to live more than three days in the open without access to either succulent food or free water. Peccaries must regulate body temperature behaviorally by avoiding environmental heat load through seeking shade, foraging during cooler parts of the day, using the ground as a heat sink and by artificial evaporation through splashing water on themselves or rolling in their own urine. Death occurred at water losses between 15-20 percent of body weight. Because the animals could loose no more than approximately 500 grams of water per hour by panting (a natural response in peccaries) they could not maintain a normal body temperature when subjected to the normal heat load of a sunny summer day. The animals must have access to free water during the summer months in order to avoid water loss, salt imbalance, loss of thermal regulatory ability and, finally, death (Phelps, 1971).

Minnamon (1962) studied the home range of the collared peccary in the Tucson Mountains. Several times he observed an untagged herd near a watering station where peccaries had been extensively trapped and tagged. He concludes that the presence of this untagged herd indicates peccaries do not require free water. Sowls (1979) also eludes to the fact that many herds survive without free drinking water for months during the driest parts of the year and depend only on the water in cactus for their survival.

Through the use of tritiated water, Zervanos (1977) was able to determine water loss and turnover in free-living peccaries. Peccaries under field conditions lost 1.35 liters of water per day during the summer compared to 1.7 liters in the winter. He noted that water holes were frequented only for short periods every 3 or 4 days during the summer and less often, if at all, during winter. It was calculated that 1.54 kg. (wet weight) of prickly pear would need to be consumed each day during the summer in order to compensate for water loss (assuming efficiency for assimilating water from the cactus is 100 percent).

Dyson (1969) conducted the pioneer search into nutrition of the collared peccary. In what has been the only thorough study of its type, he sought to gain information on B vitamin synthesis, nonprotein nitrogen (NPN) utilization, amount and location of fiber digestibility and extent of volatile fatty acid (VFA) production.

In the B vitamin study Dyson concluded there was no need to supplement B vitamins to ground milo and soybean meal diets fed to young peccaries (less than six months of age). However, dietary requirements for the peccary have not been established. Because his study was conducted as a penned experiment, copraphagy may have contributed to satisfying their B vitamin needs. Results from the NPN study were nonconclusive. Diets were bulky, not readily consumed and weight loss consistent.

Fiber digestion was higher on a milo-alfalfa pellet than on an all alfalfa pellet. Volatile fatty acid levels were higher in the stomach area than in the cecum and anterior large intestine. In-vitro production of VFA was negligible, which may have been due to improper preparation of the samples.

Hayer (1961) could show no cellulose digestion in in-vitro studies. Gastric fluid obtained from freshly killed peccaries was spun down at 1500 RPM for three minutes, and the supernatant used for VFA determinations and in in-vitro inoculum. No bacteria were observed in the gastric fluid but the presence of motile bacilli in the cecum was noted. He concluded cellulose digestion probably occurs in the cecum, although VFA's were detected in the stomach area. Total VFA levels were found to be higher on a prickly pear (natural) diet than on a commercial supplement (177 vs 90 mMol/l of gastric fluid).

Prins (from Langer, 1977) worked with the gastric contents of three different peccaries to which two diets had been fed (commercial pellets and straw supplemented with commercial pellets). In all animals the blind sac area showed higher VFA concentrations than the glandular portion of the stomach. Acetic to propionic acid ratios (C_2/C_3) differ only slightly between blind sac region and glandular stomach area of the same animal. In the one animal where straw had been fed in addition to commercial pellets, the C_2/C_3 ratio was higher. Highest overall concentrations of VFA's in both glandular and blind sac portions of the stomach have been found in animals feeding primarily on prickly pear (natural diets). No protozoa were found in the gastric contents of the three peccaries (Langer, 1977).

All work conducted to date has been in penned areas using foods customarily fed to domestic animals. Most researchers are divided as to whether or not the peccary has the ability to digest cellulose in its stomach area. The presence of VFA's in this area indicates the presence of bacteria although direct proof for their presence has not been shown. All workers would like to see more investigation in this area and suggest that the studies would be more easily accomplished if conditioned or tame animals could be used.

MATERIALS AND METHODS

Handling and Taming of Experimental Animals

Two orphan sibling female peccaries, approximately two months old, were provided by the Arizona Cooperative Wildlife Unit for this experiment. At the time this experiment was initiated, they were housed together in a pen adjacent to other peccaries. They were given names to aid in differentiation between the two in hopes this would assist in the taming process. Even at this early age, they could be distinguished one from another by their contrasting personalities. One was always bolder, while the other was timid but more alert.

Daily the two young peccaries were allowed to play freely in the aisle way surrounding all pens. Here, they would run about sniffing at plants and other penned peccaries, and were handled whenever they would allow it. In time, they came to appreciate the attention.

Since the peccary is a tropical animal, unable to cope with low environmental temperatures, many of the peccaries housed at the Wildlife Unit became ill with colds and pneumonia. This is a common problem among many animals in the southwest during the spring and fall, when daytime temperatures differ greatly from nighttime temperatures. During the month of March, the two young female collared peccaries were moved to a rather large pen about 50 meters away from the others to minimize possibility of health problems. At this time, they began to crave attention, probably because they were separated from their neighbors.

At this same time, harnesses were designed to fit the peccaries and a period of "halter breaking" was carried out so that eventually the two peccaries could be taken for walks on leashes. This aided in keeping the animals gentle enough to handle.

The young peccaries had been fed a commercial pelleted hog diet since arriving at the unit. The pellets were fed in a commercial hog feeder (having a gravity fed compartment with two hinged covers) with the covers left open. As the peccaries became older and more accustomed to the feeders, the covers were left down and the peccaries learned to open them when hungry.

Throughout the spring, the animals were handled (held, petted, scratched and carried around inside their pen) as much as possible. They came to know the author and her vehicle by sight alone. The animals became quite tame and would allow others to pet them.

Alteration of the Metabolism Crates

Metabolism crates intended for use with sheep were modified for this study. The crates were 55 cm wide by 127 cm long and 34 cm high. Of the total length, 28 cm were taken up by the feed hopper, which measures 51 x 28 x 61 cm deep.

The feeders were much too deep for the peccaries, so a false bottom was made and secured inside with pop rivets. The feeder bottoms were adjusted to a height and angle which would make food accessible to the young peccaries. At a later date (during the feeding of the purified pellet) a metal container (15 cm deep x 10 cm in diameter) was added to the center of the metal sheets using pop rivets.

A final modification of the feeders was necessary when the animals were fed the prickly pear diet. The original false bottom was replaced with another measuring 51 x 46 cm. This bottom was bent to fit inside the feeder and give a trough with an angle large enough to allow complete consumption of the feed. A silicone sealing compound was placed along the edges of the metal to prevent any bits of food from falling into the bottom of the hopper.

The original access opening to the water pan was so large the peccaries could escape through it. The opening was modified using a piece of sheet metal with a hole just large enough to allow a peccary access to water.

Metal strap 1 inch (2.54 cm) in width was mounted to the new head gate into which a bread pan, measuring 25 x 14 x 8 cm was placed. The long axis of the watering pan was placed perpendicular to the long axis of the crate. This arrangement allowed the animals to drink even when water levels in the pan were low.

It was also necessary to modify the wire floor in the crate to allow separate collection of feces and urine. In the original design, movement of lambs in the crates is restricted by adjusting the width so there is no room for an animal to turn. Collection pans at the bottom of the crate are divided into two portions. The front portion allows collection of urine, and the rear compartment is for the collection of feces. The peccaries were allowed to move about within the crates and consequently, the original collection system was not suitable.

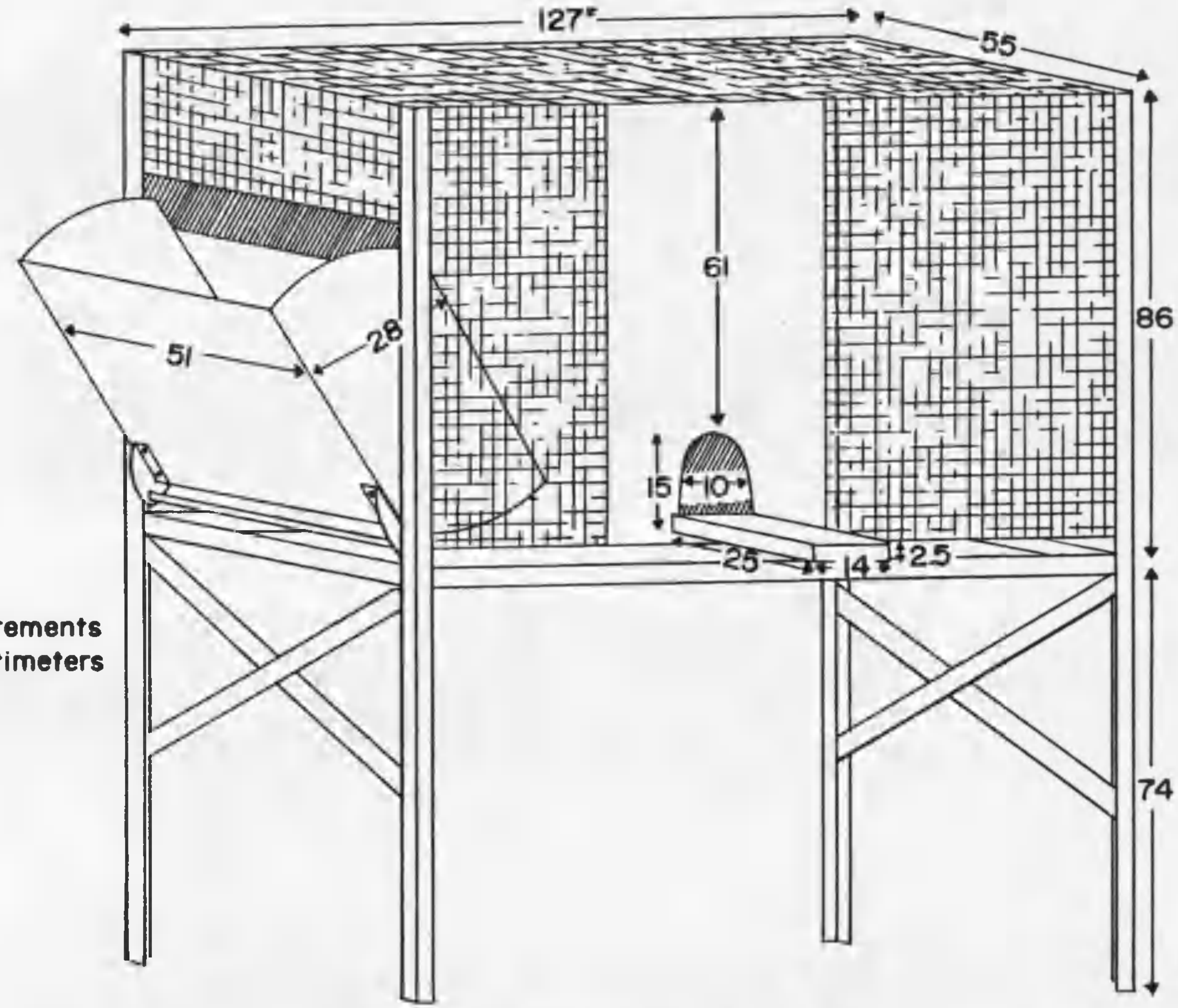
An angle iron (2.54 cm) frame covered with wire mesh (3 x 3 mm) was built to cover the entire top of the collection pan. A piece of sheet metal was cut to fit below the screen and angle from the front of the unit to the original divider. The rear portion of the original collection pan was not used. Feces are retained on the screen running the length of the crate, and urine passes through the screen down onto the metal collection pan and into a collection bottle (see Figs. 1 and 2).

Digestion Trials

General Procedures

Two collection periods were completed for both animals on each diet (a total of six separate measurements for three different diets). Preliminary periods of at least two weeks were allowed for adjustment to new diets. Digestibility coefficients were determined following five day total collections of feces. Animals were returned to the Wildlife Unit between collections.

During collection periods, total feces from each peccary were collected daily and dried to constant weight in a forced air oven (45° C). The daily feces from each animal was pooled and ground through a 1 mm screen in a Wiley mill. The ground composites were retained for analysis. Samples of each diet were obtained daily during collection periods and prepared for analysis in the same manner as fecal samples.



*all measurements are in centimeters

Fig. 1. Altered metabolism crate

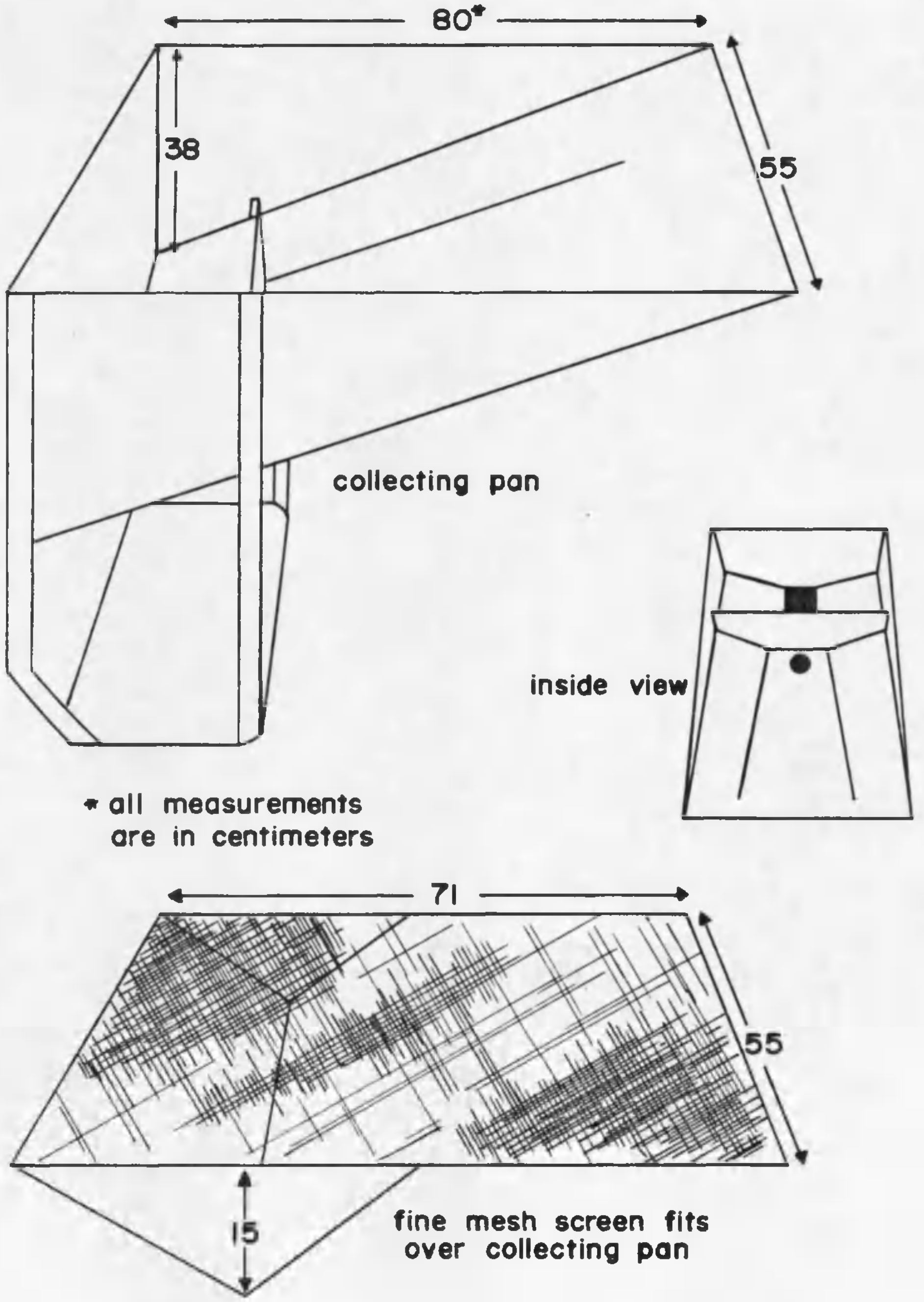


Fig. 2. Collection unit for metabolism crate

Total urine was collected each day also. After the output volume was recorded, the urine was diluted to the nearest liter with distilled water. Aliquots of at least 50 mls were retained and stored in a refrigerator for analysis.

Water and feed intake were recorded on a daily basis. The animals were given food twice a day (7 a.m. and 4 p.m.). Any uneaten portions from the prior feeding were removed and weighed before the next feeding. Water intake was recorded by subtracting the water remaining in the pan after a 24 hour period from that which had originally been allotted.

In the manner described above, both fecal and urinary outputs and water and feed intake was recorded for each animal every day they were in the crates.

All analyses were conducted in duplicate. Dry matter (DM), ash, nitrogen, ether extract (EE and acid detergent fiber (ADF) were determined using AOAC (1970) methods. Gross energy was determined using an adiabatic bomb calorimeter. Neutral detergent fiber (NDF) was determined using the NDF method described by Robertson and Van Soest (1977). Starch was determined using the method reported by Doyle (1978).

During the first collection period it was noticed that, even though the crates were in the shade where a breeze could pass freely through them, the animals were panting due to the heat load (ambient temperatures reaching 46° C). This problem was alleviated with the use of an evaporative cooler placed near the crates. Following installation of the cooler, the temperature within the area of the crates was never higher than 93° F (34° C).

Trial 1--Commercial Diet

Because the peccaries had been fed the commercial hog diet since their arrival at the unit, this was the first diet to be fed in the crates. Crude protein levels of the pellets was close to 15 percent, fiber content was 21 percent and nitrogen free extract (NFE) was 58 percent. The pellets were used to ease the peccaries into the trials with as little stress as possible. They were also used to test the suitability of the crates and collection units and to provide base line values for digestibility data. The two collection periods on this diet were performed two days apart.

Trial 2--Purified Diet

Composition of the purified diet is given in Table 1. The diet was mixed in a batch mixer at The University of Arizona poultry farm. Enough water was added to produce a mash which could be forced between the fingers when compressed. Satisfactory pellets could not be made in a pellet mill and thus, a small sausage grinder was used to produce pellets. The blade was removed and the mixture extruded through the die, resulting in long strands of wet mash .5 cm in diameter. These strands were broken into pieces 1.25 cm (about 1/2 inch) in length and dried in a gas oven at approximately 250° F (120° C). There was a twelve day delay between the two collections conducted using this diet.

Table 1. Composition of the Purified Diet

Ingredient	Percent of Diet
Sulka floc (cellulose	20
Casein	15
Vitamin premix[a]	1
Di Calcium phosphate	3
Tallow	3
Trace Mineral Mix[b]	.25
Corn starch	57.74
Salt	.01

[a]Vitamin premix supplied per pound of diet; 113635 IU Vitamin A, 10908 IU Vitamin D_3, 99.1 IU Vitamin E, .341 mg. Vitamin K, 136 mg Riboflavin, 999.99 mg Niacin, 173 mg. Calcium pantothenate, 25000 mg. Choline, 99.99 mg. Thiamine, 22.72 mg. Folic acid, 45 mg Pyridoxine, 227 mg. Biotin.

[b]Trace Mineral Mix

Ingredient	Percent
Ferrous sulfate	10.00
Zinc oxide	7.47
Sodium molybdate	0.26
Manganese dioxide	11.18
Ground limestone	0.98
Potassium iodide	0.20
Cobalt chloride	0.61
Cerclose	24.89
Total	100.00

Trial 3--Prickly Pear

The third diet fed to the peccaries was prickly pear (Opuntia, spp.). Since prickly pear is said to be the mainstay for peccaries in the wild it was thought that this diet might yield some relevant information to be used in dealing with questions concerning digestion and intake of food by animals in the wild.

At first a spineless variety (Opuntia laevis) of prickly pear was fed to the animals. After four days on the pads the animals developed a severe diarrhea. It was thought that perhaps the high water content was causing the problem, but, after drying the pads and feeding them in this form, the diarrhea persisted. The animals were taken off the pads and put back on hog pellets. At this time a rectal culture was performed to try to discover the possible cause of the diarrhea. Nothing abnormal was found in the culture.

It was eventually determined, through personal communication with Dr. R. Reed of the Department of Veterinary Science at The University of Arizona, that prickly pear pads contain a high level of oxalic acid which forms oxalate crystals and clogs the kidney tubules, causing decreased water absorption. This, in turn, results in the animal having diarrhea. Some animals, in past penned studies, had died from oxalate crystals completely blocking tubules, resulting in kidney failure.

The diarrhea severely stressed the animals and also made collection of fecal matter in the metabolism crates impossible. It was decided that diluting the concentration of the oxalic acid ingested might alleviate the problem and still yield information regarding the digestion of prickly pear. This was accomplished by feeding the prickly pear in combination with the commercial hog pellets.

When the animals were put back on the prickly pear they were fed a spiny variety (Opuntia engelmannii, from which the spines had been singed with a propane torch) along with the pellets at a ratio of 50 percent prickly pear and 40 percent pellets, with the peccaries being fed a given amount of prickly pear and pellets each morning and evening. Unlike the other diets, this one was not fed ad libitum, but was fed in an amount which would ensure complete consumption of prickly pear and pellets in order to keep the ratio constant. There was a six day interval between the two collections conducted using this diet.

Digestibility coefficients for prickly pear alone were calculated using the following equation from Lloyd, McDonald, and Crampton (1978):

$$\left[\frac{100\begin{pmatrix}\text{coefficient of}\\ \text{digestibility of}\\ \text{total ration}\end{pmatrix} - \begin{pmatrix}\text{coefficient of}\\ \text{digestibility of}\\ \text{pellets}\end{pmatrix}}{\text{\% of prickly pear in diet}}\right] + \begin{matrix}\text{digestibility coef-}\\ \text{ficient of pellets}\end{matrix}$$

Supplemental Investigations

An adult male peccary at the Wildlife Unit was sacrificed to obtain various tissue samples for other studies. The peccary had been fed the commercial diet for several years prior to slaughter. At the time of slaughter, blood samples were collected in heparinized tubes and stored at 7° C for blood glucose determinations. Blood glucose concentrations were determined using a Beckman recording spectrophotometer and a commercial hexokinase-glucose-6-phosphate degygdrogenase kit.[1]

In an effort to pinpoint the nature of digestive action occurring in the stomach, gastric contents were obtained to be used in VFA determinations and in-vitro incubation. Stomach contents were collected and filtered through two layers of cheesecloth. For VFA determinations, 5 mls of strained fluid were mixed with 1 ml of metaphosphoric acid and frozen for later analysis. Volatile Fatty Acids were determined by gas-liquid chromatography using the method reported by Erwin, Marco and Emery (1961).

The remaining gastric fluid was used to prepare inoculum for in-vitro incubation. At the same time stomach contents from the peccary were being prepared for in-vitro work, rumen contents were collected from a fistulated steer and prepared in the same manner. Gastric contents from both species were used as in-vitro inoculum to allow comparison between the digestive action in the peccary and that of a true ruminant.

Stomach fluid from both the peccary and steer was immersed into a water bath (39° C) and CO_2 bubbled through it for 3-4 minutes. Polyethylene tubes (50 ml) fitted with gas release valves had been secured in a constant temperature water bath (also 39° C). These contained either .5 gm of cellulose or ground hog pellets, in duplicate. Two tubes containing only reagents served as controls.

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1. Calbiochem glucose, S.V.R. #L03419. 10933 N. Torrey Pines Rd., La Jolla, Ca. 92037.

All tubes were inoculated with 20 mls. of carbon dioxide saturated, prewarmed McDougalls buffer (McDougall, 1949), and 7.5 mls of either peccary or bovine stomach fluid. These were then allowed to incubate in the warm water bath for 24 hours. After this time, the tubes were removed, and contents filtered through 6 layers of glass wool in a preweighed gooch crucible. These were washed with distilled water and dried for 8 hours in a 105° C vacuum oven. Dry matter disappearance was calculated using the following formula:

$$\%\text{IVDMD} = \frac{\text{dry sample wt.} - (\text{dry residue wt.} - \text{blank correction})}{\text{dry sample wt.}} \times 100$$

RESULTS

Chemical composition of diets used is given in Table 2. Values for the 50 percent commercial pellet/50 percent prickly pear diet were calculated from composition of prickly pear and hog pellets. The prickly pear pads contained only 16 percent acid detergent fiber (ADF) on a dry matter basis, which was only 2 percent higher than the commercial swine pellets.

Efforts were made to partition the nitrogen free extract (NFE) fraction of the prickly pear pads into its component parts. Total starch and sugars accounted for only 8.5 percent, which was much lower than the value of 56.1 percent given for NFE in Table 2. NFE is obtained by subtracting the total of ash, NDF, EE and CP from 100, and is intended to represent easily digestible carbohydrates. Failure of separate starch and sugar analyses to equal NFE is not unique to prickly pear and has led many researchers in the field of animal science to question its usefulness as a definitive analytical fraction. No comparative data concerning starch or sugar content in the pads could be found, however two sources did show NFE values similar to the ones obtained in this study. In one source, The Atlas of American and Canadian Feeds (National Academy of Science, NAS, 1971), NFE is given as 60.6 percent on a DM basis. In an older study Vinson (1911) reports carbohydrates to make up 14.7 percent of the prickly pear pads on a wet basis (77.2 percent water), or 65 percent on a DM basis.

Table 2. Chemical Composition of the Various Diets

Diet	Commercial Pellets	Purified Pellets	Prickly Pear Pads and Pellets[b]	Prickly Pear Pads
Organic Matter, %	91.59	98.41	89.60	87.63
Dry Matter, %	93.94	93.33	92.10	90.25
Crude Protein, %	12.22	14.66	9.05	5.59
ADF, %[a]	13.17	21.42	14.12	15.76[c]
Starch, %[a]	53.02	52.98	28.97	4.91
NFE, %[a]	60.37	57.66	62.78	56.14
E.E., %[a]	5.83	4.67	3.78	1.68
Energy (cal.)	36.78	34.79	34.71	32.60

[a]Dry matter basis.

[b]Calculated values

[c]NDF for prickly pear pads was 25.34 percent.

Average peccary weights and feed intakes for all trials are given in Table 3. Intake as percent of body weight was highest for the commercial pellet and lowest for the purified diet. Dry matter intake as a percent of body weight for domestic steers is usually 2-4 percent, while a value of 3-6 percent is reported for domestic swine (Church, 1977).

Foose (1978) has conducted research with large, nondomestic ungulates and reports somewhat lower intake values for both ruminants and nonruminant herbivores. His trials were conducted using zoological specimens which had been accustomed to eating a diet of Timothy hay ad libitum. The lower intakes compared with domestic animals could be due to quality of the forage or to the physiological maturity of his animals. Foose observed daily consumption of DM as percent of body weight ranged from a low of .6 percent for a River Hippopotamus (which possesses a two chambered stomach and no cecum) to a high of 3.2 percent for a Plains Zebra (a nonruminant herbivore). The equids (two species of zebra) had the highest dry matter intake as percent of body weight (averaging 3.0 percent) while the elephants (monogastric) had intakes very similar to the wild ruminants (average of 1.2 percent for the elephants vs. 1.4 percent for the ruminants). Two rhinoceri (monogastric) had average intakes of .85 percent of body weight while a tapir (also monogastric, same order as the equids and rhinoceri) had an intake of 1.3 percent.

Water intake (Table 4) was highest on the commercial pellet and lowest on prickly pear. The water intake data may be confounded with

Table 3. Animal Weights and Dietary Intake

Animal Identification	H	C
Average weight, kg[a]		
Trial 1	12.65	12.85
Trial 2	15.70	16.45
Trial 3	18.50	19.70
Average feed intake/day, kg[bc]		
Trial 1	.364	.358
Trial 2	.228	.256
Trial 3	.403	.391
Feed intake as percent of body weight, %		
Trial 1	2.88	2.79
Trial 2	1.45	1.56
Trial 3	2.18	1.98

[a]Animal weight at initiation of digestion trials.

[b]Intake during digestion trials, represents mean values from both collection periods.

[c]Dry matter basis.

Table 4. Water Intake/Day

Animal Identification		H	C
Water intake/day (mls)	Trial 1	1990	1428
	Trial 2	9035	1518
	Trial 3	675	8875

environmental temperature. The first two trials were conducted in the summer months with ambient temperatures up to 93° F (33.9° C), while the trial performed with prickly pear was conducted later in the year when ambient temperatures averaged only 55° F (12.8° C).

Digestibility coefficients and digestible nutrients for all trials are reported in Table 5. On the whole, fiber digestibility was very low, the highest coefficient being 26 percent. This was measured while the animals were on commercial pellets in Trial 1. The purified diet, in which pure cellulose was used as a fiber source, had fiber digestibility coefficients averaging 4 percent.

On the 50 percent prickly pear/50 percent commercial pellet diet, the coefficient of digestibility for fiber was 6 percent during the first collection and 15 percent during the second one. Calculated values for prickly pear alone showed a negative coefficient of digestibility for fiber in the first collection period, while during the second collection the value increased to 6 percent. This is higher than that obtained on the purified diet. One reason for the higher value for fiber digestion on the prickly pear as compared to the purified diet may be that the prickly pear contains 10 percent hemicellulose on a CM basis, whereas the purified diet contained none. It is generally assumed that himicellulose is more easily digested than cellulose, depending on the degree of lignification (stage of maturity). This may also be a factor in the high digestibility coefficient for fiber in the commercial pellet compared to the purified diet.

Table 5. Digestibility Coefficients and Digestible Nutrients for all Trials

Diet	Trial 1 Commercial Pellets	Trial 2 Purified Diet	Trial 3 50% Prickly Pear/ 50% Pellet	Prickly Pear (calculated)
Digestibility Coefficients				
Organic Matter, %	78	76	75	73
Crude Protein, %	68	84	67/57[a]	67/46
ADF, %	26	4	6/15[a]	-13/6[a]
NFE, %	93	100	91	90
EE, %	79	88	88	97
Energy (%)	75	72	77/69[a]	79/65[a]
Digestible Nutrients				
Organic Matter, %	71	75	75	65
Crude Protein, %	8.32	12.6	--	3.8/2.6[a]
ADF, %	3.4	.84	--	0/.82[a]
NFE, %	57	58	--	50
EE, %	4.62	4.4	--	1.7
Energy (cal)	2762	2505	--	2054/1389[a]
TDN	79.44	81.34	--	58/57

[a]Top values represent data from the first collection period, bottom values are from the second collection.

Average crude fiber (ADF) digestibility for the domestic cow and pig are given as 49 percent and 28 percent respectively (Hale, 1977). Comparisons are difficult because of the difference in various fiber determinations, difference in digestibility of fiber from different sources and the effect of level of intake and diet composition of fiber digestibility.

Foose (1978) has found cell wall digestibility (NDF, which includes hemicellulose) averaging near 65 percent for wild ruminants (includes a camel, giraffe, two species of water buffalo, a gaur, bison and gemsbok). Average fiber digestibility for the nonruminant herbivores was 47 percent (this group includes two species of elephants, zebra and rhinoceri and one species of tapir--which gave a low value of 36 percent).

Fiber digestibility for other animals on prickly pear were found in the Atlas of American and Canadian Feeds (NAS, 1971). Values of 42 and 13 percent, respectively, are given for crude fiber digestibility in domestic cattle and sheep.

In the present study, apparent digestibility of crude protein ranged from a high value of 84 percent on the purified diet to a low of 46 percent on prickly pear. The value for the commercial pellet was 68 percent. Casein was used as the protein source and it is understandable why the digestion coefficient for crude protein was highest on this diet.

Foose (1978) obtained values of 51 percent for CP digestibility in large wild ruminants. A low value of 23 percent for the tapir was noted. The zebras digested an average of 54 percent of the crude protein, while the elephants averaged only 40 percent. All of Foose's data was obtained while the animals were on a diet of Timothy hay, with a mean crude protein level of 4.5 percent. These values may be low due to the effect of dietary protein level (which was, in this case, quite low) on the apparent digestibility of crude protein.

Domestic cattle and sheep on a diet of prickly pear showed crude protein digestibility coefficients lower than the average value of 57 percent obtained in this study with peccaries (average obtained from readings from both collections). In the case of cattle the CP digestibility coefficient was 34 percent, while in sheep it is reported as 50 percent.

There was considerable variation in digestibility coefficients for ADF, CP and DE between the first and second collections using the 50 percent prickly pear/50 percent pellet diet. This was the only diet in which there was any great change in digestibility coefficients from one collection to the next, which is why these numbers are reported separately in Table 6. There was an increase in the digestibility of fiber with a concurrent decrease in crude protein and digestible energy coefficients between the first and second collection periods using the same diet.

Because of the diarrhea problem caused by the feeding of prickly pear, there was a two month delay between Trial 2 and 3. Much of this time the peccaries were exposed to a diet of prickly pear (intermittently, until two weeks prior to the start of Trial 3, when

Table 6. Nitrogen Balance of Experimental Diets

Diet	Commercial Pellet	Purified Diet	50% Prickly Pear/ 50% Commercial Pellet
Number of animals	2	2	2
Number of trials	2	2	2
Nitrogen intake (g/day)	7.04	5.65	5.81
Fecal nitrogen (g/day)	2.27	.91	2.21
Urinary nitrogen (g/day)	2.20	1.31	2.40
Nitrogen retained as % of nitrogen intake, %	36.51	60.71	20.65
Nitrogen retained as % of nitrogen absorbed, %	53.88	72.36	33.33

they were actually placed on the diet). The second collection period of Trial 3 was conducted a week after the first collection, by this time the animals had been on the prickly pear/pellet diet for approximately four weeks. It is possible that there was some type of adaptation of the microbial population in the gastric region which caused the discrepancy between the two collections. This would be consistent with Eadie et al. (1970) who found that the most significant changes in microbial populations in the rumen of cattle, especially in ciliate populations, occurred at two and four weeks after introduction of a new diet.

Total digestible nutrients (TDN) was highest on the purified diet (81.3 percent) and lowest on the prickly pear (58 percent), while the commercial pellet had a TDN of 79.4 percent. Even though digestion coefficients for ADF, CP and DE in prickly pear diets differed between the two collection periods, the changes seem to compensate for each other, and TDN from both periods was similar (58 vs. 57 percent). Even if fiber digestibility in prickly pear had been as high as in the commercial pellet (26 percent) the TDN for prickly pear would increase by only 4 percent since prickly pear is so low in fiber. This would give a TDN of 62 percent and place prickly pear on the borderline between what would be considered a roughage and a concentrate. Church (1977) defines a roughage to be greater than 18 percent crude fiber, less than 60 percent TDN and a concentrate to be less than 18 percent crude fiber, less than 20 percent crude protein and greater than 60 percent TDN.

Weight gains during the collection periods occurred only on the commercial pellet. However, weight losses on the other diets were not large and the animals seemed to maintain a fairly constant weight.

Nitrogen balance (Table 6) was greatest on the purified diet and lowest on the 50 percent prickly pear/50 percent pellet diet. Values for prickly pear alone could not be calculated using data from the trials.

Volatile fatty acid concentrations (Table 7) were found to be 55 m mole/liter in the stomach of the peccary which had been sacrificed. Molar percent of VFA were similar to those obtained by Hayer (1961), Dyson (1969) and Langer (1977) from peccaries on commercial supplements. Molar percentages of acetic acid (C_2) were always highest, followed by butyric acid (C_4). This observation is different from that made using wild peccaries on natural diets (Hayer, 1961; in his paper, Hayer assumes the diet to be mostly prickly pear). In that case, molar percentages decreased from acetic (C_2) to valeric (C_5) acid, and are similar to the molar percentages of VFA found by Dyson (1969) when the peccaries he had studied were on a diet of pellets of ground milo and alfalfa hay (30 percent alfalfa, 52 percent milo). However, total concentrations of VFA found in the stomachs of Dyson's (1969) seven animals on the milo/alfalfa pellet were lower than those from Hayer's (1961) study. Molar percentages of VFA found by Hayer in the animals on the alfalfa/milo pellet are similar to those found in domestic cattle on a diet of alfalfa and grain (Hale, 1977). Overall VFA

Table 7. Volatile Fatty Acids in Gastric Contents of Peccary on Commercial Swine Diet

Total UFA, m moles/liter	Molar Percentages C_2	C_3	C_4	C_5	C_6
55.1	43.4	19.2	26.8	10.0	.7

production for the peccary on all diets is only one-half to one-third that found in domestic cattle.

Comparative In Vitro Dry Matter Disappearance (IVDMD) data using inoculum from the steer and peccary are shown in Table 8. There was essentially no disappearance of cellulose using inoculum from the peccary. This is in contrast to the 26 percent disappearance of cellulose DM where rumen fluid from the fistulated steer was used. Even though cellulose digestion by contents of the peccary stomach was low, there was definite disappearance of DM when the commercial pellet was used as a substrate and IVDMD of the pellet using peccary inoculum was very similar to that observed using rumen fluid inoculum (73 vs. 74 percent).

Table 8. In Vitro Dry Matter Disappearance (IVDMD) of Cellulose and Commercial Pellets

	Pellets	Sulka floc (cellulose)
	Percent IVDMD	
Peccary	73.01	.32
Steer	74.87	26.32

Since the peccary which was sacrificed for use in this experiment had been on this commercial pellet for several years, observation of low cellulose digestion does not necessarily rule out microbial digestion of fiber in the stomach of the peccary. The pH of the gastric contents of the animal studied was found to be 5. This is comparable to values of 5.5, 7.2 and 5.6 reported by Dyson (1969) and Hayer (1961). These lower pH values are similar to those found in the rumen of cattle fed high grain diets. However, in those animals, low pH corresponds to high organic acid levels. Possible cause of low readings in the peccary are secretion of HCl by gastric mucosa or a delay in actual measurements. The reading taken during the present study was recorded at least 30 minutes after the death of the peccary.

Blood glucose levels of 70 mg percent were measured in the peccary sacrificed during this experiment. This value is similar to that obtained by Dyson (1969). Blood glucose in the domestic steer is generally close to 50 mg percent while that of a monogastric (domestic swine) approximates 100 mg percent.

DISCUSSION

Fiber digestibility coefficients in this study were far lower than those usually observed for true ruminants, both domestic and wild. The values were also lower than those seen with many nonruminant herbivores. Fiber digestibility in the peccary compares closest to the general value given for the domestic pig (Church, 1977).

If prickly pear accounts for as much of the diet as has been assumed (Knipe, 1957; Eddy, 1959), then fiber digestibility would not be a prerequisite for this animals survival, since prickly pear is only 15 percent fiber. Since peccaries apparently lack the ability to digest fiber to any great extent, the adaptational significance of the ruminant-like stomach may be more closely related to this animals need to behaviorally thermoregulate, and spend much of its time in the shade, rather than gathering food. But, because of the oral anatomy of the peccary, resulting in the inability of the peccary to reduce particle size of its food to any great extent, microbial digestion could be beneficial. Also, since the peccary in the United States is at one extreme of its range and because this animal seems to be more tropically distributed, the need for thermoregulation may not have been extremely important to the survival of this species.

Prickly pear may not make up as much of the diet as previously thought. Since the peccaries used in this study exhibited a poor nutritional response to prickly pear cactus (in the form of diarrhea) it is possible that those animals in the wild would also exhibit this same response. If this were the case, water losses would be high and would diminish the nutritive value of prickly pear for the peccaries.

Zervanos (1977) predicted that 1.54 kg of cactus on a wet basis would need to be ingested by peccaries to meet their water needs (based on an average weight of 18.2 kg and assuming assimilation of water to be 100 percent). This amount would supply only one-third the protein necessary to meet these animals needs (based on NRC requirements for domestic pigs). If protein requirements were to be met by prickly pear alone, the peccary would need to eat approximately 20% of its own body weight of prickly pear on a DM basis each day.

Also, studies indicate that VFA levels are highest on a natural diet and yet in the current study it was found that prickly pear is low in fiber and this fiber has a low digestibility _in vivo_. If VFA's are indeed being produced in the stomach, then they must be from a nutrient source other than fiber. It is possible that on a DM basis prickly pear is not the major food item of the collared peccary.

Results of the IVDMD do not support the theory that fiber digesting microbes inhabit the gastric region of the peccary and reinforces the observation of little or no fiber digestion _in vivo_ for both prickly pear and the commercial pellet. It was not ascertained whether the disappearance of the commercial pellet was due to microbial or enzymatic digestion or simple solubility.

Blood glucose levels of 70 mg percent for the peccary are midway between those of a domestic cow and pig. Domestic cattle utilize VFA as their major energy source while swine use glucose. It would seem that if microbial digestion is important in the peccary, then this animal might utilize both glucose and VFA for energy, which would be a useful adaptation depending on the type of food available.

Much of the anatomical and histological work conducted by Langer (1977, 1978) indicates the peccary stomach possesses cell structure similar to that of domestic cattle. Also, development from birth to adult in surface areas of the gastric regions is similar between the two species. However, there is no papillae development in the stomach of the peccary. These are common in the rumen of all true ruminants and function in VFA absorption.

In spite of data obtained from this study and others in the past, it is still unknown to what extent microbial digestion occurs and whether or not it is important to the nutritional economy of the animal. Studies so far conducted have helped to define areas which deserve further attention. Observations in this study that tamed peccaries can be used satisfactorily in metabolism crates would simplify further research.

More complete characterization of the microbial populations in the stomach and analysis of VFA in blood would be helpful in determining the importance of microbial digestion. Fistulation or some other method for removing contents directly from the stomach would also be useful. If this could be accomplished, then it would be simpler to determine the types and relative amounts of food eaten by animals in the wild by allowing tamed animals access to enclosed natural areas with subsequent capture and removal of ingesta from the stomach. Both physical and chemical analysis could be conducted to aid in discovering the biological basis for digestion in the collared peccary.

SUMMARY

Three digestion trials using two tame female collared peccaries were conducted with three different diets. The diets included a commercial swine diet, a purified diet and a diet of prickly pear (_Opuntia engelmannii_). Two collection periods were conducted per diet. The commercial swine diet was 13 percent fiber and 12 percent protein. The purified diet contained 15 percent protein and 21 percent fiber, while values for protein and fiber in prickly pear are 16 percent and 5 percent respectively.

Digestion coefficients for fiber was highest on the commercial pellet (26 percent), and lowest on the purified diet (4 percent). Fiber digestibility on the prickly pear diet varied from one collection period to the next (-13 percent vs. 6 percent). Digestion coefficients for protein on the commercial, purified and prickly pear diet were 68, 84, and 56 percent, respectively. TDN and nitrogen balance were highest for the purified diet and lowest for the prickly pear.

Blood glucose levels averaged 70 mg/100 ml which in midway between usual values for monogastric and ruminant animals. VFA concentrations in the stomach of an animal were low (55 m mole/l) but molar percentages were similar to those obtained by other workers. In vitro gastric contents showed the ability to digest the commercial pellet (76 percent) but not cellulose. When rumen fluid from a fistulated steer was used, cellulose digestion was higher (26 percent

disappearance) and commercial pellet disappearance was approximately the same as when peccary gastric fluid was used.

This study demonstrates that conventional techniques for nutritional research can be adapted for use with collared peccaries. This approach could be used to define nutritional requirements as well as to gain additional information on digestive and physiological processes in this species.

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