THE UTILIZATION OF BANANA MEAL AS A SUBSTITUTE FOR TRADITIONAL HIGH ENERGY FEEDS FOR LACTATING DAIRY CATTLE IN ECUADOR

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ABSTRACT

THE UTILIZATION OF BANANA MEAL AS A SUBSTITUTE FOR TRADITIONAL HIGH ENERGY FEEDS FOR LACTATING DAIRY CATTLE IN ECUADOR

By

Connie Nielsen Detering

There is a need to develop feed sources for livestock production in Ecuador. Approximately 1.14 million metric tons of bananas are estimated to go to waste every year in Ecuador. These bananas are a potential source of livestock feed.

The research was conducted as a field trial in collaboration with the National Institute of Agriculture and Livestock Research and the Swiss Technical Mission in Quito, Ecuador, at an altitude of 2850 m. Thirty purebred Holstein cows in the first 100 days of lactation were assigned to three treatment groups of ten each using randomized blocks based on production and number of lactations. The three groups of cows were fed a concentrate containing either 71 per cent banana meal, 71 per cent corn, or 75 per cent wheat bran as the primary energy source. Cows were on ryegrass and white clover pasture for 20 hours per day. The experiment lasted for 112 days. During this time a study was made of changes in milk production, milk composition, body weight, concentrate intake, blood glucose, calcium, phosphorus, and magnesium, and reproductive performance.

Average daily milk production for the 112-day trial was not significantly different among groups. Concentrate intake for the group receiving the banana meal based concentrate decreased significantly over time, indicating a palatability problem. Body weight increased significantly with time in all three groups, but there was no significant difference due to treatment. Milk composition was similar for all three treatment groups.

The results of blood analysis showed that plasma glucose, calcium and magnesium concentrations were not different among treatments. Plasma phosphorus concentrations were higher for the group receiving the wheat bran based concentrate. Data on reproductive efficiency were inconclusive.

It is concluded from this study that banana meal was an acceptable substitute for corn and wheat bran in concentrate for lactating Holsteins.

SUMMARIO

LA UTILIZACION DE HARINA DE BANANO COMO SUBSTITUTO
DE ALIMENTOS TRADICIONALES DE ALTA ENERGIA
PARA VACAS LECHERAS EN EL ECUADOR

Por

Connie Nielsen Detering

El desarrollo de fuentes de alimento para la producción animal es una necesidad en el Ecuador. Se calcula que approximadamente 1.14 milliones de toneladas métricas de banano se desperdician cada año en el Ecuador. Este banano es una fuente potencial de alimento animal.

La investigación se llevó a cabo en la forma de un ensayo en regional en colaboración con el Instituto Nacional de Investigaciones y la Misión Téchnica Suiza in Quito, Ecuador, a una altura de 2850 m s.n.m. Se asignaron treinta vacas Holstein de raza pura durante los 100 primeras días de la lactancia a tres tratamientos de diez vacas cada uno, usando bloques al azar basados en la producción y en el número de lactancias. Se alimentó a los tres grupos de vacas con un concentrado que contenía ya sea 71 por ciento de harina de banano, 71 por ciento de maiz, o 75 por ciento de afrecho de trigo como, fuente primaria de energía. Las vacas estuvieron pastoreando rye grass y trébol durante 20 horas cada día. El experimento duro 112 días. Durante este tiempo se hizo un estudio de los cambios en

produccion de leche, composición de la leche, peso vivo, consumo de concentrado, eficiencia reproductiva, y niveles de glucosa, calcio, fósforo y magnesio en el plasma sanguíneo.

La producción diaria promedio de leche para el ensayo de 112 días no fue significativamente diferente entre grupos. El consumo de concentrado para el grupo que recibió harina de banano disminuyó significativamente al pasar el tiempo indicando un problema de palatabilidad. El peso vivo incremento significativamente con el tiempo en todos los grupos pero no hubo diferencia significativa debida al tratamiento. La composición de leche fue similar para todos los grupos.

Los resultados de los análisis de sangre no indicaron ninguna diferencia en glucosa, calcio y magnesio en el plasma entre tratamientos. Las concentraciones de fósforo en el plasma fueron más altas en el grupo que recibió concentrado con afrecho de trigo. Los datos sobre eficiencia reproductiva no fueron concluyentes.

Se concluye de este estudio que la harina de banano fue un sustituto aceptable para maiz y afrecho de trigo en concentrados para vacas lecheras Holstein.

THE UTILIZATION OF BANANA MEAL AS A SUBSTITUTE FOR TRADITIONAL HIGH ENERGY FEEDS FOR LACTATING DAIRY CATTLE IN ECUADOR

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Connie Nielsen Detering

A THESIS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The dairy industry in Ecuador is primarily located in the Andean intermountain regions known as the *sierra*. The population of dairy animals is approximately one million, which includes about 300,000 milking cows. The cattle are primarily crosses between Holsteins and native, or *criollo*, cattle, with some purebred Holstein-Friesian herds. The average daily milk production is approximately 3 kg per cow as compared to an average daily production of 15 kg per cow in the United States.

Increasing demands and a steady rate of population growth in Ecuador have created a serious shortage of milk and dairy products. At present, the average annual per capita consumption of dairy products is about 32 kg. Most dairy products are consumed in the urban centers, with little reaching the rural population.

Several factors prevent rapid development of the dairy industry in Ecuador. These include the genetic quality of dairy cattle, the prevalence of diseases such as brucellosis and foot-and-mouth, a high culling rate which inhibits the growth of population numbers, improper management of young stock, plus the lack of supplemental feed sources.

The climatic conditions of the *sierra* have permitted the development of high quality pastures with temperate zone grasses and

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legumes. The dairy industry in this region has developed around the use of pasture systems.

The low productivity of the dairy cattle is thought to be due more to inadequate nutrition than to genetic quality. Fonseca (1973) states that the problem is one of limited dry matter and energy intake, especially during the dry season. Espinosa (1973) demonstrated in a field trial in the Machachi Valley near Quito, Ecuador, that milk production increased 0.26 liters/pound of supplemental concentrate when cows were supplemented with 12 pounds of concentrate per day as compared to cattle that received no supplemental feed. Generally, either no concentrate or low levels of low quality concentrates are fed. This is primarily due to the unavailability of traditional feed grains which emphasizes a need to develop low cost feeds to improve livestock production.

Bananas are the major agricultural export commodity for Ecuador. Bananas are harvested green and processed at packing plants, where bruised, spotted, under- or oversized, and unripe or over-ripe fruit is rejected for export. This rejected fruit is normally left to rot. The Junta Nacional de Planificacion (National Planning Committee) in 1973 estimated that in the years 1973 through 1977 about 33 per cent of the banana production, or 1.14 million metric tons of fresh fruit per year, will be wasted.

Fresh bananas are highly perishable and expensive to transport to livestock producing regions due to their high moisture content. A pilot plant to process the reject green bananas into a dehydrated meal has recently been constructed near Quevedo, Ecuador. It is

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thought that this industrially produced banana meal will be an acceptable substitute for traditional high energy feeds for livestock.

The objective of this research was to estimate the replacement value for milk production of banana meal and to study milk composition, body weight, reproductive performance, and blood calcium, phosphorus, magnesium, and glucose of cattle fed banana meal or traditional feeds.

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LITERATURE REVIEW

Bananas have been grown for many years in tropical regions as a fruit for human consumption. Recently bananas have been considered as a possible energy source for domestic animals in areas where this fruit is grown. The nutrient composition, the importance of specific organic compounds present in bananas, and the feeding value of the banana will be discussed as they relate to livestock feeding.

Nutrient Composition of the Banana

Fresh ripe bananas contain approximately 80 per cent moisture and 20 per cent dry matter. Bananas contain 5 per cent protein, 5 per cent fiber, 1 per cent fat, 5 per cent ash, and 84 per cent nitrogen free extract on a dry matter basis (Clavijo and Maner, 1975; Pond and Maner, 1974). Bressani et al. (1961) demonstrated that the composition of bananas is variable among varieties. The mineral composition of fresh ripe bananas is shown in Table 1.

The skin or peel of the ripe banana contains 84 per cent moisture. On a dry matter basis, the skin contains 6 per cent protein, 9 per cent fat, 10 per cent fiber, 12 per cent ash, and 63 per cent nitrogen free extract (Archibald, 1949). The banana skin contains approximately the same amount of protein as the pulp but contains considerably higher amounts of fat, fiber, and ash and thus has a lower nitrogen free extract.

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Table 1. The mineral composition of ripe banana pulp[1]

	mg/100 gm fresh fruit		mg/100 gm fresh fruit
potassium	373	copper	0.2
magnesium	31	manganese	0.6
sodium	42	iodine	0.003
phosphorus	28	zinc	trace
calcium	8	cobalt	trace
iron	0.6		

[1]Bogert (1942).

There is a difference in the palatability of ripe and green bananas, specifically noted in man and swine. The green banana is dry and bitter, while the ripe banana is moist and sweet. This is due to chemical changes which occur in the banana during the ripening process. There is a 3 to 4 per cent increase in the moisture content of the banana during ripening. There is also a rapid decline in starch content with a corresponding increase in sugar content as the banana ripens (von Loesecke, 1949).

A dehydrated meal made industrially in Ecuador from the green fruit with peel contains from 89 to 92 per cent dry matter. This product contains 5.5 to 6 per cent ash, 4.5 to 5.5 per cent protein, 1.1 to 1.7 per cent fat, 3.5 to 4.5 per cent fiber, and 82 to 86 per cent nitrogen free extract (Rihs et al., 1975a).

The digestible energy of ripe and green bananas is 3.1 and 3.2 Mcal/kg dry matter (DM) for swine, respectively. The digestible energy of dehydrated ripe and green bananas for swine is 1.7 and 3.2 Mcal/kg DM, respectively (Clavijo and Maner, 1974). For cattle, fresh green bananas have a digestible energy of 3.6 Mcal/kg DM (Vohnout and Jimenez, 1975). These values can be compared to corn, which has a digestible energy of 3.98 Mcal/kg DM (Anonymous, 1971).

Important Minor Organic Compounds Present in Bananas

Bananas contain several phenolic substances. Certain of these phenolic substances, the tannins, have been implicated in the astringent or bitter taste of the unripe or green banana. Tannins have been defined as those phenolic compounds of sufficiently high molecular weight (>500) to complex and precipitate proteins (Goldstein and Swain, 1963). Tannins are divided into two classes. The hydrolyzable tannins are characterized by having a polyhydric alcohol as a core and yield carbohydrate and phenolic acids upon hydrolysis. The condensed tannins contain only phenolic nuclei and polymerize upon hydrolysis to form dyes (Haslam, 1966). The majority of tannins in edible fruit are leuco-anthocyanins, a type of condensed tannin (Goldstein and Swain, 1963). Astringency arises from the cross-linking of the proteins and glycoproteins of the mouth by tannins.

Barnell and Barnell (1945), using the diastase inactivation method, found that the peel of the green banana contains four times as much soluble tannin as the pulp. This relative amount decreases

with ripening so that the peel of the ripe banana contains only twice as much soluble tannin as the pulp. Goldstein and Swain (1963), using aqueous methanol extraction of tannins from the fruit, showed the unripe banana to contain approximately 1 per cent leucoanthocyanins. These authors also showed that there was an increase in polymerization of tannins with ripening. The loss of astringency upon ripening of the fruit is thought to be due to the increased polymerization of tannins. Highly polyermized tannins are either insoluble or too large to bind with protein molecules.

Tannins as a component of livestock feeds has received little attention. Tannins affect animals by depressing feed consumption due to their astringent properties and by forming insoluble fractions in the digestive tract due to their protein binding properties. Feeding tannins to chicks and rats at levels of 1 per cent of the diet leads to growth depression, lowered energy conversion, and the excretion of high levels of nitrogen in the feces (Singleton and Katzer, 1973). Feeding tannins at levels of 5 per cent of the diet resulted in a high mortality of chicks. Condensed tannins appear to be less detrimental than hydrolyzable tannins (Singleton and Katzer, 1969).

Ruminants are more tolerant to tannins than monogastrics, possibly due to the modification and destruction of phenols by the rumen microflora (Singleton and Katzer, 1969). Hawkins (1955) found that the addition of 5 per cent tannic acid to an alfalfa hay diet fed to six-month-old dairy calves had no effect on dry matter consumption, water consumption, or average daily gain. Driedger and Hatfield (1972), feeding soybean meal treated with 10 per cent

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Tara tannin to lambs, found that average daily gains, feed efficiencies and nitrogen balances were greater than for lambs receiving a diet with untreated soybean meal. The toxicity of shin oak (*Quercus havardi*) leaves is due to high levels of hydrolyzable tannins. The leaves contain as much as 15 per cent tannins in early spring (Pigeon et al., 1962). Shin oak poisoning causes large annual livestock losses in the Southwestern United States (Singleton and Katzer, 1969).

The tannin content of some common feedstuffs is: alfalfa hay, 1.76 per cent (Hawkins, 1955); *Sericea lespedeza* hay, 4.0 per cent (Hawkins, 1955); sorghum grains, 0.2 to 2.0 per cent (Fuller et al., 1966); and rapeseed meal, 3.0 per cent (Clandinin and Heard, 1968).

The tannin content of bananas is approximately 1 per cent of the dry matter. This amount should have little or no effect when feeding bananas to ruminants, but should be taken into consideration when feeding bananas to monogastrics.

Bananas also contain relatively large quantitites of physiologically active phenolic amines. Anderson et al. (1958) observed that feeding bananas to monkeys caused a drastic increase in urinary excretion of 5-hydroxy indole acetic acid (5HIAA). Urinary excretion of 5HIAA is used as a diagnostic test for malignant carcinoid in man. 5HIAA is a metabolite of serotonin. The presence of possible precursors of 5HIAA was studied in bananas (Waalkes et al., 1958). Bananas were found to contain large amounts of serotonin, norepinephrine and dopamine. Their values are given in Table 2.

Further experiments showed that the norepinephrine and dopamine extracted from bananas have biological activity. The oral

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Table 2. The serotonin and catecholamine content of bananas[1]

	Banana pulp µg/gm	Banana peel µg/gm
Serotonin	28	65
Norepinephrine	1.9	122
Dopamine	7.9	700

[1]Waalkes et al. (1958).

administration of 20 mg of serotonin had no apparent physiological effect, although injecting 1 mg intravenously produced marked effects.

The major significance of the presence of serotonin and catecholamines in bananas is that the ingestion of this fruit may lead to erroneous chemical diagnosis of malignant carcinoid tumors in man by producing increased urinary excretion of these compounds and their metabolites. Pharmacologists teach that dietary monoamines are metabolized in the gastrointestinal tract and probably have no systemic action. Also, since serotonin and norepinephrine decompose at 191 C and dopamine at 240 C (*Merck Index*, 1968), those compounds would not likely be present in commercially dehydrated banana meal.

Several sterols and triterpenes have been identified in banana peel. They are primarily in the form of palmitate esters and represent approximately 30 per cent of the total extractable lipid (Knapp and Nichols, 1969). The possible implications of the presence of these compounds is not known.

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Osswald (1973) obtained negative results in a study designed to reproduce observations of a bladder carcinogenic effect in guinea pigs fed a banana diet. Male guinea pigs and rats were fed bananas for 5 days and a stock diet for 2 days each week or consumed the stock diet for 7 days. The treatment was continued until all survivors were sacrificed at 1,084 days. No malignant tumors of the bladder were seen in either group.

Subrahmanyan et al. (1958) found that feeding dried bananas at 65 per cent of the diet to rats decreased the number of coliform, aerobic and microaerophilic organisms of the cecum as compared to rats on a control diet. The number of anaerobic bacteria in the cecum was not affected by diet.

Feeding Trials with Domestic Livestock

Fresh ripe bananas are more palatable than fresh green bananas and more efficient in producing live weight gains in growing and fattening swine (Clavijo and Maner, 1975; Shillingford, 1971). Several reports indicate that feeding ripe bananas *ad libitum* with a high protein supplement gives satisfactory gains in growing and fattening swine (Butterworth and Houghton, 1963; Calles et al., 1970; De Alba, 1951; De Alba and Basarde, 1952; Squibb and Salazar, 1951; Squibb et al., 1953). Ripe bananas fed with a protein supplement were also an adequate substitution for corn in rations for gestating sows and had no negative effects on reproductive performance (Clavijo et al., 1971). However, ripe bananas should not be the only energy source for lactating sows due to an inability to consume all the bananas needed to supply their energy needs (Clavijo and Maner, 1971, 1975).

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Work done in Cameroon and Costa Rica shows that acceptable gains were made feeding fresh green bananas to fattening swine (Alpizar et al., 1974; Branckaert and Lecoq, 1971).

Viteri et al. (1974) have shown that banana meal made from the green fruit pulp is satisfactory up to levels of 45 per cent in a starter diet for baby pigs. Another study using this same product for fattening swine found that when fed up to levels of 60 per cent of the diet no significant difference was found in daily weight gain, feed efficiency, or in days to reach market weight of 90 kg as compared to a corn based control ration (Alvardo, 1971; Alvardo et al., 1974).

Celleri et al. (1971) showed that every increase in the level of banana meal from 0 to 75 per cent in the diet of fattening swine caused a linear decrease in average daily gain and a linear increase in the amount of feed required per unit gain. These authors used a locally available sun dried meal, while a more recent experiment used an industrially dehydrated banana meal and showed no significant difference in average daily gain, feed efficiency, or feed consumption between swine fed 0, 21, or 42 per cent banana meal in the diet. However, when there was a total substitution of corn by banana meal, there was a significant reduction in the above parameters (Rihs et al., 1975).

Swine fattened on a banana based diet have been shown to exhibit acceptable carcass qualities (Branckaert and Lecoq, 1971; Shillingford, 1971). Carcasses have less fat but similar loin muscle dimensions (Butterworth and Houghton, 1963).

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Clavijo and Maner (1974) studied factors that affect the digestibility and energy value of bananas for swine. They found that ripe bananas have significantly higher digestion coefficients for protein, fiber and fat than green bananas. There was an unfavorable reaction to unspecified heating during artificial drying by ripe bananas with or without peel as compared to green bananas with or without peel. Dried ripe bananas had significantly lower digestibility coefficients for dry matter, protein, nitrogen free extract, and total digestible nutrients as well as digestible energy than did dried green bananas.

A slight reduction in growth rate was reported when green banana meal with peel was fed in chick grower diets at levels of 15 and 30 per cent to replace corn, although chicks on the banana meal treatments consumed more feed, which resulted in lowered feed efficiency (Platt, 1950). Sun dried ripe banana meal was fed at levels of 0, 21, 42, and 63 per cent of the diet for week-old chicks. Each increase in the level of banana meal in the diet suppressed growth and significantly reduced feed conversion. The diet containing 63 per cent banana meal had 75 per cent mortality. Artificially dried (80 C) green banana meal with or without peel was fed at levels of 20, 40, and 60 per cent in diets of week-old chicks. Although growth was suppressed with both banana meals as the level in the diet increased, the effect of banana meal made without peel was least severe. There was 33 and 54 per cent mortality with banana meal without and with peel, respectively, when fed at levels of 60 per cent of the diet. No significant increase in mortality was noted at the lower levels of banana meal in the

diet. Bressani et al. (1961) recommend that banana meal be used only up to levels of 10 per cent in growing chick diets. The high fiber content of the diet, the inability to utilize the carbohydrate of the banana, and/or the growth depressant effect of tannins in chick diets may have been responsible for the negative results reported.

Wallace et al. (1951) used a mixture containing 20 per cent banana meal in a milk replacer for dairy calves. This mixture was very palatable and promoted growth comparable to calves on a control diet and also appeared to help prevent scours. However, three- to four-week-old calves were able to utilize only 50 per cent of the dry matter in a mixture containing 50 per cent banana meal, even though the calves showed a satisfactory growth response. Calves fed levels of 5, 20, and 40 per cent banana meal in the starter ration showed no significant difference in rate of growth measured as body weight, chest circumference and height at withers. The authors found that the banana meal diets decreased the severity of scours but not the incidence (Fyock and Knott, 1949). A study in Ecuador utilizing either banana meal or corn at a level of 48 per cent in the grain ration fed to bull calves from two weeks to six months of age showed no significant difference in average daily gain between the two groups (Espinosa et al., 1971).

Hererra (1974) in Costa Rica studied the feasibility of fattening cull Zebu cows with varying ratios of fresh green bananas and molasses (total isocaloric intake equivalent) where 60 per cent of the protein was from urea. There was a positive effect with additions of banana until it represented 35 per cent of the total

energy of the diet. Feed efficiency increased as the level of banana increased up to 25 per cent of the total energy, after which feed efficiency remained constant. No difference was noted between groups in either carcass yield or composition. The author concluded that in diets where high levels of urea are fed, at least 35 per cent of the energy should be in the form of starch. The low efficiency of feed conversion of cull cows along with low prices for this type of meat resulted in an economic loss for this type of operation.

Ruiz et al. (1974) supplemented green bananas to Brahman steers that grazed Guinea grass (*Panicum maximum*) pastures sixteen hours per day. Daily gains increased from 0.460 to 0.590 kg per animal as a result of feeding each animal 0 to 5 kg bananas per day. Higher quantities of green bananas did not improve yield above this level, indicating 5 kg per animal per day constitutes a limit to the efficient utilization of bananas as a supplement to pasture. Quality of pasture may alter this substitution rate. Another study determined the effect of stocking rate on weight gain of Brahman, Charolais, and Angus crossbred steers and heifers when supplemented with green bananas *ad libitum*. Stocking rates on Guinea grass *(Panicum maximum)* pasture were 2, 4, 6, 8, and 10 animals per hectare. These authors reported that banana consumption varied from 4.4 to 5.5 kg dry matter per day per 100 kg body weight. At the low stocking rates weight gain decreased from 0.61 kg per animal per day for those not supplemented with bananas to 0.52 kg per animal per day for those which were supplemented with bananas. At the high stocking rate, animals which were not supplemented with

bananas just maintained body weight while those supplemented had 0.49 kg per animal per day gain (Alpizar, 1974; Alpizar and Vohnout, 1974).

Isidor (1973) found that the intensive use of cull green bananas under feedlot conditions resulted in average daily gains of 1 kg per animal with Brahman-Charolais and Brahman-Red Polled steers. This can be compared to average daily gains of 0.5 to 0.6 kg per animal which were reported for similar breeds on pasture in the same climatic zone (Alpizar, 1974; Alpizar and Vohnout, 1974). Isidor (1973) reported that, although average daily gain was affected by the level of supplementary protein fed, it was not affected by the addition of cut forage (*Eschinochloa polystachia*). Under these feedlot conditions the intensive use of cull green bananas with a low level of protein supplementation (0.216 kg protein/100 kg body weight) would result in maximum economic benefit.

Vohnout and Jimenez (1975) conclude that under typical management conditions, where beef cattle are raised on pasture, cull green bananas can be used as a buffer when forage yield is negatively affected by climatic conditions. These authors recommend that feeding 1.5 kg of green bananas per 100 kg of body weight per each 10 per cent reduction in forage yield would maintain maximum output per unit area. However, if forage yield is reduced more than 40 per cent, then protein, not energy, may become the factor limiting maximum output.

A study to determine the response of lactating dairy cattle to feeding a locally available, industrially dehydrated meal made from green bananas plus peel is currently in progress at the National

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Institute for Agriculture and Livestock Research (INIAP) in Ecuador. Banana meal is being compared at levels of 50 or 90 per cent of the concentrate ration to a concentrate ration containing 50 per cent corn to determine the effects on milk production and reproductive efficiency. Concentrates are fed at levels of 2, 3, or 4 kg per animal per day according to the stage of lactation. Preliminary results indicate that banana meal is an adequate substitute for corn and has had no negative effects on milk production, milk composition, or body weight. At these levels of concentrate feeding, the banana meal based diets are very palatable (Rihs et al., 1975b; Rihs and Isler, 1976).

Summary

Bananas can be considered a high energy food. Although they contain compounds such as tannins, serotonin and catecholamines, and triterpenes, no negative effects of feeding bananas have been reported except for poultry. Bananas have been shown to be an adequate energy source for swine. Normal performance has also been reported in the feeding of banana meal to dairy calves and fresh green bananas to beef cattle. There is little information on the substitutability of bananas for traditional high energy feeds in concentrate rations for dairy cattle. The present study was designed to determine the effects of feeding an industrially produced banana meal as the major energy source in concentrates for lactating Holsteins.

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EXPERIMENTAL PROCEDURE

The experiment was conducted as a regional field trial in collaboration with the Department of Nutrition and the Dairy Program at the National Institute for Agriculture and Livestock Research (Instituto Nacional de Investigaciones Agropecuarias - INIAP) and the Swiss Technical Mission in Quito, Ecuador. The field work was done on the hacienda "El Garrochal", a privately owned dairy farm located approximately 12 kilometers southeast of Quito and 10 kilometers northeast of the Santa Catalina Experiment Station of INIAP. The hacienda is at an altitude of 2,850 meters above sea level. All supportive and analytical work for the experiment was conducted at the Santa Catalina Experiment Station.

Treatments

The field trial was designed to determine the effects of feeding banana meal as an energy source for lactating dairy cows. Three concentrate diets (Table 3) designated negative control, positive control, and experimental were formulated using wheat bran, corn, and banana meal, respectively, as the primary energy source. The negative control was the regular herd concentrate. The positive control was similar to a concentrate diet fed in the United States. The experimental diet was based on "Banharina", an industrially

Table 3. The composition of concentrates

Feed ingredient	Wheat bran based concentrate Negative control[1]	Corn based concentrate Positive control	Banana meal based concentrate Experimental
	%	%	%
Banana meal ("Banharina")	---	---	70.7
Corn, ground	---	70.7	---
Wheat bran	75.0	---	---
Cottonseed meal	---	6.1	11.1
Royal palm oil meal	11.0	13.1	5.1
Ground ear corn with cob	7.0	---	---
Cottonseed hulls	7.0	---	---
Fishmeal	---	---	3.0
Molasses	---	8.1	8.1
Urea	---	1.0	1.0
Salt	---	1.0	1.0

[1]This diet was mixed with an undetermined quantity of a mixture of water, molasses, and salt prior to each feeding.

produced meal made from reject, green, unpeeled bananas. The chemical composition of dietary constituents is shown in Table 4.

Experimental Animals

A total of thirty cows, twenty-nine purebred Holsteins and one Holstein-Jersey cross, were chosen from the "El Garrochal" herd of approximately one hundred lactating cows. All cows were in the first 100 days of lactation at the beginning of the adaptation period. The cows were grouped into ten blocks on the basis of number of previous lactations and average milk production of the current lactation. Animals within each block were randomly assigned to treatment groups. Assignment of cows by block and treatment is shown in Table 5. One cow assigned to the negative control group died from secondary effects of pneumonia one month after the beginning of the experimental period; hence, this group had only nine cows.

Feeding Management

Animals were adapted to their respective diets over a 35-day period. Animals were fed 3.18 kg on an as-fed basis of their respective diet per day for seven days at the morning milking to accustom them to the new concentrate mix. Over the next 21 days the feed was gradually increased to 7.26 kg of the positive control and experimental concentrates and 9.07 kg of the negative control concentrate, the animals receiving 3.63 and 4.54 kg on an as-fed basis, respectively, at each milking. During this 21-day period, the corn in the positive control concentrate became moldy, resulting in an additional seven-day delay for the initiation of the experimental period. Non-contaminated corn was acquired and included

Table 4. The chemical composition of feeds and concentrate mixtures

Feeds	Dry matter	Ash	Ether extract	Crude protein	Crude fiber	Nitrogen free extract	Gross energy	Ca	P
	%	%	%	%	%	%	cal/g	%	%
Banana meal[1]	89.7	5.2	1.5	4.4	4.9	73.8	3,736	0.16	0.12
Corn	90.1	1.9	4.2	9.4	2.7	72.0	4,108	0.04	0.32
Cottonseed meal[1]	91.5	8.2	2.2	46.4	8.2	26.6	4,274	0.45	1.37
Royal palm oil meal[1]	89.8	4.1	2.3	9.7	23.4	50.4	4,155	0.18	0.47
Fish meal	91.9	11.4	8.2	65.9	0.6	5.8	4,908	3.60	2.48
Molasses	75.2	9.4	0.4	1.7	0.2	63.7	2,858	0.86	0.09
Concentrate Mixtures[2]									
Negative control diet	60.3	4.6	2.0	8.8	7.5	37.4	2,708	0.22	0.72
	100.0	7.8	3.3	14.6	12.4	61.9	4,482	0.37	1.21
Positive control diet[3]	89.1	3.6	2.3	13.4	5.3	64.5	3,937	0.11	0.28
	100.0	4.0	2.5	15.1	6.0	72.3	4,417	0.12	0.31
Experimental diet:[3] as mixed	88.8	6.6	1.5	12.5	5.2	62.9	3,741	0.27	0.32
	100.0	7.5	1.7	14.1	5.9	70.9	4,214	0.30	0.36
Experimental diet:[4] as fed	85.6	6.4	1.6	12.1	5.5	60.1	3,626	0.26	0.36
	100.0	7.5	1.8	14.2	6.4	70.2	4,235	0.31	0.42

[1]Average value of two samples; [2]Average value of four samples; [3]Average value of three samples; [4]Values calculated using the dilution factor (page 22).

Table 5. The assignment of cows by block and treatment

Block	Negative Control			Positive Control			Experimental		
	Name	Pre-expt. average milk prod.	No. of lactations	Name	Pre-expt. average milk prod.	No. of lactations	Name	Pre-expt. average milk prod.	No. of lactations
		kg			kg			kg	
1	Vasca	14.5	1	Veterana	14.0	1	Uruguaya	13.2	1
2	Zulema	16.3	2	Zuleta	17.4	2	Undina	14.7	1
3	Lidia	20.4	2	Zapadora	20.1	2	Zancuda	25.8	2
4	Zafiro	21.2	3	Kayac	25.4	4	Lojana	26.1	3
5	Celestina	18.1	3	Zorra	17.0	3	Tailandia	23.8	4
6	Chistosa	29.9	5	Winiy	22.6	5	Jaramejo	21.2	5
7	Omegâ	18.6	5	Guinda	20.0	5	Judith	20.5	5
8	Novicia	22.3	6	Honesta	22.3	6	Hilandera	20.1	6
9	Elenita	17.4	8	Piluca	24.8	7	Ranchera	20.7	7
10	Fabiola	22.4	4	Periquita	20.6	4	Pulga	21.3	4

subsequently. Also, during this 21-day period, the cows would not consume 3.63 kg of the experimental diet. Consequently, the experimental diet was diluted with 0.45 kg of the negative control concentrate for every 3.63 kg so that this group of animals actually received 4.08 kg of concentrate per milking. The dilution was made immediately prior to feeding. One-half liter of watered molasses was mixed with the allotted concentrate prior to feeding. In order to placate the farm owner, an attempt was made to increase concentrate consumption of the experimental and positive control diets during the last six weeks of the experimental period. This did not measurably change feed intake (see Figure 2). The experimental period lasted 112 days.

An attempt was made to buy sufficient feeds for the experiment at one time to assure quality control and uniformity of feeds. The positive control and experimental concentrates were formulated to contain 13 per cent crude protein (as-fed basis) for the adaptation period using published tables of nutrient composition (McDowell et al., 1974). These two concentrates were reformulated before the beginning of the experimental period based on analysis of the actual feeds by the Department of Nutrition at INIAP. The positive control and experimental concentrates were mixed every eight days at feed mixing facilities of INIAP to prevent feed spoilage due to the high humidity at the storage facilities on the farm. The formulation and mixing of the negative control concentrate, the normal herd ration, was done at the dairy farm. The dry ingredients were mixed in quantity and stored. This mixture was then mixed with watered molasses immediately prior to each milking.

The entire herd, including experimental animals, were on pasture approximately 20 to 22 hours per day. The pasture consisted of a rye grass and white clover mixture and was grazed at 45-day intervals. Chemical composition of pasture samples is shown in Table 6.

General Management

Cows were milked in a 60-stall stanchion barn at 12-hour intervals. They were milked using a bucket-type milking machine. The herd was separated into two groups at milking, with the 60 highest producing cows entering the barn first to be milked and fed while the remainder of the herd waited in a corral next to the barn. During the adaptation and experimental periods, the animals on experiment were assigned two sets of 15 consecutive stanchions at the first milking. The animals were fed concentrate in individual plastic containers immediately after they entered the barn. Each cow's feed had been weighed into plastic bags prior to milking to facilitate the feeding.

Animals used in the experiment were identified by using neck chains and numbers.

Sample Collection

The amount of concentrate offered to the cows and the amount refused was weighed and recorded at each feeding. Milk production was recorded at each morning and evening milking by the farm manager.

The cows were weighed every fifteen days on a Sure-Weigh Model 800-B portable scale. On the day of weighing the cows remained in the stanchion barn after the morning milking and were weighed

Table 6. The chemical composition of f

Table 6. The chemical composition of forage samples taken simultaneously from five representative pastures during the preliminary period

Sample	Dry matter	Ash	Ether extract	Crude protein	Crude fiber	Nitrogen free extract	Gross energy	Ca	P	IVDMD[1]	IVOMD[2]
	%	%	%	%	%	%	cal/g	%	%	%	%
Pasture 1	35.1	2.3	0.99	4.4	9.2	18.2	1,572	0.25	0.09	63.8	64.3
Pasture 2	22.8	1.7	0.73	3.1	5.3	12.0	1,008	0.18	0.05	72.6	68.5
Pasture 3	29.9	1.8	0.81	2.7	9.7	14.9	1,334	0.16	0.03	55.1	53.0
Pasture 4	20.4	1.5	0.75	4.1	4.2	10.0	953	0.18	0.04	72.3	70.3
Pasture 5	22.8	1.6	0.45	1.9	6.4	12.4	987	0.08	0.06	66.0	64.4

[1] *In vitro* dry matter digestibility.

[2] *In vitro* organic matter digestibility.

between 0700 and 0730 hours. Since the cows usually entered the barn at 0330 hours, they were in the barn approximately three and one-half hours and had free access to water.

Milk samples were collected every fifteen days at the evening and morning milkings. Samples were transported to the experiment station for analysis.

Blood samples were collected every fifteen days from the coccygeal artery or vein. On these days cows remained in the stanchion barn after the morning milking and blood sampling began at 0630 hours. One 20-ml evacuated tube containing 4 mg of heparin was filled with blood for mineral determinations. A second evacuated tube of 7-ml volume containing 14 mg of potassium oxalate and 17.5 mg of sodium fluoride was filled with blood for glucose analysis. Blood was transported to the experiment station within one hour after sample collection.

Records of individual animal health and heat dates were maintained throughout the adaptation and experimental periods. Cows were artificially inseminated and the inseminations were recorded. Animals were pregnancy checked by the herd veterinarian. Previous reproductive history on all experimental animals was obtained from farm records.

Analytical Methods

All analytical work was conducted in the Department of Nutrition at the Santa Catalina Experiment Station of INIAP. All determinations were done in duplicate and, with the exception of plasma glucose, are routinely conducted by the Department of Nutrition using standard procedures.

Proximate Analysis

Proximate analysis was conducted on all samples of feeds, concentrates and forages by INIAP personnel using approved procedures.

Total nitrogen was determined using the Kjeldahl method (AOAC, 1965). Approximately one gram of samples was digested and distilled. The distillate was collected in a 4 per cent boric acid solution and titrated with 0.5 N sulfuric acid. Protein was calculated multiplying total nitrogen by 6.25.

For crude fiber analysis, approximately one gram of samples was digested in 200 ml of 0.7 per cent sulfuric acid for 30 minutes. Twenty milliliters of a 22 per cent sodium hydroxide solution were added to the digest and the mixture was refluxed for another 30 minutes. The residue was collected in a Gooch crucible with a cap of glass wool, washed with distilled water and acetone, dried at 105 C, weighed and ashed at 600 C. Crude fiber was calculated by difference.

Ether extract was determined using one to two grams of sample mixed with two grams of sodium sulfate and then extracted for seven hours with hexane. Hexane was removed by distillation. The extraction flasks were dried at 105 C for four hours and weighed.

Dry matter was determined on samples containing more than 15 per cent moisture by weighing 400 grams of sample before and after drying at 80 C for four hours. Dry matter was determined on samples containing less than 15 per cent moisture by weighing two grams of sample before and after drying at 105 C for eight hours.

The ash content of samples was determined by preincinerating three-gram samples on an electric hotplate prior to ashing in a muffle oven at 650 C for sixteen hours.

Gross energy was determined by combusting one-gram samples in an IKA C-400 Adiabatic Bomb Calorimeter in a 30 kg/cm^2 pure oxygen atmosphere.

"*In vitro*" digestibility of dry and organic matter was determined on forage samples using the two-stage technique of Tilley and Terry (1963) as modified by Alexander (1969). Forages were dried at 105 C for 16 hours and ground through a 0.75 mm mesh. One-half gram samples were incubated at 39 C for 48 hours with a 1:4 mixture of rumen fluid and buffer (the rumen fluid was obtained from a fistulated cow that grazed forage similar to the test material). Six milliliters of 20 per cent hydrochloric acid were added to the incubated tubes followed by 2 ml of an aqueous 5 per cent solution of pepsin. Samples were again incubated for 48 hours at 39 C. The residue was collected in filtering crucibles, washed with hot distilled water, dried at 105 C for 16 hours and weighed. The residue was subsequently ashed at 600 C for four hours and weighed.

Mineral Analysis of Feeds

Three- to five-gram samples of feeds, concentrates and forages were weighed and ashed in a muffle oven for 12 hours at 650 C. The ash was digested with a mixture of hydrochloric and nitric acids for 15 minutes. This solution was filtered, the supernatant was collected and diluted with double distilled water 1 to 100.

For phosphorus analysis the colorimetric method using ammonium molybdate-vanadate was used. Absorbance was read at a wavelength of 395 nm in 1 cm quartz cells in a Perkin Elmer 136 Spectrophotometer. The per cent phosphorus in the samples was calculated using a regression equation from a standard curve.

For calcium analysis, a 1 per cent solution of lanthanum chloride was added to a sample aliquot. The absorbance was read on a double beam Perkin Elmer 303 Atomic Absorption Spectrophotometer at a wavelength of 422.7 nm. The percent calcium in the samples was calculated using the regression equation from a standard curve.

Milk Composition

Methods published by Gerber (1954) are routinely used in the Department of Nutrition to determine the composition of milk.

Milk fat was determined using Gerber milk test bottles (butyrometers) (K. Schneider and Co., Zurich). Ten milliliters of sulfuric acid (density 1.825 at 20 C) was measured into the butyrometers followed by the addition of 11 ml of milk and 1 ml of amyl alcohol. Butyrometers were centrifuged for five minutes in a Gerber centrifuge (K. Schneider and Co., Zurich), after which they were placed in a water bath at 65 C for three minutes. Per cent milk fat was read directly from the scale on the butyrometers.

Milk density was determined using a Gerber density meter (K. Schneider and Co., Zurich). The density was corrected to a temperature of 15 C using tables published by Gerber (1954).

The per cent dry matter of milk was calculated using the values for corrected density and per cent milk fat with a d'Ackermann automatic calculator (K. Schneider and Co., Zurich). The solids not fat was calculated by subtracting per cent milk fat from per cent dry matter.

Milk protein was determined by formol titration. One milliliter of 28 per cent potassium oxalate was added to 25 ml of milk. A 0.14 N sodium hydroxide solution was added until a pH of 8.5 was reached. Five milliliter of formol were subsequently added and the solution re-titrated with the 0.14 N sodium hydroxide. The milliliters of sodium hydroxide used in the second titration corresponded to the per cent protein in the milk. A correction factor was determined using actual Kjeldahl nitrogen values on some of the milk samples.

Blood Analysis

Plasma was obtained by centrifuging the blood samples using an International Model K centrifuge. The plasma was stored at -20 C.

Blood glucose was determined using the glucose oxidase method (Anonymous, 1972). Plasma was deproteinized using a 2 per cent zinc sulfate solution and a 1.8 per cent barium hydroxide solution previously titrated to equivalency. The precipitated proteins were removed by centrifugation. Eight milliliters of glucostat reagent was added to 2 ml of the protein-free supernatant. The reaction was allowed to proceed for 10 minutes at room temperature and stopped by adding 2 drops of 4 N hydrochloric acid. Absorbance was determined

at a wavelength of 425 nm in a Perkin Elmer 136 Spectrophotometer. The plasma glucose was calculated from a standard curve prepared simultaneously.

For phosphorus determination, plasma was deproteinized using 10 per cent trichloroacetic acid. Phosphorus was determined as for feeds using a colorimetric reaction with ammonium molybdate-vanadate. Absorbance was read on a Perkin Elmer 136 Spectrophotometer at a wavelength of 395 nm. The plasma phosphorus was calculated using the regression equation from a standard curve.

For plasma calcium and magnesium determination, plasma was deproteinized with a solution of 4 per cent trichloroacetic acid and a 1 per cent lanthanum chloride solution was added to prevent the ionization of calcium during the determination. After centrifugation, the supernatant was diluted ten times with double distilled water. The absorbance was read on a double-beam Perkin Elmer 303 Atomic Absorption Spectrophotometer at the resonance wavelengths (422.7 and 2852 nm) for calcium and magnesium, respectively. The plasma calcium and magnesium were calculated using the regression equations from their respective standard curves.

Statistical Analysis

Analysis of variance for completely randomized blocks was calculated for milk production. Means were compared using Dunnett's Comparison with a control. Pooled regression analysis by treatment group was calculated on changes in milk production and feed intake with time. Body weight was analyzed with a split-plot, repeat measurement analysis with animals blocked by previous production and

number of lactations. Body weight was also analyzed using initial body weight as a covariate. Missing cow values for milk production and body weight were calculated by covariance analysis.

RESULTS AND DISCUSSION

Average daily milk production for each of the ten blocks of cows and for the 112-day experimental period is shown in Table 7.

Table 7. Average daily milk production for cows in each block fed three different concentrates during the 112-day experimental period

Block No.	Negative Control kg	Positive Control kg	Experimental[a] kg
1	14.9	11.6	11.5
2	12.4	19.2	13.4
3	14.3	16.1	19.8
4	14.3	21.7	13.9
5	20.3[b]	17.1	27.4
6	20.4	15.5	16.4
7	8.4	13.6	15.3
8	12.9	20.1	13.6
9	16.0	18.6	10.9
10	15.0	23.3	17.4
Average	14.9	17.7	16.0

[a]The negative control group received wheat bran based concentrate, the positive control group received corn based concentrate, and the experimental group received banana meal based concentrate.

[b]Animal died and milk production was calculated by covariance analysis.

Milk production for the animals fed the wheat bran, corn, or banana meal based concentrate averaged 14.9, 17.7, and 15.9 kg, respectively. There were no significant differences among treatments ($P<.05$). Average daily milk production for each treatment group for eight consecutive two-week periods is presented in Table 8 and Figure 1.

Table 8. Average daily milk production for cows fed three different concentrates at stated intervals during the experimental period

Days	Negative Control kg	Positive Control kg	Experimental kg
Preliminary period (1 to 35 days)	17.5	19.5	18.1
1 to 14	16.5	18.8	17.6
15 to 28	16.4	19.2	17.7
29 to 42	16.1	19.3	17.3
43 to 56	14.6	18.2	16.8
57 to 70	13.6	17.3	15.4
71 to 84	13.3	16.9	15.2
85 to 98	12.2	16.3	14.1
99 to 112	11.7	15.4	13.4
Average	14.3	17.7	15.9
Number of cows	9	10	10

The average daily milk production during the 35-day adaptation period was 17.5, 19.5, and 18.1 kg for animals fed the wheat bran, corn, or banana meal based concentrates, respectively. Average daily milk production decreased to 11.7, 15.4, and 13.4 kg or to 67, 79, and

Figure 1. Average biweekly milk production when ryegrass pasture was supplemented with three different concentrate mixtures for 112 days.

(O-O negative control, □-□ positive control, Δ-Δ experimental)

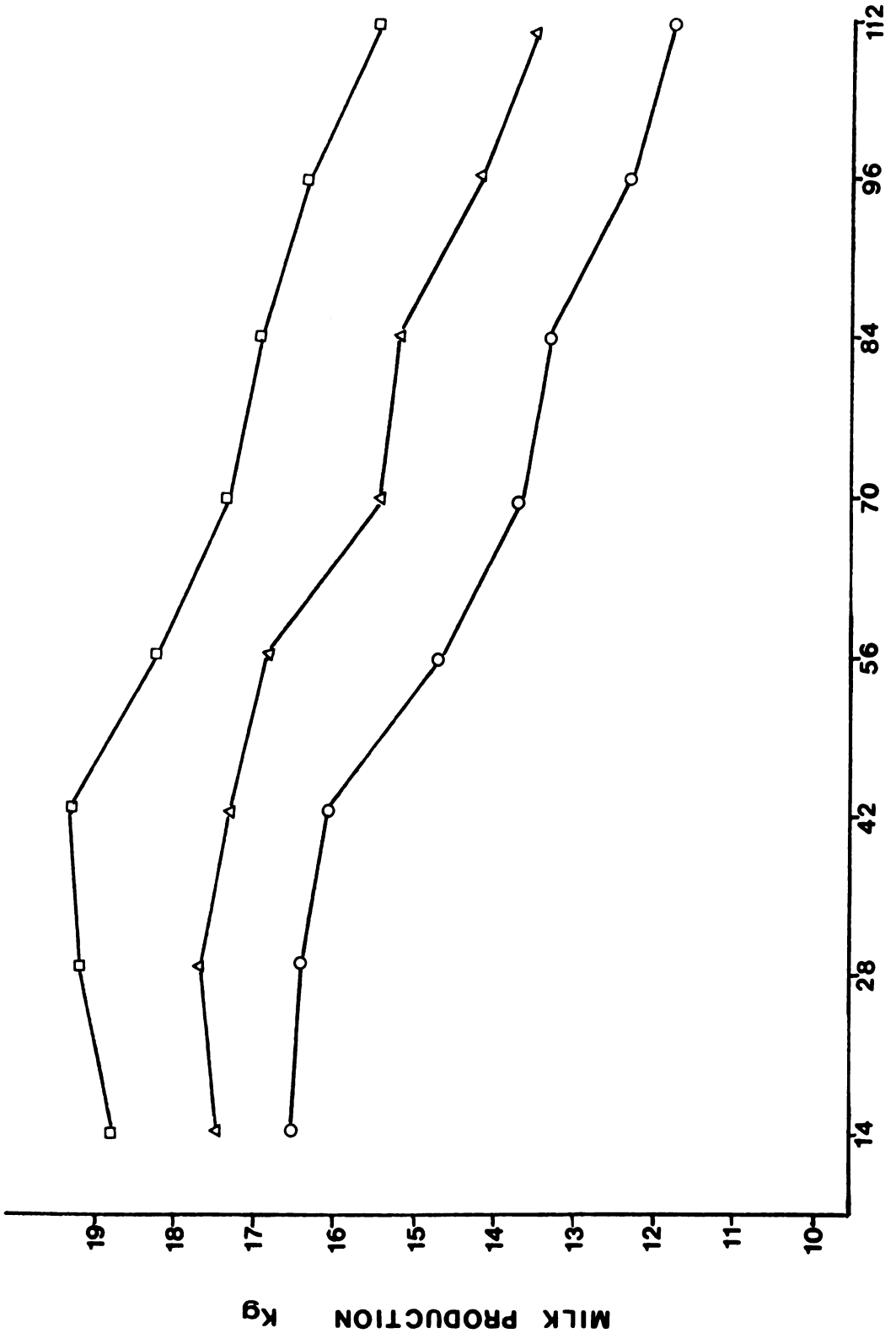
MILK PRODUCTION kg
19
18
17
16
15
14
13
12
11
10
14
28
42
56
70
84
96
112
DAYS

Figure 1

74 per cent by the end of the experimental period for the three groups, respectively.

The pooled regression of milk production over time was determined for each of the three treatment groups. The slopes of the regressions were -0.128, -0.098, and -0.111 for cows fed the wheat bran, corn, and banana meal based concentrates, respectively. There was no significant difference ($P<.05$) between the slopes for cows receiving banana meal or corn based concentrates, or between cows receiving banana meal or wheat bran based concentrate. However, the slope for cows receiving wheat bran based concentrate was greater than for those cows receiving corn based concentrate ($P<.05$). This regression analysis indicates that banana meal did not change rate of milk production decline compared to that of wheat bran or corn, but the corn concentrate was superior to the wheat bran concentrate in sustaining milk production.

Rihs and Isler (1976) reported that lactating cows fed a concentrate containing either 50 per cent corn, 50 per cent banana meal, or 90 per cent banana meal produced equal amounts of milk over a four-month period. Their results are in accordance with those presented in this thesis.

Although banana meal did not increase milk production in this study, when banana meal is used to supplement cows receiving only pasture, an increase in milk production would be expected. This would be similar to results obtained by Espinosa (1973), who observed increased milk production when pasture was supplemented with concentrate. When used in this manner, banana meal would add to the milk supply of Ecuador.

Concentrate dry matter intake averaged 6.0, 6.3, and 6.5 kg per day for animals fed the wheat bran, corn, or banana meal based concentrates, respectively (Table 9). Forage dry matter intake was not measured. The average daily dry matter intake for eight

Table 9. Average daily consumption of concentrate on a dry matter basis for the 112-day experimental period for each animal in the ten blocks fed the three concentrate mixtures

Cow Block No.	Negative Control kg	Positive Control kg	Experimental kg
1	5.4	6.4	6.4
2	5.4	6.1	6.1
3	5.4	5.9	5.6
4	5.4	6.5	6.7
5	---[a]	6.5	8.1
6	10.9	6.1	5.9
7	5.4	6.4	6.3
8	5.4	5.9	6.5
9	5.4	6.9	6.6
10	5.4	6.4	6.4
Average	6.0	6.3	6.5

[a]Animal died

consecutive two-week periods during the 112-day experiment is presented in Table 10 and Figure 2. The concentrate intake (DM basis) was relatively constant over the 112-day period for the animals fed the wheat bran and corn based concentrates. However, the concentrate intake for the animals on the banana meal based concentrate decreased

Figure 2. Average daily consumption of concentrate and apparent digestible energy intake from concentrate during eight consecutive two-week periods.

(O-O negative control, □-□ positive control, Δ-Δ experimental)

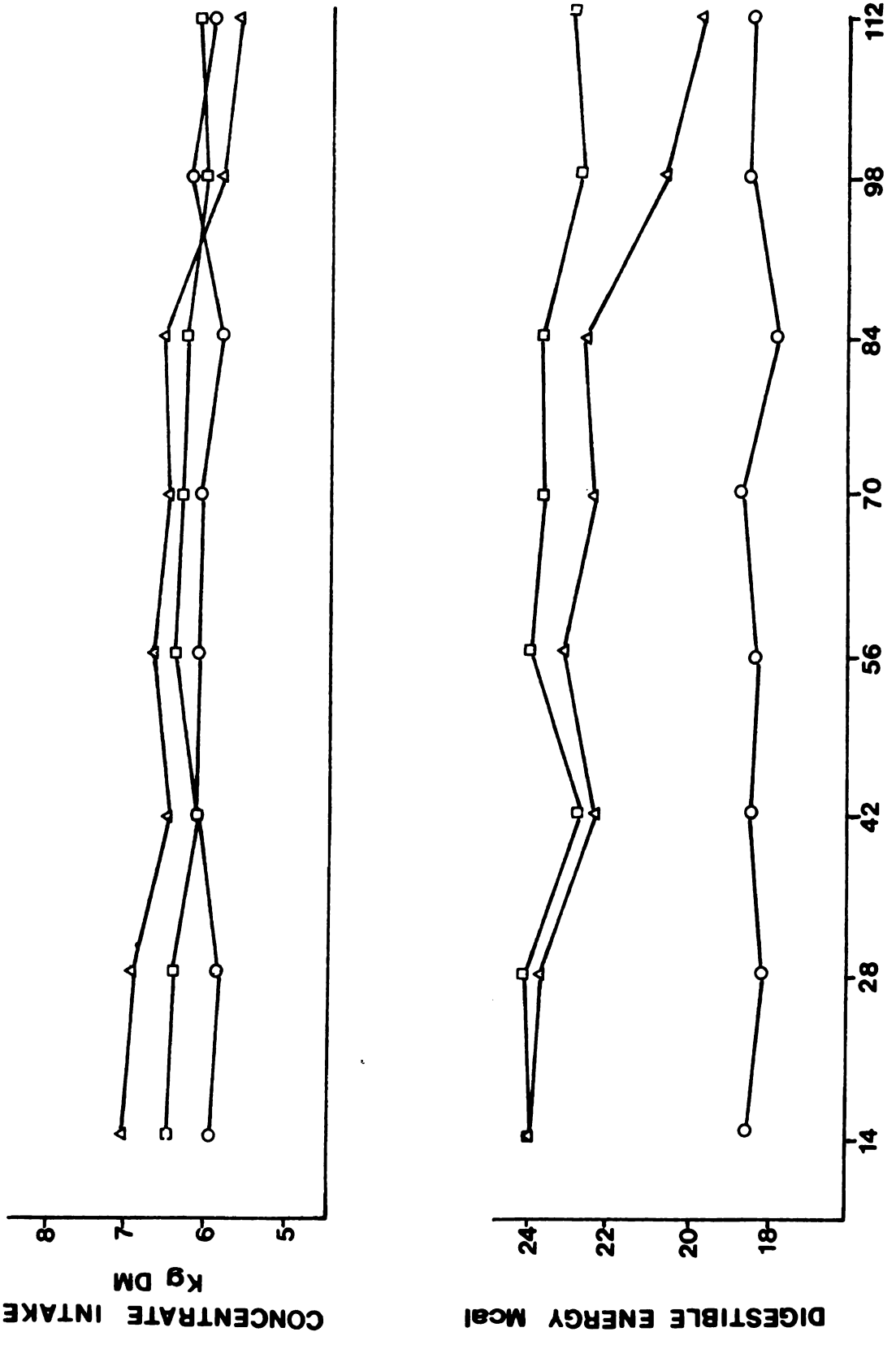
CONCENTRATE INTAKE
Kg DM
8
7
6
5
DIGESTIBLE ENERGY Mcal
24
22
20
18
14
28
42
56
70
84
98
112
DAYS

Figure 2

Table 10. Average daily consumption of concentrate on a dry matter basis during eight consecutive two-week periods for cows fed three concentrate mixtures

Days	Negative Control kg	Positive Control kg	Experimental kg
1 to 14	6.1	6.4	7.0
15 to 28	5.9	6.4	6.9
29 to 42	6.1	6.1	6.5
43 to 56	6.1	6.4	6.7
57 to 70	6.1	6.3	6.5
71 to 84	5.8	6.3	6.6
85 to 98	6.1	6.0	5.9
99 to 112	6.0	6.1	5.7
Average	6.0	6.3	6.5
Number of cows	9	10	10

from 7.0 kg at the beginning of the experiment to 5.7 kg at the end of the experiment. As stated previously, the cows on the banana meal based concentrate would not consume this ration as formulated in the quantities desired for this experiment. The banana meal based concentrate was diluted 8 to 1 with the normal herd ration in order to obtain an adequate level of consumption. The decrease in intake during the last month caused no decrease in milk production.

The pooled regression of concentrate intake over time was determined for each treatment group. The slopes of the regressions were -0.65×10^{-3}, -8.12×10^{-3}, and -30.0×10^{-3} for cows receiving the wheat bran, corn, and banana meal based concentrates,

respectively. The differences among all slopes are highly significant ($P<.01$). This could be partially attributed to the regression slope being determined with only eight points and to the lack of variation for cows consuming the wheat bran based concentrate. This group of animals consumed all that was offered and were fed at a level below what they would have consumed *ad libitum*. These animals had also been raised since calves on this concentrate. The significant decline in concentrate consumption of cows receiving the banana meal based concentrate may be partially due to increased forage availability during the latter part of the experiment. This author observed that when cows were put on a new pasture there was increased refusal of concentrate by the cows on the banana meal based concentrate, although this effect was not seen for animals receiving the other two concentrates.

Total substitution of corn by banana meal decreased feed consumption in an experiment with fattening swine (Rihs et al., 1975b). Several experiments conducted in Costa Rica noted an extremely high level of consumption (4.2 kg banana DM/kg body weight) of fresh green bananas by beef cattle, indicating that fresh green bananas were very palatable for cows (Alpizar and Vohnont, 1974; Isidor, 1973). However, dehydrated, ground green bananas may not be as palatable as the fresh fruit, since animals in this experiment consumed 0.85 kg of banana meal dry matter per 100 kg of body weight, which is much less than the consumption of the fresh green fruit reported above.

Rihs and Isler (1976) and Rihs et al. (1975b) found no difference in concentrate consumption when they fed concentrate

containing 50 per cent banana meal, 90 per cent banana meal, or 50 per cent corn to lactating dairy cows. However, the level of concentrate feeding was less than 50 per cent of that fed in the present experiment.

Under the conditions of this experiment, there was some decrease in palatability when banana meal was the primary energy source at high levels of concentrate feeding. This decresaed palatability apparently does not exist at low levels of concentrate feeding even though banana meal is the primary energy source or when green bananas are fed fresh. The presence of low levels of tannins in bananas appears to have little or no effect on palatability. Since the levels of tannins in fresh green bananas are higher than in the dried product, alteration of tannins during dehydration may occur (Rihs, 1976). Possible chemical alteration of tannins or other compounds present in bananas during the drying process, the fineness of grind of the banana meal, or some unknown factor may be responsible for the lowered consumption of the banana meal noted in this experiment.

The apparent DE intake from concentrates was 18.30, 23.41, and 22.14 Mcal per day for the cows fed the wheat bran, corn, and banana meal based concentrates, respectively (Table 11). These data were calculated from values shown in Tables 20, 21, and 22 of the Appendix. The average daily apparent DE intake for eight consecutive two-week periods during the experiment is presented in Table 12 and Figure 2. The apparent DE intake from concentrate for the cows receiving the banana meal based concentrate decreased with time. Since there was no corresponding decrease in milk production, this

Table 11. The average daily apparent digestible energy intake from the three concentrate rations during the 112-day experimental period for each cow in the ten blocks

Cow Block No.	Negative Control MCal	Positive Control MCal	Experimental MCal
1	16.42	23.97	22.00
2	16.51	22.89	20.79
3	16.51	21.92	19.09
4	16.51	24.20	23.15
5	---[a]	24.16	27.94
6	32.98	22.93	20.20
7	16.51	23.90	21.55
8	16.51	21.92	22.14
9	16.26	24.16	22.56
10	16.51	24.05	21.93
Average	18.30	23.41	22.14

[a]Animal died

author concludes that this group of animals substituted forage energy for concentrate energy.

Milk production of cows fed wheat bran based concentrate was somewhat lower than that of cows fed the other two concentrates during the pre-experimental and experimental periods. This may be due to the wheat bran based concentrate having lower DE than the other two concentrates. The slight differences in milk production may be due to the difference in DE content of the three concentrates fed or to other properties of these diets or to lower initial production of this group of cows.

Table 12. The average daily apparent digestible energy intake from concentrate rations during eight consecutive two-week periods for cows fed the three concentrates

Days	Negative Control MCal	Positive Control MCal	Experimental MCal
1 to 14	18.48	24.01	23.98
15 to 28	18.06	24.01	23.67
29 to 42	18.48	22.74	22.28
43 to 56	18.42	23.97	23.01
57 to 70	18.48	23.56	22.28
71 to 84	17.72	23.56	22.63
85 to 98	18.39	22.55	20.37
99 to 112	18.36	22.89	19.47
Average	18.30	23.41	22.21
Number of cows	9	10	10

The average body weights of cows in the experiment are shown in Table 13 and Figure 3. Prior to the adaptation period, animals fed the wheat bran, corn, or banana meal based concentrates weighed 512, 499, and 475 kg, respectively. At the end of the experiment the animals weighed 530, 521, and 505 kg for the wheat bran, corn, or banana meal based concentrate, respectively. The average weight gain over the five-month period of each of the three groups was 18, 22, and 30 kg, respectively. Weight gain was not affected significantly by treatment. However, there was a significant effect of time on body weight and also a time treatment interaction. Due to this interaction, body weights at each time were analyzed using initial body weight as a covariate. Adjusted treatment means were

Table 13. The average body weight of three treatment groups of cows at stated intervals during the experimental period

Experimental Days	Negative Control kg	Positive Control kg	Experimental kg
Pre-experiment	512	499	475
0	497	480	464
14	507	500	477
28	532	526	509
42	518	511	490
56	508	509	494
70	518	528	512
84	521	521	506
98	530	521	513
112	530	521	505
Average[a]	518	513	497
Total number of cows	9	10	10

[a]Average does not include pre-experiment value.

significantly different ($P<.05$) only at day 70 of the experimental period, which indicates that over the entire experiment treatment had a negligible effect on weight gain. Rihs et al. (1975b) and Rihs and Isler (1976) also reported that banana meal in the concentrate had no effect on body weight.

Milk density, fat, dry matter, solids-not-fat and protein were determined prior to the adaptation period and at fifteen-day intervals throughout the experimental period. A summary of the data is presented in Table 14. The composition of milk was not affected significantly by treatment. Others have reported similar information

Figure 3. Average body weight of each treatment group of cows at stated intervals during the experimental period.

(O-O negative control, □-□ positive control, Δ-Δ experimental)

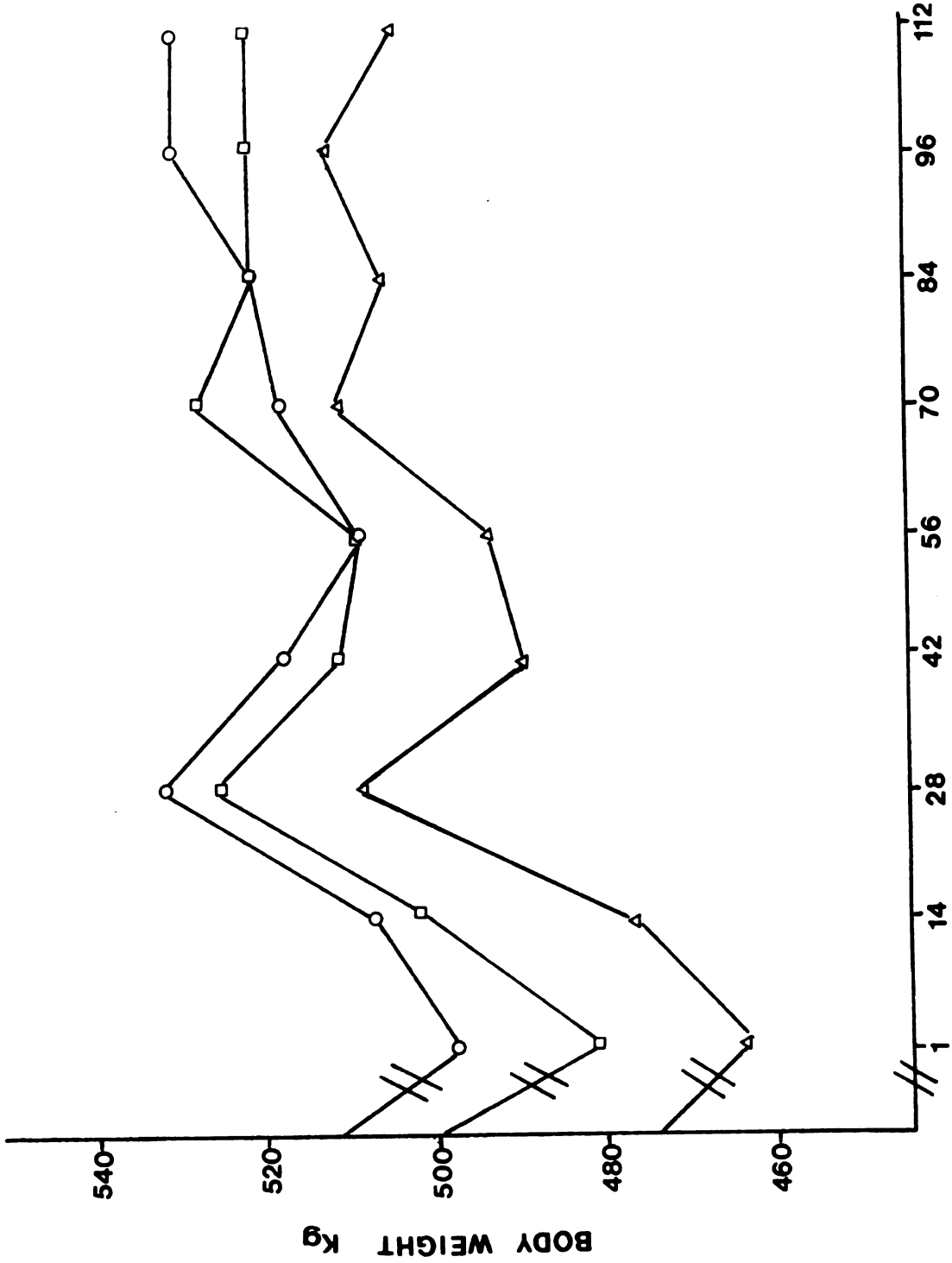

Figure 3

Table 14. Milk composition of three groups of cows receiving three different concentrates

	Negative Control		Positive Control		Experimental	
	Pre-Expt.[a]	Expt.[b]	Pre-Expt.[a]	Expt.[b]	Pre-Expt.[a]	Expt.[b]
Number of cows	8	9	10	10	10	10
Milk density, g/ml	1.029	1.030	1.030	1.031	1.031	1.031
Milk fat, %	3.2	3.4	3.1	3.3	3.3	3.4
Milk dry matter, %	11.4	11.8	11.5	12.1	11.9	12.2
Solids not fat, %	8.2	8.4	8.4	8.8	8.6	8.8
Milk protein, %	2.3	2.7	2.5	2.8	2.6	2.9

[a]Group average of one sample period.

[b]Group average of nine sample periods.

in that there was no difference in milk composition from dairy cows receiving either 50 or 90 per cent banana meal in the concentrate or 50 per cent corn (Rihs et al., 1975b; Rihs and Isler, 1976).

In all three treatment groups there was a tendency for fat, protein and solids-not-fat content to increase as the experiment progressed. This follows normal trends of changes in milk composition with advancing stage of lactation (Rook and Campling, 1965). The average composition of Holstein milk in the United States is 3.6 per cent fat, 8.5 per cent solids-not-fat, and 3.1 per cent protein (Foley et al., 1972). The composition of the milk of

Holstein cows in this experiment was similar, although the value for milk protein was slightly lower.

Plasma glucose, calcium, phosphorus, and magnesium were tabulated for all animals prior to the adaptation period and at fifteen-day intervals throughout the experimental period. The data, averaged by treatment group for each sampling, are presented in Tables 15 through 18 and Figures 4 and 5.

Average plasma glucose was 63.2, 59.0, and 61.2 mg per 100 ml for animals on the wheat bran, corn, and banana meal based concentrates (Table 15). Plasma glucose increased with time during the experiments for all three treatment groups and was not affected by diet. Smith et al. (1976) found that plasma glucose increased as days postpartum increased for cows fed silage based diets.

Plasma calcium averaged 10.0, 10.2, and 9.4 mg per 100 ml for animals fed wheat bran, corn, and banana meal based concentrates (Table 16). These values are within the normal range of plasma calcium for Holstein cows, which is 9.1 to 12.3 mg per 100 ml (Altman and Dittmer, 1961). Plasma calcium levels or trends with time were not affected by treatment. All three concentrates were low in calcium (.3 per cent of DM), while pastures contained an average of .64 per cent calcium on a dry matter basis. The National Research Council (1971) estimates calcium requirement at .4 to .5 per cent on a dry matter basis. Blood data and the above estimate indicate that cows were not receiving insufficient calcium in the diet.

Plasma phosphorus averaged 8.1, 7.0, and 6.8 mg per 100 ml for cows fed wheat bran, corn, or banana meal based concentrates,

Table 15. Average plasma glucose concentrations for three treatment groups of cows at stated intervals during the experimental period

Experimental Days	Negative Control mg/100 ml	Positive Control mg/100 ml	Experimental mg/100 ml
Pre-experiment	49.8	47.1	53.6
1	56.1	55.7	55.4
14	63.3	60.2	61.4
28	61.2	57.2	56.5
42	67.6	60.8	61.2
56	64.2	63.1	63.6
70	61.6	56.0	61.7
84	63.0	57.2	62.4
98	65.6	59.7	62.8
112	65.9	61.5	65.7
Average[a]	63.2	59.0	61.2
Number of cows	9	10	10

[a]Average does not include pre-experiment value.

Table 16. Average plasma calcium concentrations for three treatment groups of cows at stated intervals during the experimental period

Experimental Days	Negative Control mg/100 ml	Positive Control mg/100 ml	Experimental mg/100 ml
Pre-experiment	10.3	11.0	10.6
1	10.2	9.8	9.5
14	9.6	9.9	10.0
28	9.9	10.7	9.9
42	10.5	9.8	9.9
56	10.1	11.3	10.0
70	9.4	10.7	10.5
84	10.4	10.3	10.1
98	9.5	9.8	9.6
112	10.2	9.8	10.0
Average[a]	10.0	10.2	9.9
Number of cows	9	10	10

[a]Average does not include pre-experiment value.

respectively (Table 17). The group receiving the wheat bran based concentrate maintained slightly higher plasma phosphorus levels than the other two treatment groups throughout the experimental period.

Table 17. Average plasma phosphorus concentrations for three treatment groups of cows at stated intervals during the experimental period

Experimental Days	Negative Control mg/100 ml	Positive Control mg/100 ml	Experimental mg/100 ml
Pre-experiment	7.5	6.5	8.5
1	7.9	6.6	6.2
14	7.1	5.7	5.0
28	8.8	7.5	7.2
42	9.0	8.1	7.6
56	7.8	6.9	7.8
70	8.8	8.1	6.9
84	8.6	6.5	7.1
98	7.4	6.9	6.9
112	7.2	6.8	6.7
Average[a]	8.1	7.0	6.8
Number of cows	9	10	10

[a]Average does not include pre-experiment value.

The wheat bran based concentrate contained 3 to 4 times as much phosphorus as the other two concentrates. Wheat bran has a higher phosphorus content than either corn or bananas. The normal range for plasma phosphorus in Holstein cows is 2.35 to 7.40 mg per 100 ml (Altman and Dittmer, 1961).

Plasma magnesium averaged 2.7, 2.6, and 2.5 mg per 100 ml for cows receiving the wheat bran, corn, or banana meal based concentrate, respectively (Table 18). The normal range of plasma magnesium for Holstein cows is 1.93 to 3.50 mg per 100 ml (Altman and Dittmer, 1961).

Table 18. Average plasma magnesium concentrations for three treatment groups of cows at stated intervals during the experimental period

Experimental Days	Negative Control mg/100 ml	Positive Control mg/100 ml	Experimental mg/100 ml
Pre-experiment	2.4	2.5	2.4
1	2.2	2.7	2.3
14	2.3	2.1	2.0
28	2.9	2.5	2.6
42	2.5	2.4	2.4
56	2.8	3.1	2.6
70	3.1	3.1	2.8
84	3.2	2.5	2.7
98	2.6	2.4	2.3
112	2.6	2.4	2.5
Average[a]	2.7	2.6	2.5
Number of cows	9	10	10

[a]Average does not include pre-experiment value.

Under the conditions of this experiment, plasma glucose, calcium and magnesium were not affected by dietary treatment, but plasma phosphorus concentration was greater for the wheat bran diet. The values obtained fall within normal ranges reported in the

Figure 4. Average plasma glucose and calcium concentrations of cows fed three concentrates at indicated intervals during the experiment.

(O-O negative control, □-□ positive control, Δ-Δ experimental)

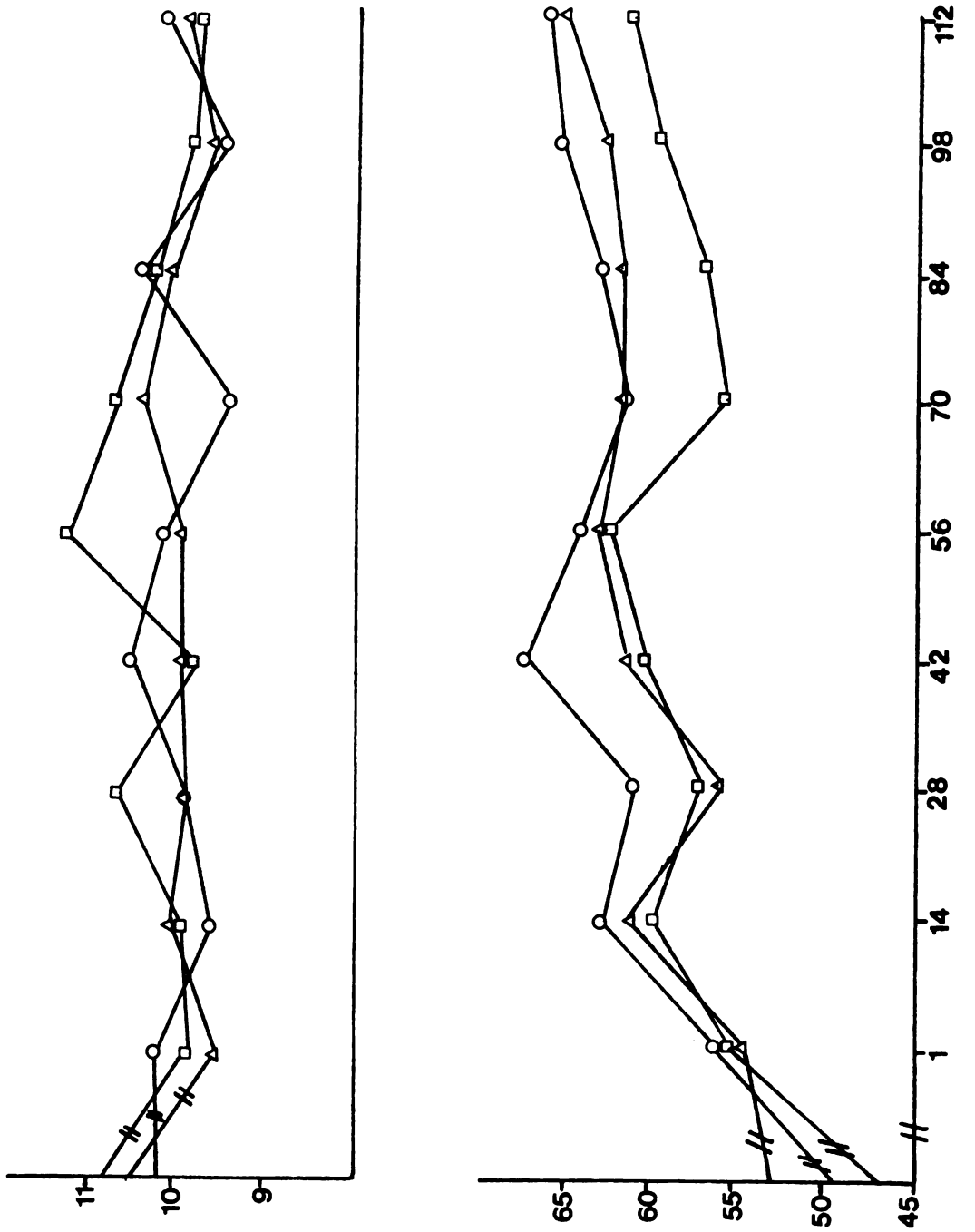
PLASMA CALCIUM
Mg/100ml
11
10
9
PLASMA GLUCOSE
Mg/100ml
65
60
55
50
45
1
14
28
42
56
70
84
98
112
DAYS

Figure 4

Figure 5. Average plasma phosphorus and magnesium concentrations of cows fed three concentrates at indicated intervals during the experimental period.

(O-O negative control, □-□ positive control, Δ-Δ experimental)

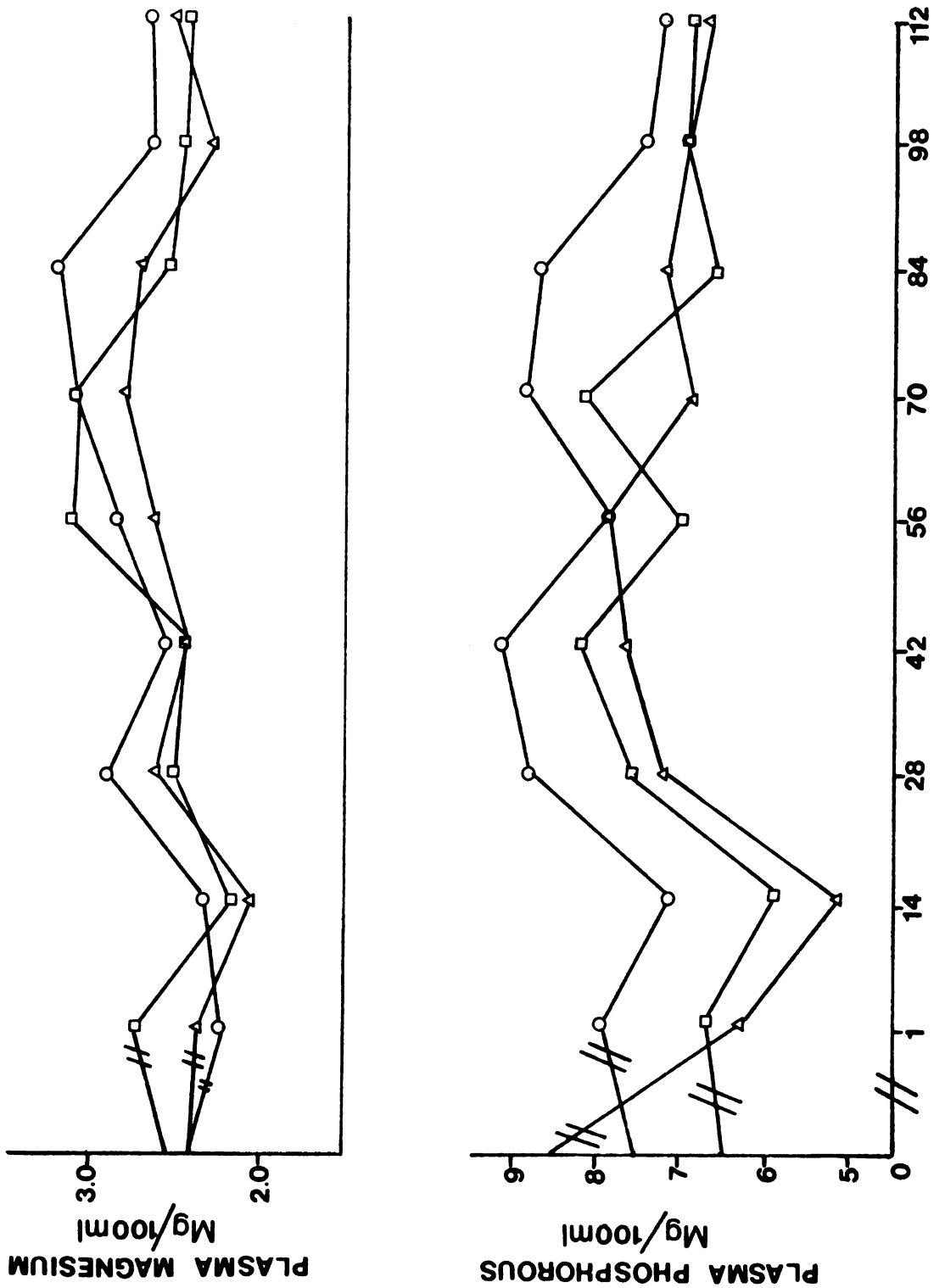
PLASMA MAGNESIUM
Mg/100ml
3.0
2.0
PLASMA PHOSPHOROUS
Mg/100ml
9
8
7
6
5
0
1
14
28
42
56
70
84
98
112
DAYS

Figure 5

United States and, although there was variation in blood mineral levels during the experiment, they were maintained within the normal ranges.

Reproductive status of the animals on experiment is summarized in Table 19. At the end of the experiment, there were 6 of 9 cows pregnant (67 per cent) in the group that received wheat bran based concentrate, 6 of 10 cows pregnant (60 per cent) in the group that received the corn based concentrate, and 4 of 10 cows pregnant (40 per cent) in the group that received the banana meal based concentrate. At this time, the average days of lactation were 228, 199, and 192 for the cows fed the wheat bran, corn, or banana meal based concentrates, respectively.

Attempts to relate reproductive processes to possible dietary influences were complicated by inconsistent policies and procedures used in the herd regarding reproduction. For instance, not every cow was inseminated at every heat. Ovarian cycling activity was not determined nor other factors which might relate to low reproductive efficiency. Nevertheless, for cows diagnosed open or of unknown pregnancy status at the end of the experiment, there had been more inseminations per cow and fewer heats without insemination for cows fed the banana meal and corn based concentrates as compared to cows on the wheat bran based concentrate. Nutrition, health, or management may have been contributing factors. This experiment was not designed to be definitive about reproduction. Due to the factors mentioned above and the short duration of this experiment, the data are inconclusive as to any effects of treatment on reproductive efficiency.

Table 19. Reproductive status of the cows at the end of the experimental period for the three treatment groups

	Negative Control	Positive Control	Experimental
Number of cows	9	10	10
Pregnant during,			
Pre-adaptation period	1	1	1
Adaptation period	2	3	1
Experimental period	3	2	2
Pregnancy status unknown at end of experiment	2	1	0
Diagnosed non-pregnant at end of experiment	1	3	6
Inseminations per conception[1]	1.67	1.0	1.0
Heats per insemination	18/10	11/6	11/4
Animals diagnosed pregnant	(6 cows)	(6 cows)	(6 cows)
Animals diagnosed non-pregnant or status unknown	11/5 (3 cows)	19/11 (4 cows)	32/19 (6 cows)
Inseminations per conception[2]	1.89	1.33	1.94

[1]For those cows diagnosed pregnant.

[2]Average of total number of cows for two previous lactations except in case of first calf heifers.

The reproductive efficiency of dairy cattle in Ecuador has been characterized as being low (Wilson, 1975). The average calving interval has been estimated to be from fifteen to eighteen months. This may be due to poor estrus detection, incorrect timing of breeding or insemination, low fertility of bulls, and the limited amount of semen available for artificial breeding. Some of these factors

may have been responsible for the low reproductive efficiency noted in this experiment.

In summary, where wheat bran, corn, or banana meal was fed as the primary energy source in the concentrate, there was no significant difference in milk production between the three groups. However, the cows fed the corn based concentrate produced slightly more milk than those receiving the banana meal based concentrate, while both of these groups produced slightly more milk than cows fed the normal herd ration.

As the experiment progressed, there was a decreased intake of the concentrate which contained 70 per cent banana meal concentrate when fed at a level of 7 kg per day.

Diet had no effect on body weight, milk composition, or plasma glucose, calcium and magnesium. Plasma phosphorus was affected by diet. The data are inconclusive as to any effect of treatment on reproductive efficiency.

CONCLUSIONS

The National Institute of Agriculture and Livestock Research and the Swiss Technical Mission in Ecuador were interested in conducting research to determine if an industrially produced banana meal could be fed as a part of the concentrate to lactating dairy cattle. The utilization of this product, which is presently produced at a stable price and whose quantities do not fluctuate with season, would improve the quality of concentrates presently fed to dairy cattle and thus improve milk production.

The results of this field trial demonstrate conclusively that industrially produced banana meal is an adequate source of feed energy for lactating Holsteins. Milk production and composition were not different for groups of cows receiving either banana meal, corn, or wheat bran as the primary energy source in the concentrate.

Further research is needed to determine at what level banana meal should be used in the concentrate for maximum nutritional and economic benefit. Further experimentation is also needed to determine the cause of decreased concentrate intake with high levels of banana meal. Reproductive performance should be studied more carefully to determine whether or not banana meal has any effect on reproduction.

APPENDIX

Table 20. Digestible energy values used to estimate apparent digestible energy intake from concentrate throughout the experimental period

Feed Ingredient	Source*	Reference number	MCal DE per kg of DM
Bananas, green	3	---	3.60
Corn grain	1	4-02-920	3.98
Corn, ground with cob	1	4-02-849	3.75
Cottonseed hulls	1	1-01-599	2.28
Cottonseed meal	2	5-13-697	3.23
Fishmeal	2	5-01-985	3.39
Molasses	2	4-13-251	3.65
Royal palm oil meal *(Roystonea regia)*	1	1-08-477	3.33
Wheat bran	2	4-11-741	3.02

*
1. Anonymous, 1971.
2. McDowell et al., 1974.
3. Vohnout and Jimenez, 1975.

Table 21. Concentrate composition on an as-fed and dry matter basis[1]

FEED INGREDIENT		WHEAT BRAN BASED CONCENTRATE (Negative Control)		CORN BASED CONCENTRATE (Positive Control)		BANANA MEAL BASED CONCENTRATE (Experimental)	
Name	DM %	As fed %	DM %	As fed %	DM %	As fed %	DM %
Banana meal	89.65	---	---	---	---	70.70	71.29
Corn	90.12	---	---	70.70	71.52	---	---
Wheat bran	88.80	75.00	74.98	---	---	---	---
Cottonseed meal	91.48	---	---	6.10	6.26	11.10	11.42
Cottonseed hulls	90.90	7.00	7.16	---	---	---	---
Royal palm oil meal	89.77	11.00	11.13	13.10	13.20	5.10	5.15
Fishmeal	91.90	---	---	---	---	3.00	3.11
Molasses	75.20	---	---	8.10	6.85	8.10	6.85
Corn, ground with cob	85.40	7.00	6.73	---	---	---	---
Salt	99.95	---	---	1.00	1.12	1.00	1.12
Urea	94.90	---	---	1.00	1.06	1.00	1.06

[1]Calculated on the basis that the negative control, positive control, and experimental concentrates contain 88.82, 89.09, and 88.90 per cent dry matter, respectively.

Table 22. The apparent digestible energy of concentrates

Feed Ingredient	Negative Control Mcal/kg concentrate DM	Positive Control Mcal/kg concentrate DM	Experimental Mcal/kg concentrate DM
Banana meal	---	---	2.57
Corn	---	2.85	---
Wheat bran	2.26	---	---
Cottonseed meal	---	0.20	0.37
Cottonseed hulls	0.16	---	---
Royal palm oil meal	0.37	0.44	0.17
Fishmeal	---	---	0.11
Molasses	---	0.25	0.25
Corn, ground with cob	0.25	---	---
Salt	---	---	---
Urea	---	---	---
Total Mcal DE per kg concentrate DM	3.04	3.74	3.47

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