Preference and Acceptability of Four Protein Sources by Ruminating Holstein Calves

by

Susan Anderson Wampler

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Science

in

Dairy Science

APPROVED:

C. E. Polan, Chairman

M. A. Barnes

P. B. Siegel

May 22, 1988

Blacksburg, Virginia

Preference and Acceptability of Four Protein Sources by Ruminating Holstein Calves

by

Susan Anderson Wampler

C. E. Polan, Chairman

Dairy Science

(ABSTRACT)

Four successive groups of four calves each (~ 4 mo old) were individually penned and observed during a 14 d trial period for choice of concentrate. Prior calf diets contained soybean meal (SBM) for two groups and distillers grains in place of SBM for two groups. Concentrates contained approximately equal amounts of corn with either SBM, peanut meal (PNM), fish meal (FSM), or corn gluten meal (CGM). Each day of four trials, .45 kg of each concentrate was randomly assigned to one of four equal feed box sections. Calf feeding position was recorded every 30 sec for no more than 50 min or until calves stopped eating. In addition, 1.36 kg of first cutting orchardgrass hay was offered twice per day. Measurements of amount of each feed consumed, order of consumption and length of time spent eating each feed were analyzed statistically to determine preference. Overall preference was for SBM, closely followed by PNM, both over FSM and CGM, with the preference status of FSM showing the most change over time by decreasing throughout the trial periods. Neither section in which feed was offered nor previous experience with SBM significantly influenced preference. In addition, twenty calves ranging in age from 4 mo to 7 mo were divided and housed in four groups of five and observed during a 30 d trial period for acceptability of the protein feeds tested for preference. Acceptability, measured subjectively as length of time required by calves to eat each feed, was greatest for SBM, closely followed by PNM and CGM, and least for FSM. Analysis of calf weight gain showed no differences between feeds.

Acknowledgements

I would like to thank my husband for his love, encouragement and patience throughout my master's program. I am also grateful to him for teaching me how to be a better writer and how to get the words on paper using SCRIPT.

I thank Dr. Carl Polan for allowing me to pursue a research project which was of professional and personal interest to me and a little different from research he typically conducts. I also thank him for his helpful insight into how to conduct research and for encouraging me to be more self-confident. I thank Dr. Paul Siegel for teaching me a great deal about animal behavior and for his willingness to discuss subjects completely unrelated to research and academics. I thank Dr. Mike Barnes for his interest in my research, for helping expand my limited knowledge of the dairy industry, and for his willingness to serve on my committee.

To and I extend tremendous thanks for helping me turn lots of numbers into meaningful information and SAS-graphs. In addition, I thank Dr. Mike McGilliard for helping me better understand statistics and how to interpret my data.

I thank my fellow graduate students for assistance during my research project and throughout my time as a graduate student.

I also wish to thank my parents for their love and the support, encouragement and advice they have given me throughout my college career.

Finally, I thank the Lord for allowing me to have a personal relationship with Him which will continue to give my life meaning and purpose into eternity.

Table of Contents

Introduction **1**

Literature Review **3**
Methods of Studying and/or Determining Preference 3
  Observation 3
  Feed Consumption 5
  Operant Conditioning 6
Factors Affecting Feed Preference 8
  Sensory Aspects 8
  Previous Experience 12
  Nutritional Wisdom 13
  Individual Animal Differences 15
Feed Preferences of Dairy Cattle 15
Objectives 17

Materials and Methods **18**
Experiment 1 18
  Herd and Husbandry 18
  Experimental Procedure 21
  Statistical Analysis 24
Experiment 2 27
  Herd and Husbandry 27
  Experimental Procedure 28
  Statistical Analysis 28

Results and Discussion **29**
Experiment 1 29
  Positional Preference 34
  Protein Source Preference 38
  General Discussion of Experiment 1 56
Experiment 2 57
Summary and Conclusions 59

References **60**

Appendix A. Analysis of Variance Examples **64**

Vita **69**

List of Illustrations

Figure 1. Overhead View of Housing and Observation Facility 19
Figure 2. Average total time calves spent eating each day. 32
Figure 3. Average total amount of protein feeds consumed by calves per day. 33
Figure 4. Average total time calves spent eating during each interval. 35
Figure 5. Average time calves spent eating each feed during each interval. 40
Figure 6. Average time each calf spent eating each feed. 43
Figure 7. Average amount of each feed eaten by each calf. 44
Figure 8. Average time calves spent eating each feed, each day. 46
Figure 9. Average amount of each feed eaten each day. 47
Figure 10. Average time calves spent eating each feed, each day during interval 1. 48
Figure 11. Average time calves spent eating each feed, each day during interval 2. 49
Figure 12. Average time calves spent eating each feed, each day during interval 3. 50
Figure 13. Average time calves spent eating each feed, each day during interval 4. 51
Figure 14. Average time calves spent eating each feed, each day during interval 5. 52
Figure 15. Average time calves spent continuously eating the first feed chosen. 55

List of Tables

Table 1. Assignment of Calves to Sets and Groups 20

Table 2. Dietary crude protein content of feeds offered 22

Table 3. Level of statistical significance of independent variables for time calves spent eating from any given box (days 4-17)* 30

Table 4. Level of statistical significance of independent variables for amount of any given protein feed eaten* 31

Table 5. Effect of position on first box calves selected when fed weaned calf feed 36

Table 6. Effect of Position on First Box Calves Selected When Fed Choice of Four Protein Sources 37

Table 7. Average Eating Time for Each Feed 39

Table 8. Average Amount of Each Feed Eaten 42

Table 9. Effect of Feed on First Box Calves Selected 54

INTRODUCTION

The importance of properly designed and conducted animal behavior studies to different disciplines in the animal sciences, such as nutrition and reproduction in the animal sciences is now generally recognized. Animal scientists realize that without consideration of animal behavior in experimental design, the animal as a whole is overlooked (1). In 1982, Curtis and McGlone (25) evaluated the status of farm animal behavior research in North America. They found that of the 218 total projects identified as recent or current research efforts, the largest percentages of studies, which were considered to be in accord with the importance of these disciplines in animal production, were concerned with feeding and reproductive behavior at 26 and 23%, respectively. Also, dairy cattle were involved in more of the 218 studies than any other species. According to Coppock et al (24), dairymen are concerned about feeding and nutrition because of their importance to herd health and reproduction, and because feed represents the premier production cost. Baile and Della-Fera (7) supported such statements by concluding that often the most obvious limitation for sustained milk production or growth rate is daily feed intake, and that "use of cheaper feedstuffs often is limited by the voluntary intake of the higher producing cows." In order to increase consumption and thereby milk production or growth rate, which may lead to increased efficiency of production, Bines and Davey in 1970 (13) and Aseltine in 1987 (5), discussed the need to develop a better understanding of the factors that regulate dry matter intake. As of 1981, behavioral feed intake research has been directed toward the effects of varying feeding frequency, density and form of feed, competition, and other environmental stresses on feed intake (1, 59).

Palatability of a ration is also an important aspect of feed intake behavior because it can have a definite effect upon dry matter consumption (5). Feeds of equal availabilities and with similar nutritive parameters are at times consumed in different quantities even when fed alone, and such differences may be the result of differences in preference for the feeds (49). Though the terms palatability and preference are at times used interchangably, preference indicates measuring choice among two or more feeds by the animal, following sensory appraisal of the alternatives and is essentially behavioral while palatability indicates plant characteristics or conditions that stimulate a selective choice by animals (44, 47, 49).

As the importance of dietary bypass protein to the support of rapid growth or high milk production in dairy cattle becomes more evident (67), various aspects of different protein sources will continue to be compared. Because preference for and animal acceptance of such protein sources can have important effects on their intake, but have yet to determined, the following studies were conducted.

LITERATURE REVIEW

Methods of Studying and/or Determining Preference

Observation

A basic approach researchers use to measure animal preferences for a variety of factors is the recording of specific behaviors as animals are observed in controlled situations. A behavioral measurement is defined and each occurance is recorded. Comparison of the number of behavioral measurements which occurred under each of the experimental situations shows which of those situations is/are preferred (14, 15, 46, 47, 56, 57, 61).

Mate preferences of male Japanese quail were studied, using observational techniques (14, 15, 61). The observational unit, or behavioral measurement, in each study was the number of completed matings. Males from each of three genetic lines, selected for high, low or random mating frequency, were shown to prefer females from the low-mating genetic line when the males were given a sequential choice of females from each line (14). When given a simultaneous choice of one female from each line, females from the randombred control line were preferred (14). Males, from the same three genetic lines, preferred hens with wildtype plumage compared to albino hens and had no preference between wildtype and yellow females, regardless of the genetic line of the males or their rearing experience with females of their own wildtype or other plumage color (15). The cumulative number of attempted and completed matings across four tests of simultaneous choices between albino and wildtype hens and four tests between yellow and wildtype hens were recorded according to plumage color of the hens. These results were consistent with those of Traux and Siegel (61) where males of the same genetic line for mating frequency but of different plumage colors exhibited preference by cumulative number of completed matings for hens of their own or darker plumage color.

Effectiveness of five potential repellents designed to prevent cattle from chewing pine tree bark in forest farming situations was also determined by observational techniques (46). The repellents tested were egg-powder, copper carbonate, thiram, cattle dung and scatole. Four behavioral measurements were defined as: sniffing, rubbing, licking and chewing the trees. Treatments were defined as the two trees to which each repellent was individually applied, including two untreated control trees. Based upon the frequency of each behavioral measurement as it occured for each treatment, cattle dung was found to be the most effective in preventing bark chewing.

Determination of feed preference of sheep and cattle has been accomplished through observation and comparison of consumption time for different forages offered simultaneously (47). Though specific results were not given, Marten (47) cited two procedures used. First, selection from among eight forages was recorded and measured after a specific forage had been consumed for 90 sec without interruption. Second, the number of whole minutes of consumption of four forages by heifers over 15 min periods was recorded to test palatability. Schuh and Wegner (57) added Firanor-24, a feed preference agent, to whole milk to determine its effects on milk preference by dairy calves. After calves selected milk with 0 or 100 ppm of Firanor-24, the unselected milk was removed. The researchers recorded and compared the number of times each type of milk was selected. Regardless of preconditioning (fed milk with or without Firanor-24 before the study began) neither milk was significantly preferred.

Feed Consumption

Quantitative measurement of feeds or liquids consumed is another basic approach used to establish feed preference (2, 47, 49). Actual feed consumption, as measured by weight, has been used to determine preference of harvested forages and/or concentrates (47, 56, 23) plain versus calf starter with flavor or fat added (51, 53, 57, 66), forages on pasture (43, 44, 47), urea versus soy protein as a nitrogen supplement for cattle (21) and high protein versus high energy diets for chickens (38). In addition, Muller et al (54) measured weekly intake of minerals offered simultaneously in a cafeteria type feeder (separate compartments), to two groups of ten Holstein cows. Data from consumption of the minerals offered free-choice as compared to the nutritional needs of the cows was used to demonstrate which factors dictated selection of minerals by the cows. Consumption of tap water versus test fluid (chemical dissolved in tap water) has been measured by several researchers in order to study: 1) the behavioral taste responses of ruminants to the four taste qualities; sweet, bitter, sour and salty (8, 22, 30, 31, 32, 33), 2) the responses of pigs to a wide variety or concentrations of saccharin solution (40) and 3) the importance of exposure to a strong flavor during nursing on acceptance of such a flavor later in the animal's life (18). The amount of test solution consumed in such studies was expressed as a percent of total fluid intake. Factors which can confound the results of feed preference studies based completely on consumption include: 1) differences in availability of the feeds being compared, particularly for forages on pasture (2, 47, 49), 2) postingestational consequences such as rate of rumen fill and distention (6, 7, 39, 49) and 3) physiological state of the animal such as pregnancy, fatness, lactation and hunger (6, 27, 47). When determining the preference for bulky feeds such as forages, availability of too large a portion of each feed can lead to greater consumption of one feed over another, and therefore, misleading results as distention of the rumen caused by eating the first feed prohibits completion of the second feed. A similar problem can occur if too many choices of feeds are given with too limited a period of time allowed for intake because the animal may not be able to consume in equal amounts each of the feeds it prefers. Hungry animals may eat plants considered unpalatable under normal conditions so that consumption of all feeds offered would not reflect the preferences that would otherwise be detectable (47). Also, feeds that are palatable to non-producing animals may be unpalatable to high-producing animals which may be more fastidious (47) and high-producing animals simply ingest more feed (27).

Operant Conditioning

Operant conditioning is a type of learning which involves positive or negative consequences of animal responses leading to reinforcement or punishment of the responses (35, 49). Whittlestone et al in 1975 (64) concluded that the principles of operant conditioning which were well established with small animals could be applied to dairy cattle to solve practical problems and answer questions. Their research showed that response patterns of seven Jersey cows to four types of operant schedules using a highly palatable barley-cornmeal mix as the reinforcer, corresponded to responses by small animals found in the literature. Similarly, Matthews and Kilgour (49) concluded that because "ruminant feeding responses are controlled by their pleasant (reinforcing) or aversive (punishing) consequences," such feeding responses fit the operant model of learning. Though operant conditioning procedures offer dairy researchers an ability to study and control important behavior responses in cattle, such procedures were seldom applied to the study of dairy cattle behavior prior to the late 1970's (52).

Determination of preference using operant conditioning is made possible by concurrent availability of more than one reinforcer where each reinforcer is received when the animal acts upon the corresponding manipulandum, which when using cattle is a nose plate that must be pressed. Comparison of the number of times one reinforcer is chosen as compared to the number of times the other reinforcer is chosen shows which reinforcer is preferred by allowing for a calculated preference ratio (49). Because of the ability to determine preference using operant conditioning, these techniques have been applied to problems such as that of threshold levels of electric leakage detection by dairy cows (64). Cows in this study were trained to obtain food by pressing either one of two nose plates. When pressed, one plate turned current on to electrodes fitted to either the teats, rump or chest while the other plate turned current off. Feed served as the primary reinforcer for pressing both nose plates while presence and absence of electric current served as secondary reinforcement. Marked change in the ratio of utilization of the two plates at different levels of electric current showed that a single teat, four teats together, the rump and the chest each have specific thresholds of 7mA, 6mA, 6mA and 4mA, respectively. Arave et al (3) also used operant conditioning to determine preference for the milking machine functions of pulsation ratio and rate by dairy cows.

Operant conditioning techniques such as concurrent scheduling of differing foodstuffs as reinforcers have also been used to study feed preferences. Specifically, feed preference research using operant conditioning with dairy cows has involved: 1) development of a special feed delivery system (19) and 2) determination of the effect(s) of nutritive and non-nutritive feed additives (2, 21), feed texture (2, 19), and feed type (19, 42, 50) on dairy cattle feeding behavior.

Because factors such as postingestional consequences, physiological state of the animal and availability of the feeds being tested can effect the results of studies in which preference is determined primarily by comparison of relative amounts of voluntary intake of differing feeds, an advantage of using operant conditioning methods to study feed preference in dairy cattle is the minimization of such confounding (49, 50). Operant schedules involve delivery of small, equally available quantities of feed which allow for separate analysis of the ways in which sensory and physiological parameters associated with food consumption affect dietary preferences (49, 50).

Though operant conditioning can be a very effective method of determining animal preferences, such research requires complex equipment and therefore additional expense, space and mechanical knowledge by the researcher. Also, small errors in the design of the experiment can contribute to incorrect or misleading results. For example, though it is generally known that wide pulsation ratios and absence of pulsation (continual vacuum) cause teat end damage, results of the study of preference for milking machine functions by Arave (3) showed no significant difference in preference for wide and narrow pulsation ratios or for presence or absence of pulsation. Possible reasons for failure of the animals to detect differences in stimuli and/or to prefer different stimuli included: 1) training period which was too short and 2) experimental approach which did not provide timing of the primary and secondary reinforcement such that cows could associate responses on the nose plate with changes which occured at the udder.

Factors Affecting Feed Preference

Sensory Aspects

Stimuli from feeds offered to animals elicit responses from the senses, thereby determining which feed(s) the animals will chose, and under some conditions, sensory aspects of feeding may influence the quantity of feed(s) eaten (7, 48). It appears that ruminants use the same sensory cues as other mammals for selection of feed (7). The role of the senses in modulating food selection appears, from the available data, to be basically the same in pen and pasture feeding (49).

Though sight is important for grazing animals in terms of proper orientation, other senses usually determine the initial choice of plants (47, 48, 49). Krueger (44) did show, however, that sight was related to selection of some palatable plants by sheep. The color aspect of sight is particularly unimportant in sheep because these animals were shown to be color blind (47, 48). Olfaction is important to the initial stimulation of appetite but its importance in directing selection is variable (5). Because the effect of smell is primarily reinforcement of taste, its influence upon preference for plant species is considered to be not as large or important as the influence of taste (6, 44, 47, 48). Smell can be the primary determinate of rejection, though, as is demonstrated by the fact that grazing sheep and cattle often refuse to eat forage growing over "dung spots" because of the offensive odor of dung, but the same forages are eaten when harvested and offered (9, 48). Also, alkaloids in plants give off a pungent offensive odor which is noticed by ruminants, especially sheep, so that such plants are avoided and not even tasted (48).

Touch is another sense which appears to primarily supplement the sense of taste in selection of plant species (44, 48). Ruminants use the sense of touch to remove leaves from harvested forages as well as those on pasture, leaving stems (36, 47, 48). Matthews and Kilgour (49) stated that ruminants show innate preferences for green material over dead, young over old and grass over hay or silage. Such preferences are positively correlated with succulence and negatively correlated with maturity of the plants, and succulence and maturity are closely related in that most forage species decline in moisture with increased maturity (47, 48). For example, palatability of plants on pasture may change with growth stage, as plants do not mature at the same rate (47). Harshness or hairiness of plants as well as a relatively high lignin concentration are also forage characteristics which have been associated with lack of palatability (47, 48). Another aspect of touch which effects feed preference is the form or texture of the feed as controlled by mechanization (48). When feed is offered in pelleted and/or whole grain form, it is often consumed in greater quantity than when it is fed in smaller particles (19, 36, 37, 47, 56). Larger particles resulted in more food consumption with chickens (37), calves (36, 56), cows (63) and sheep (47). Arave (2) and Cate et al (19) also demonstrated a preference for pelleted dairy meal over ground dairy meal using operant conditioning procedures. Hatton (37) suggests that a possible explanation for preference of pelleted feed, as measured by greater consumption, is that finely divided feeds may be absorbed more rapidly and therefore lead to negative feedback shut off signals sooner than feeds with larger particle size. Other researchers indicate that the function of pelleting in increasing preference is to reduce the amount of dust and therefore put the fine dusty feed into a palatable form (2, 41, 47). Also, Arave (2) states that studies with forages and concentrates indicate that pelleting only improves the acceptability of low quality feeds. For example, when Waldern and Cedeno (63) compared barley, wheat mixed feed and a control feed mix for acceptability as meal or pellets, only the acceptability of the lower quality, wheat mixed feed was improved significantly by pelleting. In addition, Ray and Drake (56) found that pellets received the highest choice rating for milo as opposed to whole, coarsely ground, finely ground and ground pellets, while pellets ranked second for corn and third for oats. They concluded that "pelleting milo improves its desirability more than does pelleting grains such as corn and oats."

Taste is the sense which is most influential in directing forage and concentrate preference (34, 44, 47, 49). Krueger et al (44) evaluated 25 sheep for relationship of taste, smell, sight, and touch to forage preferences on range by suppressing each of the senses individually and in combination, and then measuring preference using a relative preference index for forages on range developed by Krueger (43). Though all senses were related to preference for some plant species, these researchers found that "when all senses were impaired except taste, preference did not deviate significantly from that of control animals" (44).

Ruminants respond as do dogs, rats, rabbits, pigs, hamsters and guinea-pigs to the four classical taste qualities of sweet, sour, salt and bitter used in human studies, because they possess receptors for these taste qualities (8, 9, 10, 30, 31, 32, 33, 34, 48, 49, 60). Using different species of ruminants (pygmy goats, normal goats, sheep and cattle), Goatcher and Church (32, 33) showed that stimulating effectiveness, from most stimulatory to least, of chemicals which represent the four primary taste groups was in the order: bitter, sour, salt, sweet. Glucose, sodium chloride, acetic acid and quinine hydrochloride were used to represent sweet, salt, sour and bitter, respectively (32, 33). Though these results were consistent for each species, differences exist between the species in terms of response levels (5, 8, 9, 10, 32, 33, 34, 49). The order of response to increasing concentrations of the chemicals was: cattle, goats, then sheep (9, 32, 33, 49). Though sheep required the highest levels of stimulants before responding, goats were the most tolerant of high concentrations, with cattle the least tolerant, and sheep intermediate in tolerance (9, 32, 33). The exception was that cattle were more tolerant of bitter than were sheep, with goats still the most tolerant of this substance (8, 9, 32, 33). The results from the study by Krueger et al (44) confirm this response of low tolerance of bitter taste by sheep because the sheep in their study preferred sour and sweet plants and rejected bitter plants. All four species used by Goatcher and Church (32, 33) and black-tailed deer have been shown to be more tolerant of sucrose than of chemicals representing sour, salty or bitter tastes (22). In addition, it has been shown that cattle (9, 49) and goats (8) do not have a threshold for sweet substances (glucose), so that unlimited intake can occur. Though calves show preference for glucose water over regular tap water, they are indifferent to solutions containing the synthetic sweetener saccharin (40).

The ability of animals to taste particular flavors can influence their selection of feeds. Chalupa et al (21) added 2.5% urea to a diet for dairy heifers as a nitrogen supplement and compared consumption by heifers receiving this feed with consumption by heifers of a second feed supplemented with soybean meal. Heifers fed the urea diet consumed significantly less than the other heifers (21). Heifers in a previous part of this experiment had exhibited no significant aversion to or preference for tap water adulterated with urea versus regular tap water. Therefore, it was concluded that decreased consumption of urea feeds was not due to taste and/or odor of the urea per se, but "probably results from association of the flavor of urea diets with a malaise produced by ammonia" (21). However, Kilgour and Dalton (41) concluded that there is little evidence to prove that flavors which are supposed to increase the acceptance of non-preferred foods by cows achieve their claims. For example, Arave et al (2) added the flavoring agent Firanor-36 to plain and pelleted dairy meals and found that plain pellets were preferred to flavored pellets and plain meal was preferred to flavored meal, although the authors could not explain these results. Similarly, Schuh and Wegner (57) found no difference in preference for milk flavored with Firanor-24 when compared to regular milk. Possible reasons given for the lack of preference for the flavored feed were that the calves did not perceive the Firanor-24, possibly because the concentration was too low, and that the calves perceived the substance but were indifferent to it (57). Other studies have shown, however, a significant increase in calf starter consumption when flavor was added (53, 66). In these studies the flavor used was not a commercial flavor and contained butterscotch and maple flavors (53) or sugar (66) in addition to the other ingredients. These results indicate that to increase preference for and thereby consumption of a particular feed by calves, the added flavor should contain a substance which is sweet to the calves because simple perception of the flavor may not cause calves to consume more of it.

Previous Experience

Previous experience with pasture and harvested forages and concentrates by animals can influence subsequent feed selection (47, 49). Plant species experienced by grazing sheep in the first three months of life were preferred in subsequent preference rankings of various pasture species, and lambs raised on different plant communities differed in their diet selection (49). The principle that a range of feed experiences when young enhances later acceptance of familiar and novel items is supported by research which showed that sheep reared on a variety of plant species performed better than those with experience of a single species (4). The feeding experience of adult animals can also influence their subsequent preferences and intake (48, 49). Sheep preferred bromegrass to reed canarygrass regardless of preconditioning. However, the preference shown for orchardgrass was reduced when the animals were preconditioned to grazing reed canarygrass (48).

Because early experience has been shown to effect later acceptability of feeds, researchers have studied the ability to increase consumption of starter diets after weaning by addition of a common flavor to milk and starter so that transfer of dietary agents or cues can occur (49, 57). Studies with lactating rats show that mother's milk contains gustatory cues which reflect the flavor of the mother's diet and that such cues are sufficient to enable young to recognize and ingest larger quantities of feedstuffs (29) and water (18) containing these cues. Similarly, addition at 50 ppm of Firanor-3, which is a flavoring substance designed to be incorporated into sows' milk if added to her diet during lactation, to the diet of lactating sows and pig starters, resulted in enhanced starter intake in baby pigs by association of milk and starter (17). However, the results of studies incorporating flavoring compounds in milk and dairy calf starter rations have not shown the same associative effect and increase in starter intake by dairy calves (53, 57). Daily consumption of starter which contained Firanor-24 for all calves and rate of gain were not significantly different among treatment groups of calves which received Firanor-24 in milk versus those which received regular milk (57). Morrill and Dayton (53) did report increased consumption of starter by calves fed flavor in milk and starter as compared to starter consumption by calves not fed flavor from either source, but they also reported lack of conclusive evidence in their study of development of an associative effect between milk and dry feed with calves. Morrill and Dayton (53) also concluded that their results did not mean that development of an associative effect between milk and starter to increase starter consumption in calves is not possible, and that other kinds or levels of flavors should be examined.

Nutritional Wisdom

Nutritional wisdom is the ability of an animal to select needed nutrients from the materials available to it in a free-choice situation (24, 59). Before 1950, the concept of domesticated animals possessing nutritional wisdom was often accepted (47, 48, 59), and led to the recommendation of feeding minerals to ruminants free-choice on the assumption that the animals were able to select from the minerals according to appetite (24, 49). The idea of nutritional wisdom was largely based on the argument that natural selection would be expected to produce animals that genetically "know," through selective appetite, what nutrients and therefore what feeds are needed (59). However, considerable evidence has been gathered since 1950 to discount the existence of a generalized nutritional wisdom by domesticated animals (23, 38, 48, 59). Instead, research has demonstrated that animals will select plants and/or minerals on the basis of palatability or accessibility rather than need. A palatable but poor quality diet will be chosen over an unpalatable nutritious diet such that some grazing animals may even prefer toxic species of plants (47, 48). For example, palatability and nutritive value of twelve common weed species were compared using oats as control with grazing sheep as the test animals (48). Palatability of the plants was not associated with their nutritive value, though the sheep avoided eating two species which have plant parts that may be toxic to sheep and cattle. Similarly, sheep and cattle have been shown to select minerals according to palatability (24, 49, 54). Deficiencies of nutrients such as calcium, magnesium, potassium, phosphorus and protein can be created by feeding diets low in these nutrients. When cows or sheep were given the opportunity to increase consumption of these nutrients to meet requirement levels through choice of minerals (54, 16), availability of a specific supplement (24) or choice of a different diet (23), intake of the needed materials was not significant or sufficient to satisfy the animals' need(s). Such results lend support to the rationale for emphasis on blended, complete feeds (16, 23, 54). According to Matthews and Kilgour (49), the inability to learn to ingest beneficial dietary items could be caused by: 1) lack of reinforcement, in the form of feeling of well-being, soon after the consumption of the needed mineral or other nutrient or 2) inability to associate improvement in well-being, if it is detectable, with the ingestion of either a specific or general food item. Other researchers have proposed that domestication and/or artificial insemination may have altered the ability of animals to select for diets such that they are more responsive to the sensory qualities of feed than to nutritive value (38, 54).

Though evidence does not support the concept of generalized nutritional wisdom by domestic animals, ruminants do appear to have a specific appetite for salt (24, 59). Deficiency of sodium and chloride has been shown to lead ruminants to search for salt and consume larger quantities than animals not deficient (9, 11, 34, 37, 47). In addition, energy deficits lead to increased consumption of sugar (22, 34). Sheep and calves fed at maintenance level showed stronger preference, through greater consumption, of 20% sucrose solution than did calves and sheep fed ad libitum (22). Intake of substances with higher concentrations of salt and sugar than are normally accepted is made possible by changes in taste thresholds in deficient ruminants (9, 11, 12, 22, 34). As reported by Goatcher and Church (34), "as a general rule, behavioral taste thresholds are decreased in deficiency states and preferences are shifted to higher concentrations."

Individual Animal Differences

Individual animal differences in feed preference, meal frequency, and time spent eating have been shown to exist in feeding behavior research (41, 62). Though nine calves significantly preferred control (plain) calf starter, over calf starters containing brown grease and/or cottonseed oil, one calf demonstrated a decisive preference for the starter with 10% added brown grease (51). In a similar study, Wing (66) found that average consumption of flavored starter by ten calves was considerably greater than consumption of the plain feed throughout the study, but two calves appeared to prefer the nonflavored feed. Individual variation despite the nutritional needs of the animal has been demonstrated for mineral consumption (54) and forage selection (23). In addition, Goatcher and Church (30) noted large individual differences in the preference of sheep for solutions of 5% sucrose and maltose such that mean responses of the groups were not typical of individual sheep. Though individual variation is important and must be considered when researchers make conclusions and recommendations, over a period of time large differences may be reduced (47). Also, improved performance of a majority of animals due to implementation of a recommended feed or procedure may be more important than the decreased or unimproved performance of one or a few animals whose preferences differ significantly.

Feed Preferences of Dairy Cattle

The results of studies which have examined preferences of dairy cattle for different feeds, as opposed to preferences for different forms or textures of feeds, added flavors, or other factors effecting feeds, are as follows. Using operant conditioning, Matthews and Temple (50) showed that when given a choice of chopped hay and dairy meal (a commercially prepared concentrate feed), the six dairy cows being tested preferred dairy meal. Of three forages fed to dairy cattle, selection by different animals varied but, overall, corn silage was preferred to hay crop silage and each silage was preferred to hay (23). Intake of grain rations demonstrated preference for: 1) 98% barley slightly over a mixed ration of 40% barley, 20% wheat, 25% peas, 9.5% molasses and 3.5% cottonseed meal, with both significantly over 98% wheat mixed feed (63) and 2) corn and oats over milo (56). Klopfer et al (42) conducted a study using operant conditioning to compare palatabilites of twenty foods to dairy cows. The results of this study were expressed in the following ranked preference order:

- crushed barley (highest ranking of 10)
- dried peas
- dairy meal
- grass silage
- maize silage
- chopped hay
- lucerne meal (ranking of 7)
- sainfoin
- fresh pasture
- tama ryegrass
- pressed-pasture silage
- frozen pasture
- spent brewer's grain
- pressed-pasture (ranking of 5)
- frozen lucerne silage
- brewer's trub
- concentrated plant juice whey
- molasses block (ranking of 2)
- typha silage
- salt block (lowest ranking of 1)

These results demonstrate a general preference of dairy cattle for concentrate feeds over forages, silage over fresh pasture over pasture that was frozen or pressed and actual feeds over additives. Though Etgen and Reaves stated in 1978 (28) that many cows do not like FSM, that CGM is not as palatable as some other feeds, and that PNM is palatable, no specific studies were cited and there is no evidence that protein sources have been simultaneously compared to determine dairy preference.

Objectives

None of the studies with cattle which have examined concentrate preferences have determined preference for protein sources specifically. Because of the growing importance of research with regard to protein sources, and the economic and nutritional benefits of feeding different protein sources, experiments were designed with the following objectives in mind:

- determine acceptance of and preference for four protein sources by dairy calves fed a choice of each feed in equal, limited amounts

- determine calf acceptance, using the same four protein sources as above, by examining the feeding patterns and weight changes of calves not given a choice of feed

MATERIALS AND METHODS

Experiment 1

This experiment examined preference for four protein sources by ruminating dairy calves.

Herd and Husbandry

Sixteen Holstein calves, all approximately four months of age, were selected from the University herd. The calves were divided into four groups of four due to the design of the housing facility which allowed for only four animals to be studied during each 17 d observation period (Figure 1). Calves had been weaned at seven weeks of age and began receiving weaned calf feed (WCF) and hay. Calves in the first two groups observed (set one) received the WCF routinely fed to calves in the University herd which contained soybean meal (SBM) as the major protein source. WCF of the eight remaining calves from groups tree and four (set two) contained dried distillers grains in place of the SBM to minimize, in these two groups, previous experience with the feeds being tested. Table 1 shows the assignment of the specific calves to their sets and groups. During the observation period, the calves were individually penned in adjacent stalls so they could see and hear each other. The dimensions of the pens were approximately 2.0 m by 2.4 m. Calves received approximately 1.4 kg of first cutting orchardgrass hay two times per day and 1.8 kg of concentrate once daily. Refused hay was removed and weighed each morning. Water was available at all times and

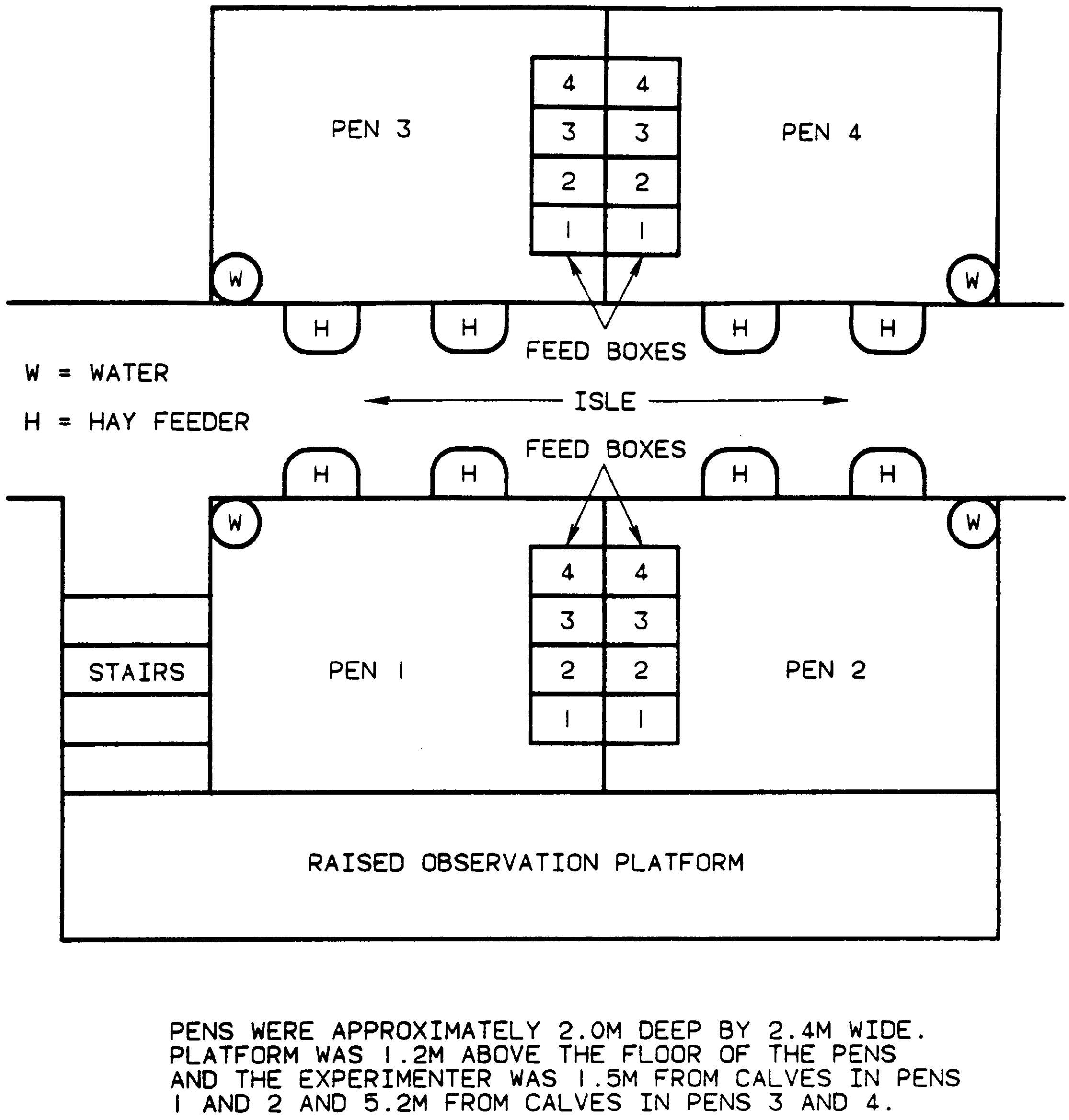

Figure 1. Overhead View of Housing and Observation Facility

Table 1. Assignment of Calves to Sets and Groups

Set*	Group	Individual Calf
1	1	1672
		2346
		2347
		2348
	2	1677
		1678
		1679
		1681
2	3	1066
		1067
		1068
		1073
	4	1079
		1080
		1084
		1695

***Set 1 =** Calves receiving weaned calf feed containing SBM

***Set 2 =** Calves receiving weaned calf feed containing dried distillers grains calves were weighed once per week during their observation period. Average weights of calves at the beginning and end of the trials were 105.7 ± 12.9 kg and 117.0 ± 13.9 kg, respectively.

Experimental Procedure

Feeding behavior was observed simultaneously for all four calves from a platform located behind and 1.2 m above the floor of the pens, such that the observer was 1.5 m away from the calves in pens 1 and 2 and 5.2 m from the calves in pens 3 and 4 (Figure 1). A preliminary trial conducted in May, 1987 showed that proximity to the observer did not influence behavior of the calves. The protein sources tested for preference were SBM, peanut meal (PNM), fish meal (FSM) and corn gluten meal (CGM). Each protein source was mixed with cracked corn and trace minerals in a 50:46:4 percent ratio, respectively. The four resulting concentrate mixes provided the following percent crude protein (CP), on an as fed basis; 24.2 for SBM/corn, 26.4 for PNM/corn, 36.2 for FSM/corn, and 37.0 for CGM/corn. Total digestible nutrient (TDN) percent ranged from 74 to 79 and percent acid detergent fiber (ADF) ranged from 2.7 for FSM/corn to 10.0 for SBM/corn. Hay quality was maintained at approximately 9.0% CP, 51.0% TDN and 37.0% ADF. Visual appearance and odor of the hay were monitored to control quality. Feed composition values were determined from samples submitted to the Virginia Tech forage testing laboratory.

Approximately 14.3% dietary CP (DM basis) is required for 100 kg Holstein dairy calves gaining 0.7 kg daily. Total dietary CP contained in feeds used in this experiment was approximately 19.5% as shown by the percent CP contained in .45 kg of each protein feed and 2.7 kg of hay (Table 2). Boxes attached to the inner wall in each pen were divided into four 24 cm square by 19 cm deep sections. Buckets containing .45 kg of each feed mix were placed in the boxes such that all calves received each feed mix every day of the preference trial. Feed mixes were randomly assigned to sections 1-4 of each box, with section 1 in each pen being the section closest to the observation platform. Each feed also appeared in each section an approximately equal number of times

Table 2. Dietary crude protein content of feeds offered

Feed Type	Amt. DM Fed (kg)	% CP(DM basis)
Soybean meal/corn	.42	26.2
Peanut meal/corn	.40	30.0
Fish meal/corn	.41	40.2
Corn gluten meal/corn	.42	40.2
Hay	2.49	9.8
Total	4.14	19.5

troughout the preference trial. Each box was covered by a lid which was raised and lowered with a rope from the observation platform.

Calves from each group were placed in the pens two days before recorded observations began. Lids of the feed boxes stayed open the first day of adjustment before, during and after calves were fed 1.8 kg of WCF to allow them to adjust to eating from the boxes. The second day of adjustment, lids were closed until calves were allowed to eat the WCF so that they would become accustomed to the lids opening to reveal the feed and closing when feeding ceased. During days 1-3 of the observation period, WCF was fed in all four boxes beginning when the lids were lifted simultaneously. Eating position of each calf (the section number of the boxes) was recorded every thirty seconds so that a measure of positional preference (laterality) could be taken. During the preference trials (days 4-17), lids were again lifted from the boxes of all four calves simultaneously. Feeding positions which represented the random placement of the feeds for each day were recorded at thirty second intervals, beginning at 0 seconds with the first feed eaten by each calf. Feed placement according to box section was the same for calves in the same groups.

In both the laterality and the feed preference trials, an observation of 0 represented any behavior which replaced eating the concentrate feeds. Examples include drinking, eating hay, and licking the box. Calves were allowed to eat for no more than 50 min or until five consecutive 0's (two minutes without eating) were recorded, signifying that they were finished. In either situation, lids were lowered closing the boxes. Ninety percent of the observation sessions ended when the calves finished before 50 min. Once all four boxes were closed, buckets were removed and any remaining feed was weighed. Feed for the next day was then placed in the boxes and lids were latched to prevent calves from having access to the feed. The 17 d observation period for group 1 was conducted from June 24, 1987 trough July 10; for group 2 from July 15 trough July 31; for group 3 from September 9 trough September 25; and for group 4 from October 14 trough November 1. Observations for groups 1 and 2 began at approximately 0830 r and for groups 3 and 4 at approximately 1115 r because of scheduling necessities and similarities in seasonal temperatures at these times.

Statistical Analysis

Positional Preference

Preference for feed position was determined primarily using average length of time (L) calves spent eating from any given section of the feed boxes during the first 10 min WCF was available on days 1-3 of the trials. Data were analyzed by analysis of variance with the model:

$$Y_{ijklmn} = \mu + S_i + G_{(i)j} + C_{(ij)k} + P_l + (PS)_{il} + (PG)_{(i)jl} + D_m + (DP)_{lm} + e_{ijklmn} \qquad [1]$$

where:

i = 1,2 sets
j = 1,2,3,4 groups
k = 1,2,...,16 calves
l = 1,2,3,4 positions left to right
m = 1,2,...,14 days
Y_{ijklmn} = L

Also, percentage of each feeding position initially chosen on days 1-3 was analyzed by Chi-square to determine the importance position had on determining where calves would begin eating. Finally, influence of position on choice of the four protein feeds was measured by including position as an independent variable in the model used to determine protein source preference (see equation[2] in the following section).

Protein Source Preference

From the data obtained during days 4-17 of the four trials, tree indices of preference for the protein sources were used for analysis: 1) average length of time calves spent eating each feed, 2) order in which calves ate each feed, and 3) average amount of each feed that was eaten. The 50 min observation periods were divided into five 10 min intervals, so that the order in which feeds were eaten could be determined. Interval one included observations made from 30 sec to 10 min; interval two from 10 min and 30 sec to 20 min, and so on. Analysis of the first two indices used the following model:

$$\begin{aligned} Y_{ijklmnop} = {} & \mu + S_i + G_{(i)j} + C_{(ij)k} + F_l \\ & + (FS)_{il} + (FG)_{(i)jl} + (FC)_{(ij)kl} + I_m \\ & + (IG)_{(i)jm} + (FI)_{lm} + (FIG)_{(i)jlm} + P_n \\ & + (FP)_{\text{ln}} + D_o + (DF)_{ol} + (DFI)_{olm} + e_{ijklmnop} \end{aligned} \qquad [2]$$

where:

i = 1,2 sets
j = 1,2,3,4 groups
k = 1,2,...,16 calves
l = 1,2,3,4 feeds
m = 1,2,...,5 intervals
n = 1,2,3,4 positions left to right
o = 1,2,...,14 days
$Y_{ijklmnop}$ = length of time calves spent eating from any given section of the feed box

The level of significance of the main effect 'feed' and the means for each feed indicated which feeds calves spent significantly more time eating. Contrasts of PNM versus SBM, CGM versus FSM, and PNM and SBM versus CGM and FSM were also examined to further distinguish preference differences between feeds based on amount of time each was eaten. The level of significance of the interaction of feed and interval and the means for each feed, interval combination indicated which feeds calves ate significantly more of in the first interval(s).

The model used to determine the amount of each feed eaten was:

$$\begin{aligned} Y_{ijklmn} = {} & \mu + S_i + G_{(i)j} + C_{(ij)k} + F_l \\ & + (FS)_{il} + (FG)_{(i)jl} + (FC)_{(ij)kl} + D_m \\ & + (FD)_{lm} + e_{ijklmn} \end{aligned} \qquad [3]$$

where:

i = 1,2 sets
j = 1,2,3,4 groups
k = 1,2,...,16 calves
l = 1,2,3,4 feeds

m = 1,2,...,14 days
Y_{ijklm} = amount of any given feed eaten

The level of significance of the main effect 'feed' and the means for each feed indicated which feeds were consumed most by calves. To further distinguish preference differences between feeds based on amount of each that was eaten, contrasts of PNM versus SBM, CGM versus FSM, and PNM and SBM versus CGM and FSM were also examined. Examples of complete analysis of variance tables for equations [2] and [3] are provided in Appendix A.

Differences in feed preference by individual calves were evaluted by examination of the significance of the feed*calf interactions and comparing the means for each calf, feed combination from models [2] and [3]. Weight gains of calves were compared to differences in individual feed preference to determine if a relationship existed between feed preferred and weight gain.

Changes in the results of the measures for feed preference were evaluated trough significance of the effect 'day*feed' in models [2] and [3] and day*feed*interval from model [2], and were considered to possibly reflect adjustment by the calves.

Importance of the first feed chosen in indicating preference was also determined by: 1) Chi-square analysis of the percentage of each feed chosen first and 2) analysis of the length of time calves continuously ate the first feed chosen before stopping for any reason. The model for 2) was as follows:

$$Y_{ijklmno} = \mu + S_i + G_{(i)j} + C_{(ij)k} + F_l + (FC)_{(ij)kl} + D_m + P_n + e_{ijklmno} \quad [4]$$

where:

i = 1,2 sets
j = 1,2,3,4 groups
k = 1,2,...,16 calves
l = 1,2,3,4 feeds eaten first
m = 1,2,...,14 days
n = 1,2,3,4 positions left to right
$Y_{ijklmno}$ = length of time first feed was eaten continuously before calves moved

Effects of the type of WCF calves received before the preference trials began were determined by significance of the main effect 'set' in all four models. Similarly, effects of particular calf groupings were evaluated by significance of the main effect 'group' in all four models.

Probability of 0.05 or less was used as the criterion for significance for all models, and the term 'different' is defined as statistical significance at the .05 level.

Experiment 2

This experiment examined calf acceptance of the four protein sources tested for preference in experiment 1. Animals were not given a choice of feed.

Herd and Husbandry

Twenty calves ranging in age from just under four months to just over seven months were divided and housed in four groups of five. Assignment of calves was accomplished using a systematic randomization such that age and experience with the feeds was evenly distributed between each group. Four of the calves had been used in experiment 1 and, therefore, had such experience. Each group received twenty pounds (four pounds per calf) of one particular protein source/corn feed mix once daily for thirty days. The feeds were randomly assigned to the groups. Feed bunks were 2.74 meters in length with no structural divisions. Calves also received first cutting orchardgrass hay two times per day. Water was available at all times. Average weight of calves at the beginning of the trial was 135.4 kg with a range from 89.5 kg to 179.5 kg due to the range in age of the calves. At the end of the trial the average weight was 155.5 kg with a range of 101.4 kg to 197.3 kg.

Experimental Procedure

Beginning August 5, 1987 at 0900 r, each group of calves received the concentrate mix randomly assigned for the 30 d trial. Feeding patterns of the calves were observed on each Monday, Wednesday, and Friday until September 4. Desire or reluctance to eat and the approximate length of time taken to finish the feeds were recorded. Calves were weighed eight days before the 30 d trial began, on day 16 and on day 30 of the trial.

Statistical Analysis

Acceptibility of each feed was measured subjectively as length of time required for calves to begin eating and to completely consume each feed.

Differences in weight gain of the calves according to feed group were analyzed to examine possible effects of feed acceptance on calf development. Weight gain differences were analyzed using the model:

$$Y_{ijkl} = \mu + G_i + C_{(i)j} + P_k + (GP)_{ik} + e_{ijkl} \qquad [5]$$

where:

i = 1,2,3,4 feed groups
j = 1,2,...,16 calves
k = 1,2 periods representing gain between days -8 to 16 and 16 to 30
Y_{ijk} = average weight changes

RESULTS AND DISCUSSION

Experiment 1

Preference among four protein sources was determined. Such determination involved examination of the influence of factors such as feed position and previous experience on preference as well as overall choice for the feeds themselves.

With the exception of three calves, all calves consumed all of the weaned calf feed offered on days 1-3, which demonstrated the calves' ability and desire to eat 1.8 kg of concentrate.

Significance of the main effects 'set' and 'group' from equations[2] and [3] are shown in Table 3 and Table 4They demonstrate that neither presence or absence of SBM in WCF nor random grouping of the calves affected the length of time calves spent eating from any given section of the feed boxes on days 4-17, or the amount of any given feed that was eaten. The preferences that were demonstrated, therefore, were not affected by these variables.

The amount of time calves spent eating was different during days 4-17 when the four protein sources were offered, with the time increasing steadily until about day 10 and then leveling off by day 13 (Table 3, Figure 2). The amount of feed eaten during this period followed the same pattern (Table 4, Figure 3), demonstrating that both measurements gave the same information about changes in the calves' overall feeding pattern over time. The shift from WCF to the protein feeds was abrupt and, therefore, initial rejection with subsequent increases in intake were not unexpected.

Table 3. Level of statistical significance of independent variables for time calves spent eating from any given box (days 4-17)*

Variable	DF	MS	Test MS	PR > F
Set	1	213.4	85.8	.2554
Group(Set)	2	85.8	146.2	.5713
Calf(Group Set)	12	146.2	12.6	.0001
Feed	3	928.8	128.8	.0205
Feed*Set	3	270.8	128.8	.2014
Feed*Group(Set)	6	128.8	103.9	.3094
Feed*Calf(Group Set)	36	103.9	12.6	.0001
Interval	4	1939.0	24.1	.0001
Interval*Group(Set)	12	24.1	12.6	.0290
Interval*Feed	12	1456.6	97.1	.0001
Interval*Feed*Group(Set)	36	97.1	12.6	.0001
Position	3	2.9	12.6	.8747
Position*Feed	9	7.9	12.6	.7773
Day	13	265.7	12.6	.0001
Day*Feed	39	32.1	12.6	.0001
Day*Feed*Interval	208	29.4	12.6	.0001
Error	4080	12.6		

*from Equation[2]
DF = degrees of freedom
MS = mean square

Table 4. Level of statistical significance of independent variables for amount of any given protein feed eaten*

Variable	DF	MS	Test MS	PR > F
Set	1	0.28	0.35	.4601
Group(Set)	2	0.35	0.23	.2547
Calf(Group Set)	12	0.23	0.01	.0001
Feed	3	2.32	0.25	.0116
Feed*Set	3	0.23	0.25	.4913
Feed*Group(Set)	6	0.25	0.13	.0907
Feed*Calf(Group Set)	36	0.13	0.01	.0001
Day	13	0.70	0.01	.0001
Day*Feed	39	0.04	0.01	.0001
Error	780	0.01		

*from Equation[3]
DF = degrees of freedom
MS = mean square

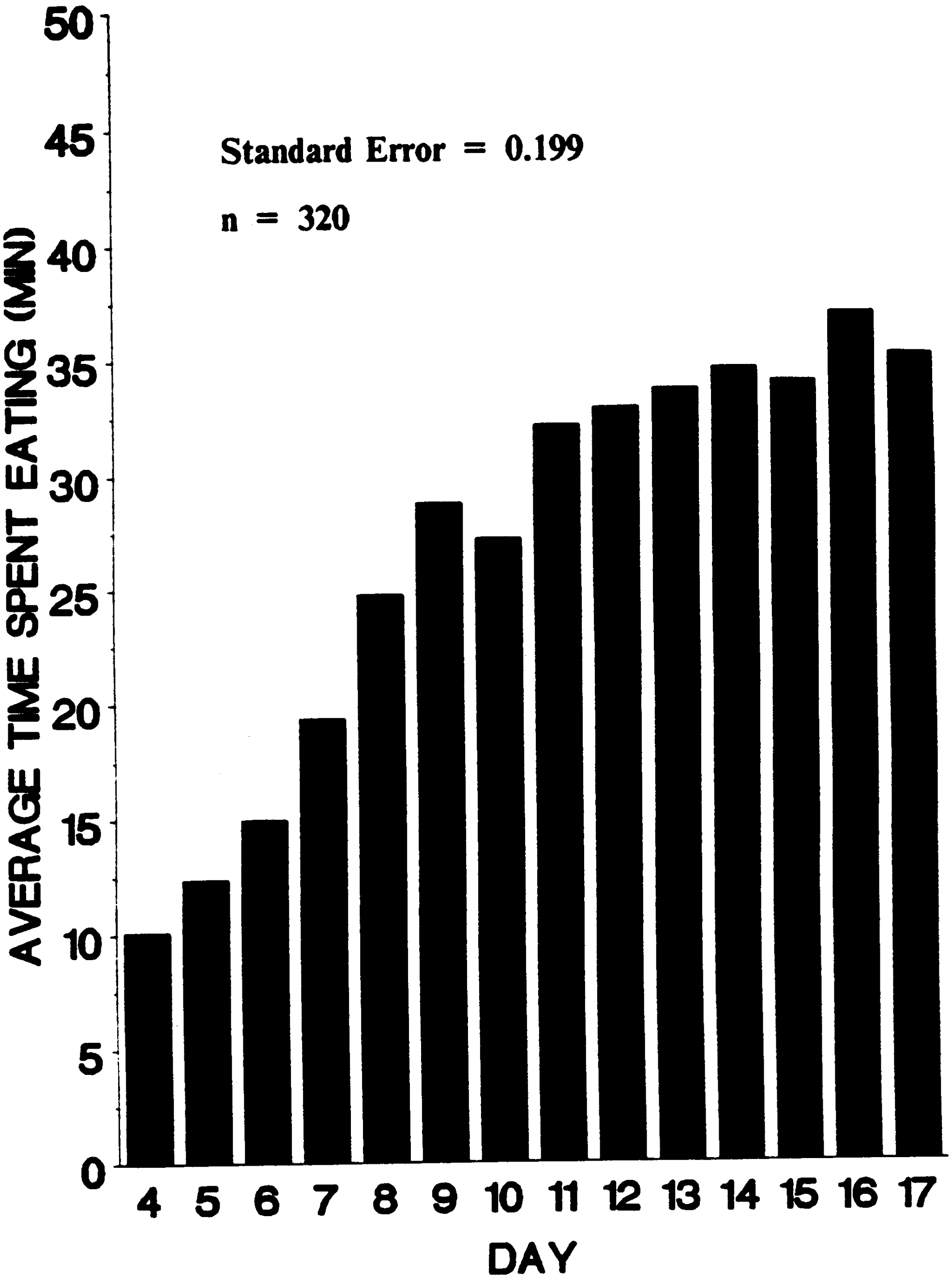

Figure 2. Average total time calves spent eating each day.

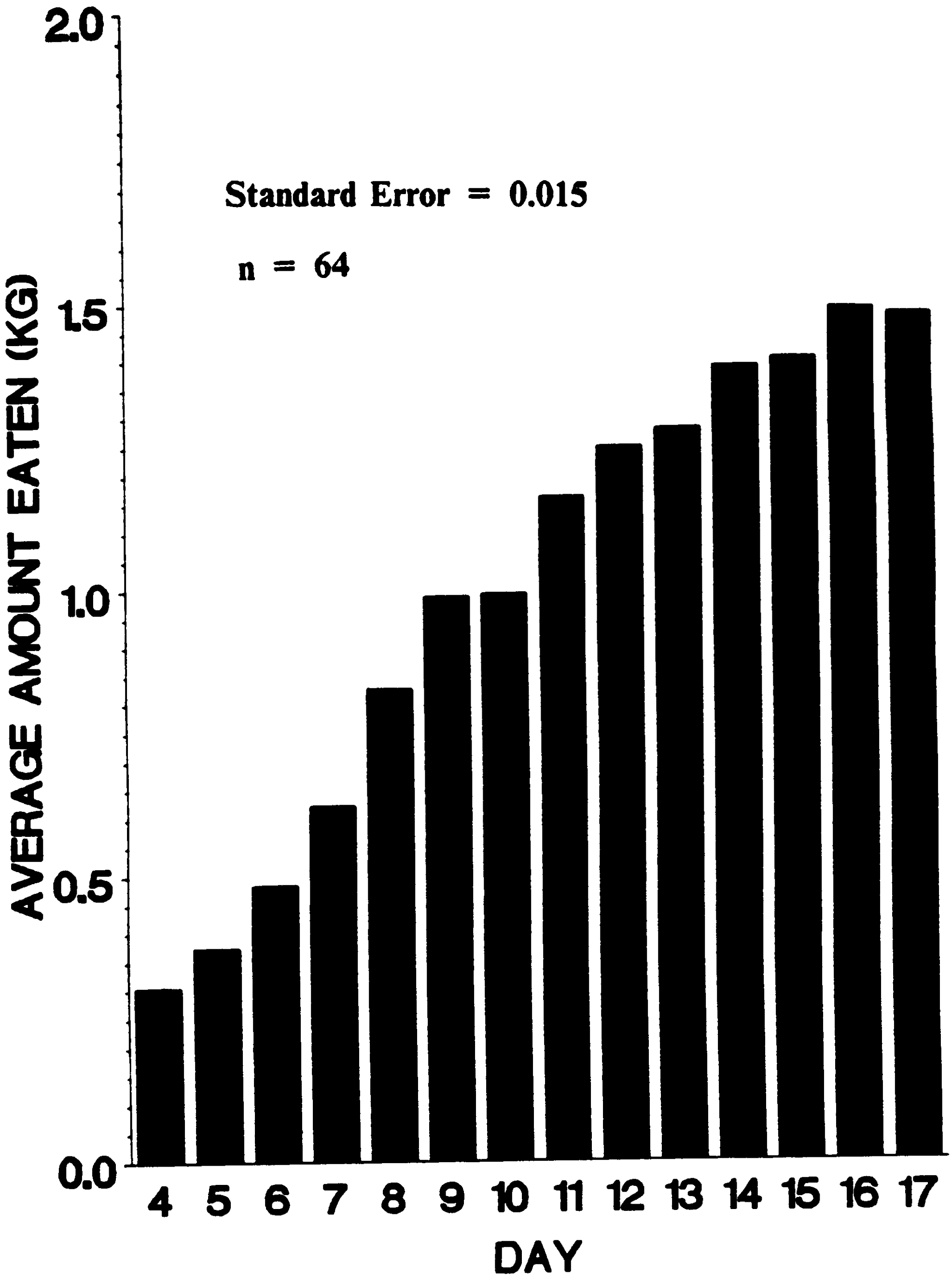

Figure 3. Average total amount of protein feeds consumed by calves per day.

As stated by Marten (46), animals may acquire taste for foods which are ignored when first introduced.

The amount of time calves spent eating decreased significantly and continuously from interval 1 through interval 5 (Table 3, Figure 4). This feeding pattern indicated that, first, calves were hungry when the feeding periods began and they spent less time idling during the first interval(s). Once they were at least partially satiated they were more likely to drink, eat hay, or perform other activities which were not considered as eating from one of the feed boxes. Second, calves ate the preferred feed(s) early (primarily during the first two intervals). During the remaining intervals they tasted or slowly consumed the less preferred feeds.

Individual calves differed in the total amounts of time spent eating (Table 3) and feed consumed (Table 4). These results indicate variation in the speed with which the calves ate and calves' ability or willingness to consume the given amount of protein concentrates, as well as variation in which feeds were preferred. Such individual calf differences are consistent with results obtained from other feeding behavior studies (23, 29, 40, 50, 53, 61, 65).

Positional Preference

Calves did not demonstrate preference for feed position when fed only WCF on days 1-3, as shown by lack of significance ($p > .20$) for the position variable from equation[1]. There was also no influence of feeding position on where calves began eating during this period (Table 5). In addition, position of the four protein sources on days 4-17 did not influence choice of the feeds (Table 3), and position did not effect the first box calves selected during this period (Table 6). These results show that laterality did not confound the preference determination of the four protein feeds when calves were tested for choice during days 4-17.

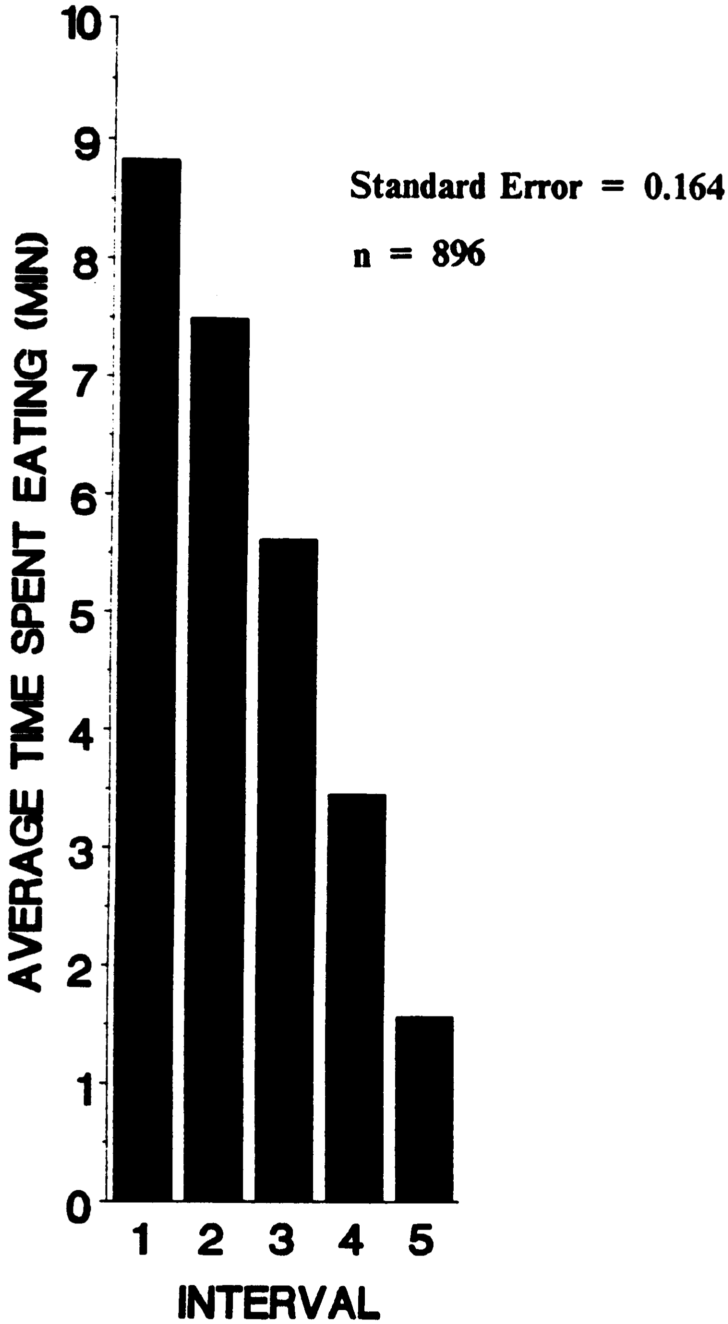

Figure 4. Average total time calves spent eating during each interval.

Table 5. Effect of position on first box calves selected when fed weaned calf feed

Side	Frequency of Each Position Chosen First (days 1-3)
Left	14
Left Center	18
Right Center	11
Right	5

Chi-Square analysis showed that positions were not chosen first significantly ($P < .05$) more or less than expected on days 1-3 (expected frequency = 12).

Table 6. Effect of Position on First Box Calves Selected When Fed Choice of Four Protein Sources

Side	Frequency of Each Position Chosen First (days 4-17)
Left	60
Left Center	66
Right Center	55
Right	43

Chi-Square analysis showed that positions were not chosen first significantly ($P < .05$) more or less than expected on days 4-17 (expected frequency = 56).

Protein Source Preference

The average amount of time calves spent eating each protein feed during any given interval differed (Table 3) and the means for each feed are shown in Table 7. Calves spent the most time consuming PNM and SBM, with no difference between these feeds, and the least amount of time eating CGM. FSM was also consumed longer than CGM though not as long as SBM and PNM. These data indicate that over the course of the trials preference was for:

$$PNM = SBM > FSM > CGM.$$

The large standard deviation for each feed was thought to be caused, first, by individual calf differences. Second, and most importantly, the means for amount of time calves spent eating each feed were averaged over all other variables, including day. Calves spent less time eating during the first several days they were fed the protein sources than at the end of the choice trial periods. Therefore, variation of eating time for each feed was increased due to variation in the time spent eating each day.

The average amount of time calves ate each feed during each interval also differed (Table 3). The means for each feed, interval combination are plotted in Figure 5 and show that during the first 10 min calves spent the most time (5 min) consuming SBM as compared to 3 min, 0.44 min and 0.41 min for PNM, CGM and FSM, respectively. During the second interval, PNM was eaten for approximately 1.6 min longer than SBM, with CGM and FSM each continuing to be eaten for less than 1 min. Eating time for SBM and PNM decreased continually from interval two through interval 5 while FSM and CGM were consumed longer than SBM and PNM during intervals three, four and five. Time spent eating FSM and CGM was very similar for intervals 1-3, while for intervals 4 and 5 FSM was eaten for a longer period than CGM. Though some calves ate PNM first and then moved to SBM, most calves ate SBM first and then PNM. As the amount of SBM and PNM decreased, calves began to spend more time eating FSM and, to a lesser extent, CGM. Therefore, overall preference, as determined by these data, was:

$$SBM > PNM > FSM > CGM.$$

Table 7. Average Eating Time for Each Feed

Feed	Ave. Time Spent Eating (min)	SD*	Max. Value(min)
SBM	1.72	2.63	10.0
PNM	1.74	2.74	10.0
FSM	1.07	2.11	9.50
CGM	0.84	1.80	9.50

Contrasts				
1	SBM	vs	PNM	$P < .8519$
2	FSM	vs	CGM	$P < .0020$
3	SBM & PNM	vs	FSM & CGM	$P < .0001$

*SD = standard deviation

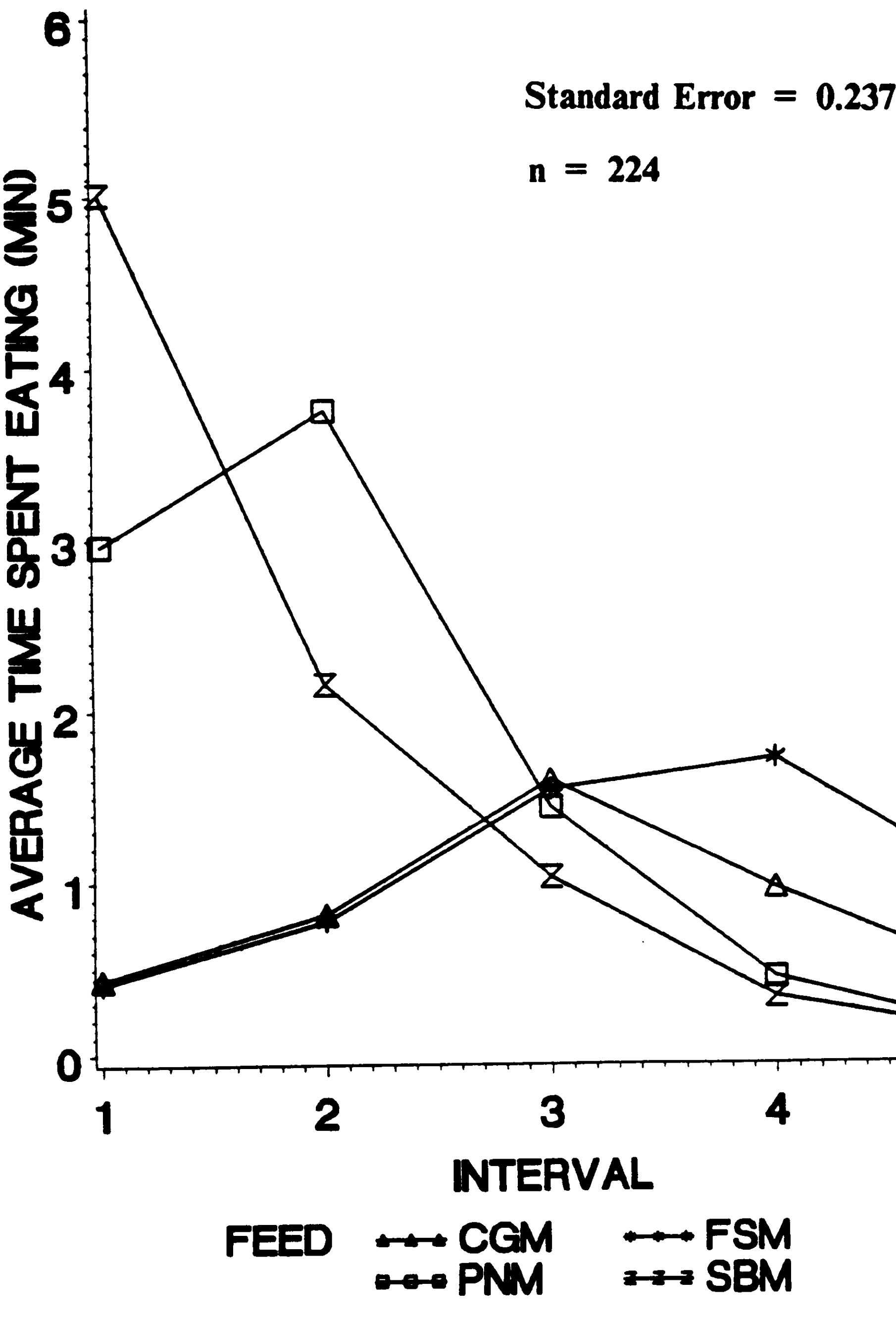

Figure 5. Average time calves spent eating each feed during each interval.

Feeds also differed in the average amounts of each that were consumed (Table 4) with SBM preferred over PNM and both preferred over FSM and CGM, which did not differ (Table 8). Complete consumption of SBM, PNM, FSM and CGM occured 77%, 58%, 21% and 25% of the 224 times each feed was offered, respectively. These data show that preference was:

SBM > PNM > FSM = CGM.

Comparisons of these results with those for average length of time that each feed was eaten (Table 7) indicate that SBM was eaten more quickly that PNM. Average eating time was the same for these feeds but average consumption was greater for SBM. Similarly, while calves consumed the same amount of FSM and CGM, they spent more time eating FSM.

Calves differed in their individual preferences for the feeds as shown by the feed*calf interaction for length of time spent eating (Table 3) and amount of feeds consumed (Table 4). Figure 6 and Figure 7 illustrate the average time calves spent eating each feed and the average amount of each feed consumed, respectively. These graphs show that eating time and amount eaten expressed the same results for individual calf differences in feed preference. SBM was the most consistently eaten feed and while PNM was eaten by most calves, it was generally rejected by 3 calves. After overall preference for SBM and PNM, calves varied in their preference for CGM and FSM. Six calves ate these feeds in approximately the same proportions while 4 calves preferred CGM to FSM. FSM was preferred over CGM by 5 calves. Only one calf rejected all protein sources other than SBM. Variation in amount of time spent eating and actual consumption were demonstrated only by the calf who was approximately eighth in time spent eating but consumed the second highest overall amount, and by the calf who ate for one of the longest periods of time but consumed only the twelth highest overall amount.

The only relationship which seemed to exist between feed preference and weight gain was that the five calves whose preference was SBM > PNM > FSM > CGM had an average daily gain of 1.02 kg compared to 0.83 kg for the six calves whose preference was SBM > PNM > FSM = CGM and 0.70 kg for the four calves who preferred SBM > PNM > CGM > FSM. These variations in daily gain were not significant (PR > .56).

Table 8. Average Amount of Each Feed Eaten

Feed	Ave. Amount Eaten (kg)	SD*	Max. Value (kg)
SBM	0.38	0.15	0.45
PNM	0.28	0.22	0.45
FSM	0.18	0.19	0.45
CGM	0.17	0.20	0.45

Contrasts

1	SBM	vs	PNM	$P < .0001$
2	FSM	vs	CGM	$P < .4308$
3	SBM & PNM	vs	FSM & CGM	$P < .0001$

*SD = standard deviation

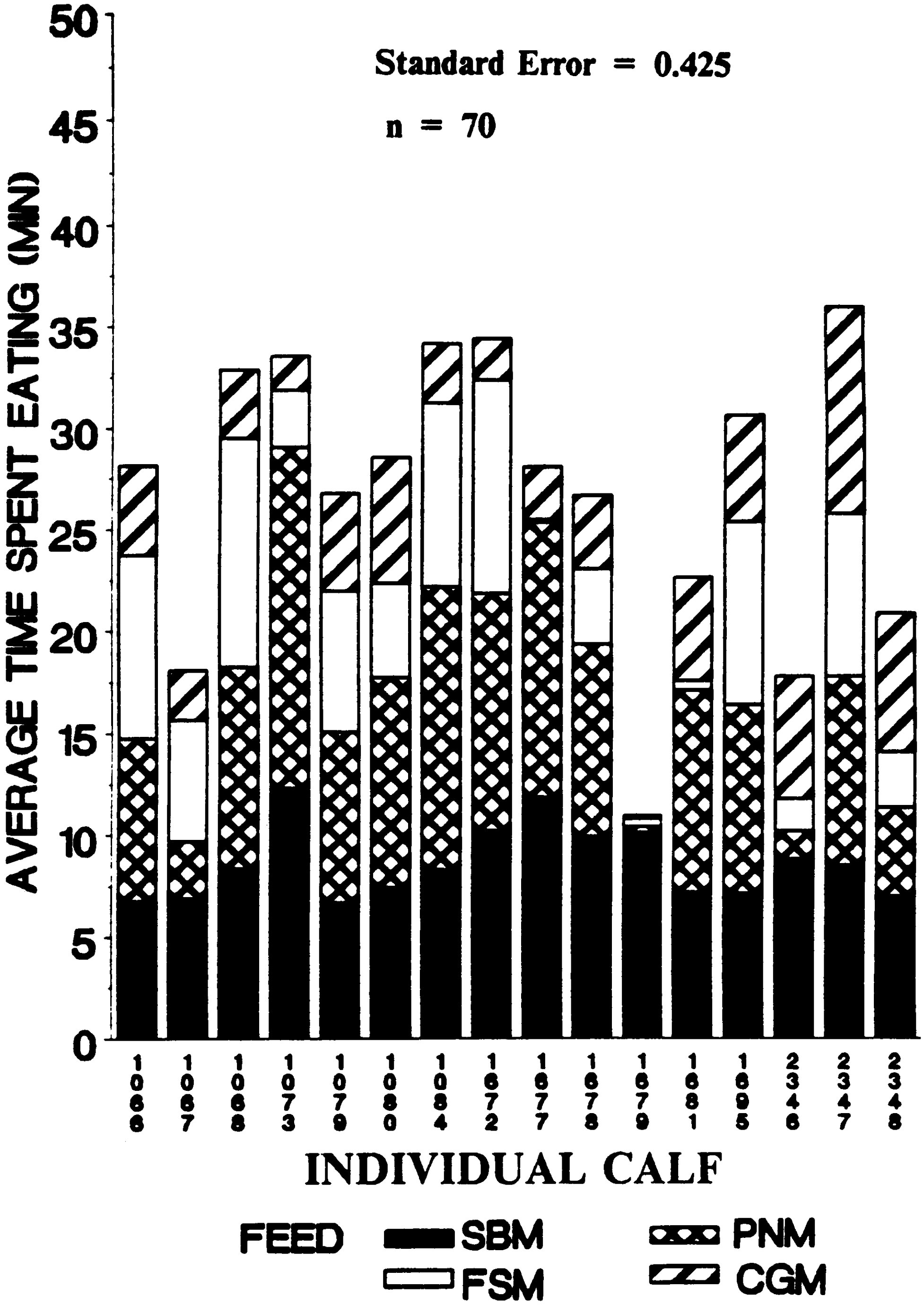

Figure 6. Average time each calf spent eating each feed.

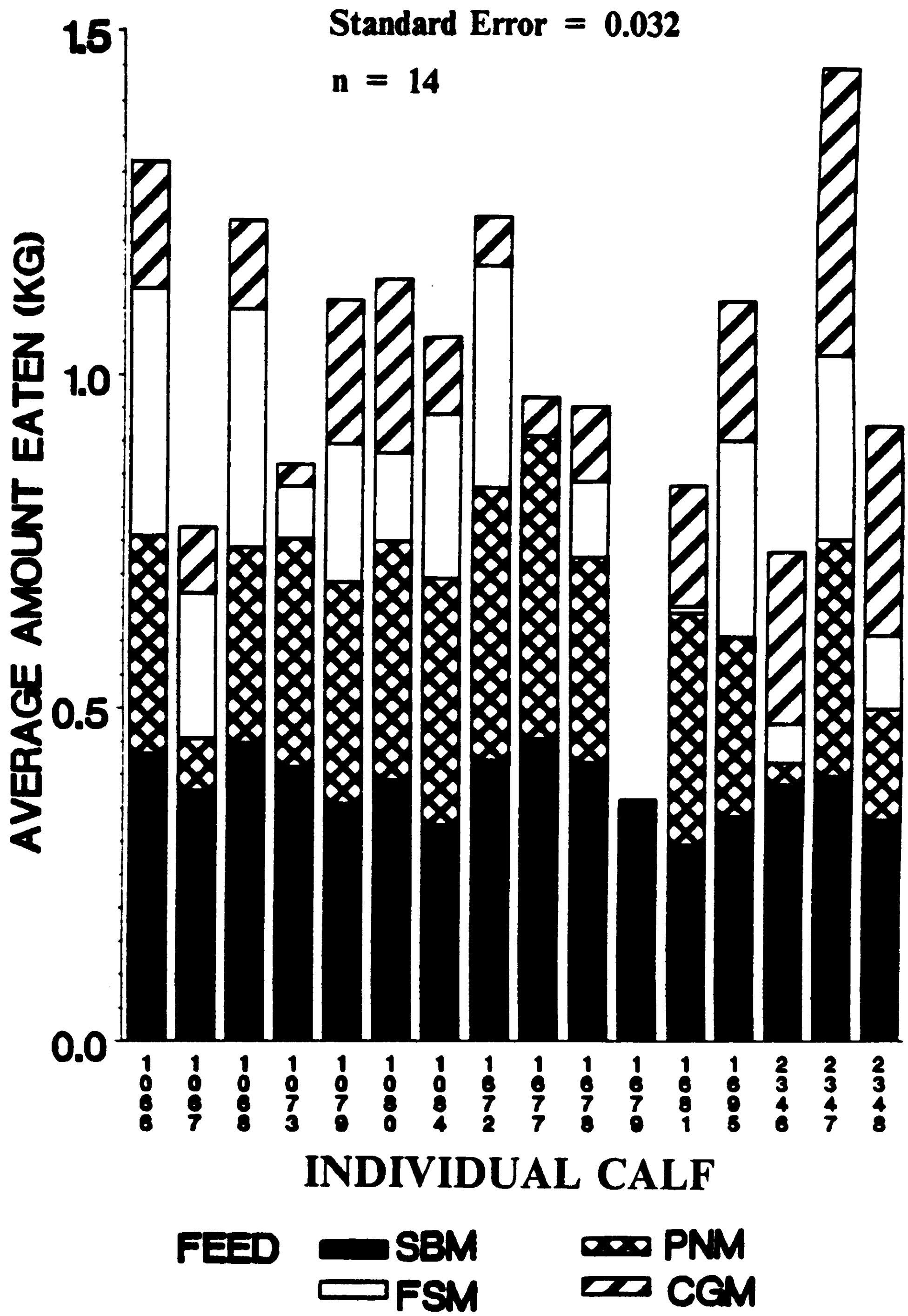

Figure 7. Average amount of each feed eaten by each calf.

Preference for the feeds changed over time as shown by the day*feed interaction for length of time spent eating (Table 3) and amount of feeds consumed (Table 4). Figure 8 and Figure 9 illustrate the average daily length of time each feed was eaten and the average daily feed consumption, respectively. Though PNM was eaten for a longer period of time than SBM from days 11-17, SBM was eaten in the greatest quantity for all 14 d. Thus, calves ate SBM more quickly during the second half of the trials. Though FSM and PNM were both novel feeds for the calves, the initial preference shown (during days 4-6) was for FSM over PNM. This preference changed such that from days 7-17, PNM was eaten for longer periods and consumed in greater quantity than FSM. The greatest change in time spent eating and amount consumed was an increase in both of these measurements for PNM from days 6-8. This adjustment was considered to be due to the taste of PNM which the calves found desirable once they tried eating it after largely ignoring it for the first three days. Except for the last three days of the trials when calves ate more CGM than FSM, CGM was least preferred in terms of time spent eating and the amount consumed.

Any feed preference adjustments by calves over the 14 d of the trials were further illustrated by plots of the average amount of time the calves spent eating each feed, each day during each interval (Figure 10 - Figure 14). SBM was eaten longer than any other feed, each day during interval 1, again indicating that SBM was the feed most preferred. Calves ate FSM longer than PNM during either interval 1 or interval 2 or both on days 4-6, but from day 7-17, PNM was eaten much longer than FSM or CGM in interval 1 and increasingly the longest of any feed in interval 2. PNM therefore was again demonstrated to be the feed preferred second to SBM. However, the length of time (3 d) required for the calves to chose PNM over FSM and CGM shows that calves adapted to PNM as their second choice more slowly than they adapted to SBM as their first choice. By the end of the trial period (days 15-17), eating time for CGM was greater than that for FSM during intervals 1, 2 and 3 which was consistent with the greater consumption of CGM over FSM during days 15-17 described above. FSM was eaten longer than any other feed during intervals 4 and 5 from days 9-17. Calves, therefore, ate most FSM and CGM once SBM and PNM had been consumed, but by the end of the trials calves ate the CGM first and in greater quantity, leaving FSM

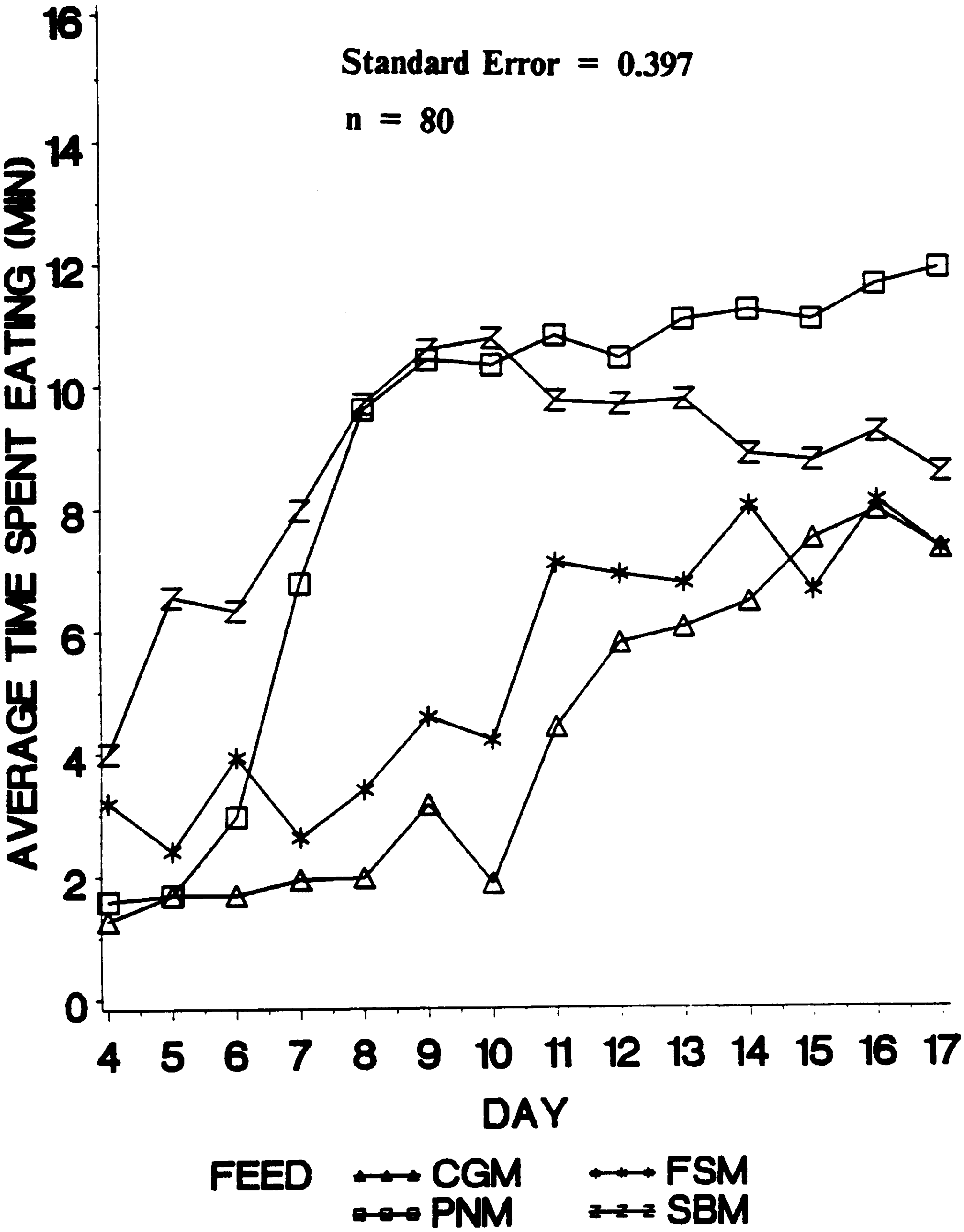

Figure 8. Average time calves spent eating each feed, each day.

Standard Error = 0.030

n = 16

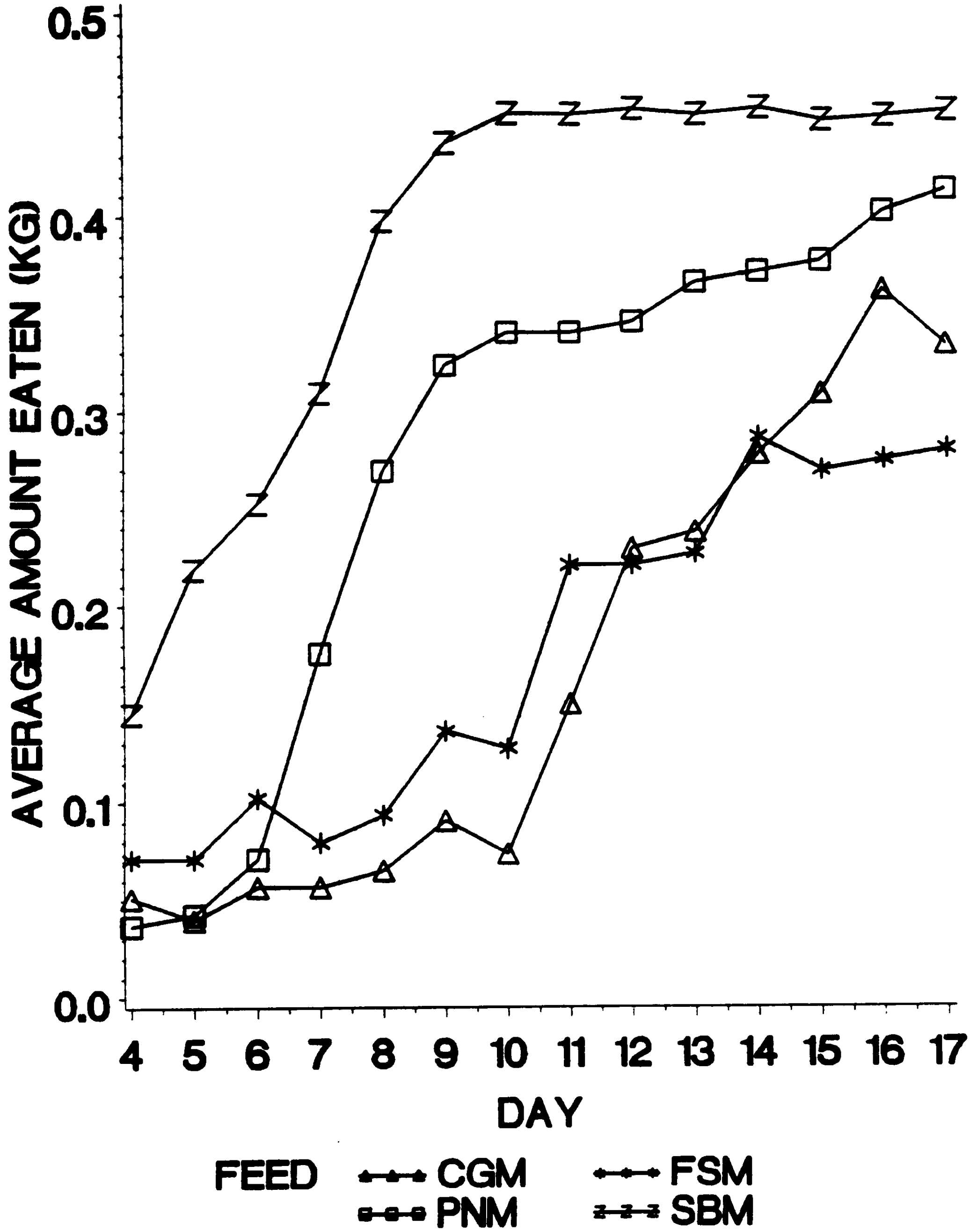

Figure 9. Average amount of each feed eaten each day.

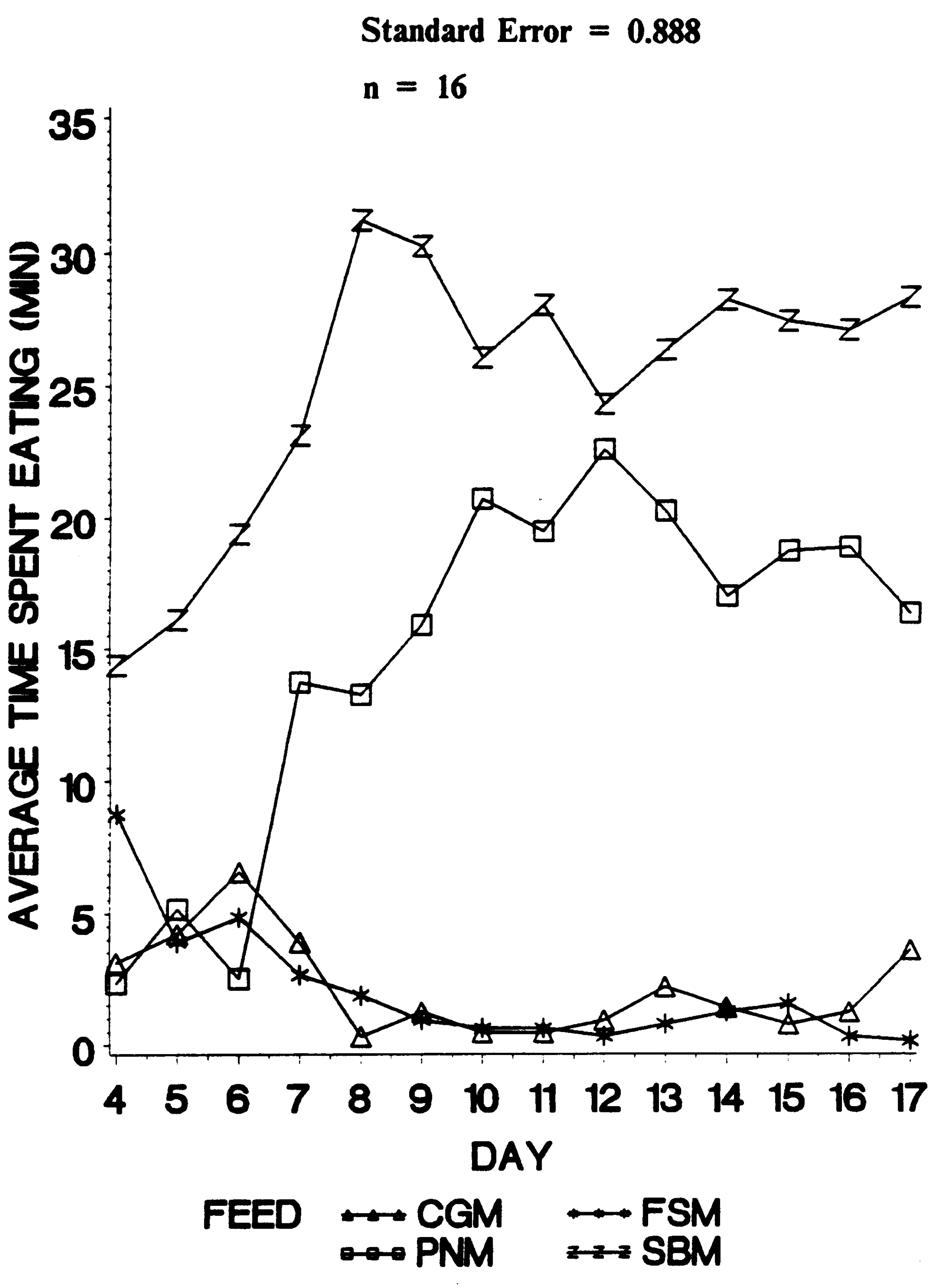

Figure 10. Average time calves spent eating each feed, each day during interval 1.

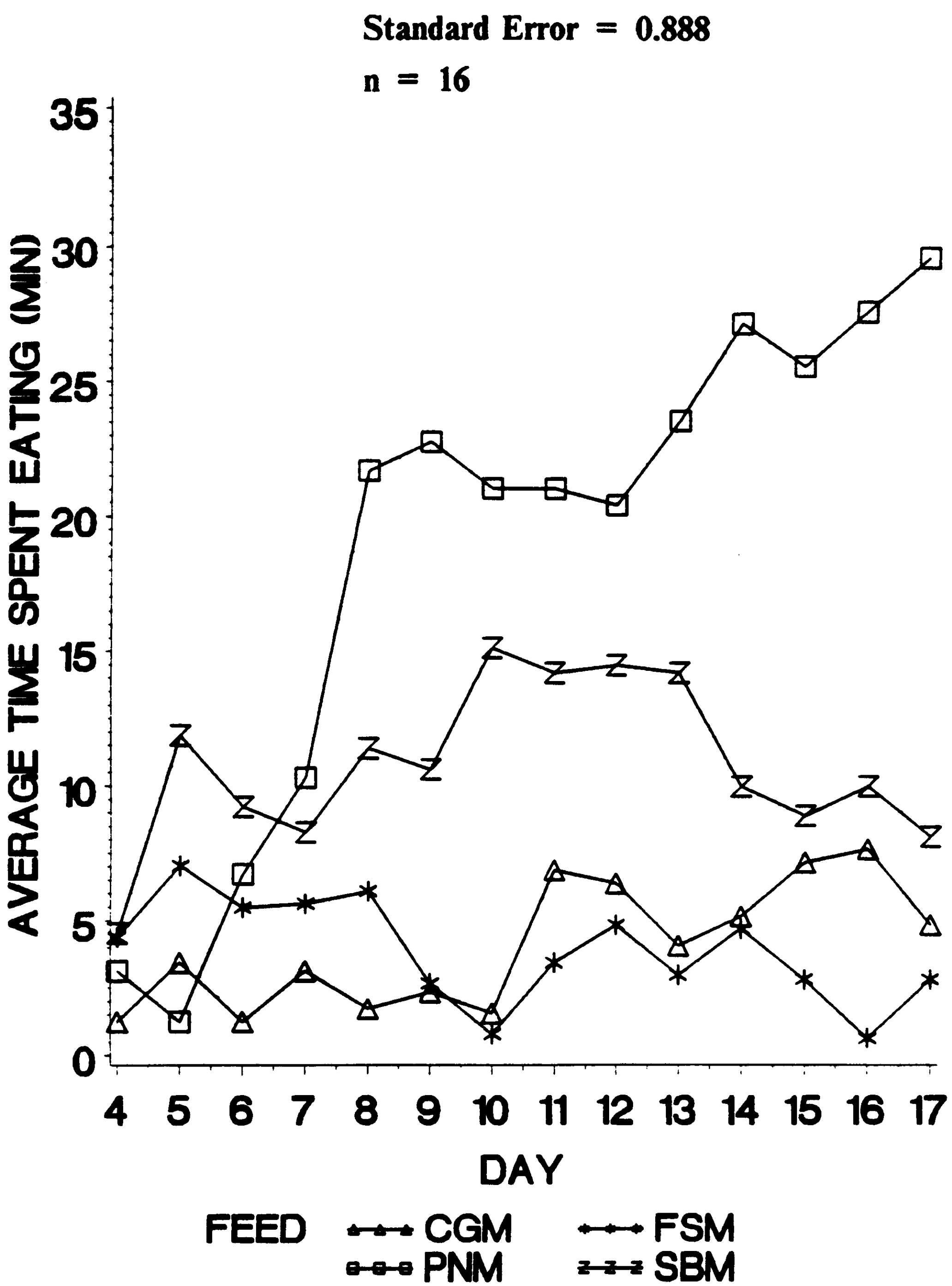

Figure 11. Average time calves spent eating each feed, each day during interval 2.

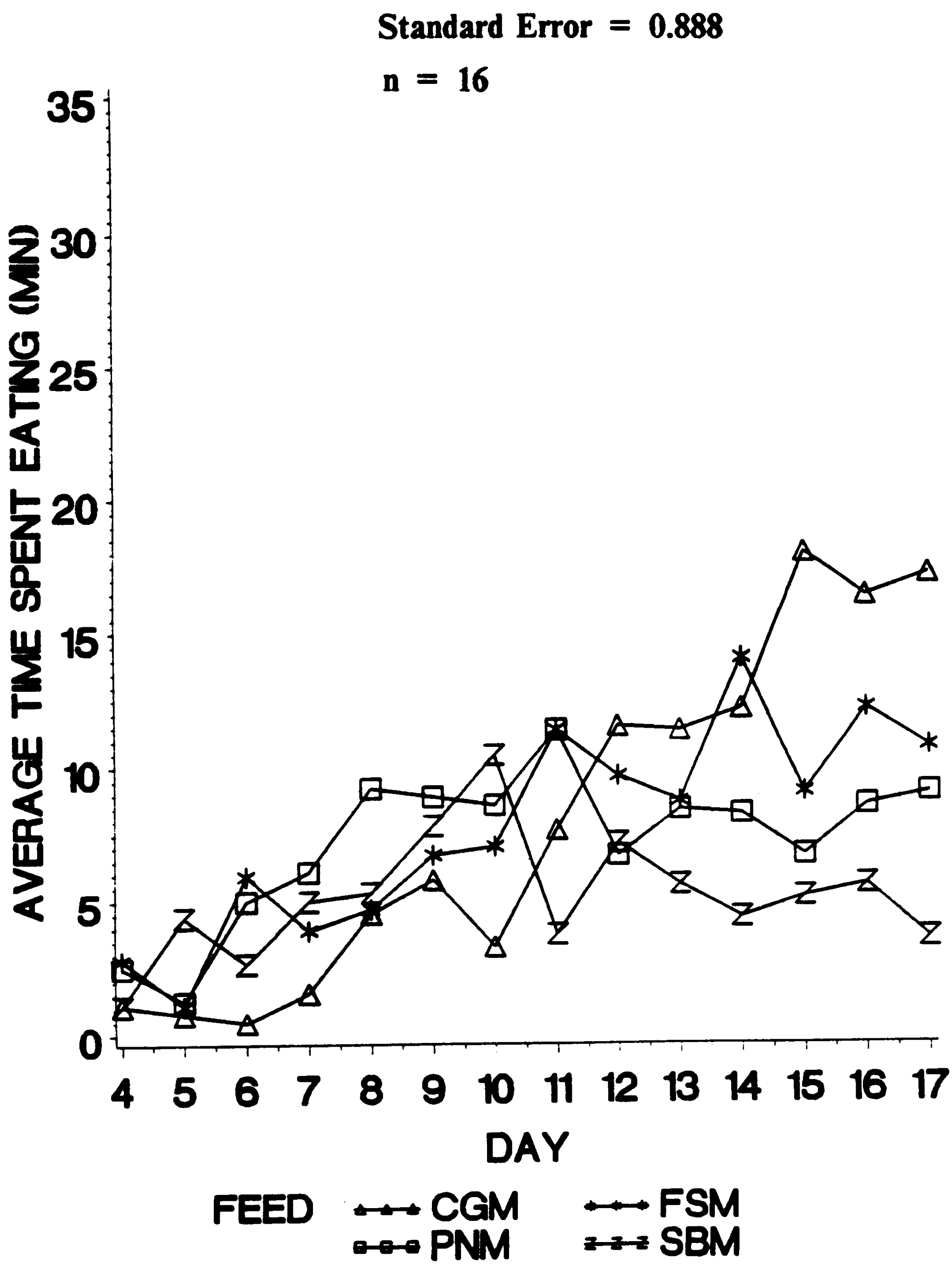

Figure 12. Average time calves spent eating each feed, each day during interval 3.

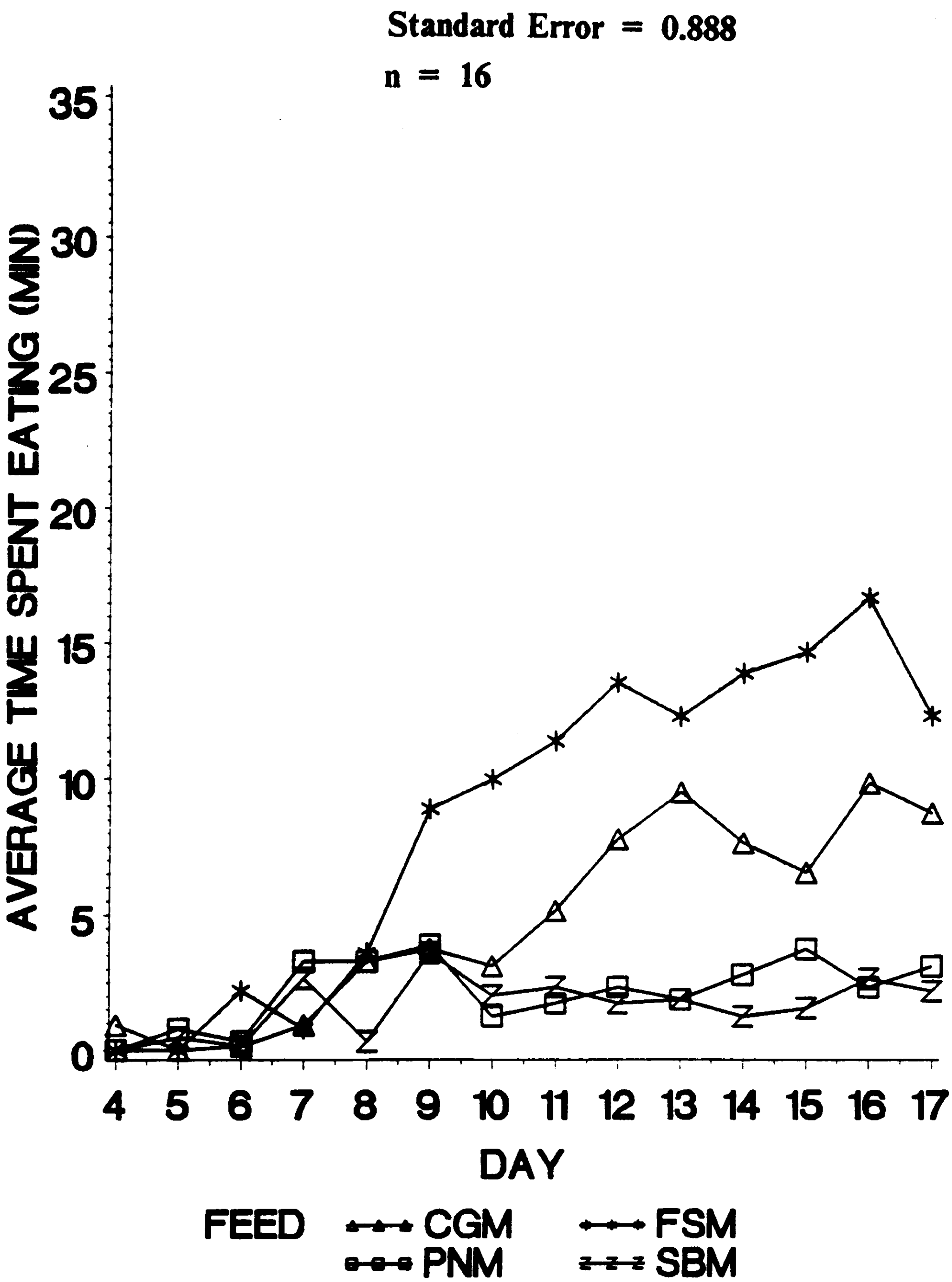

Figure 13. Average time calves spent eating each feed, each day during interval 4.

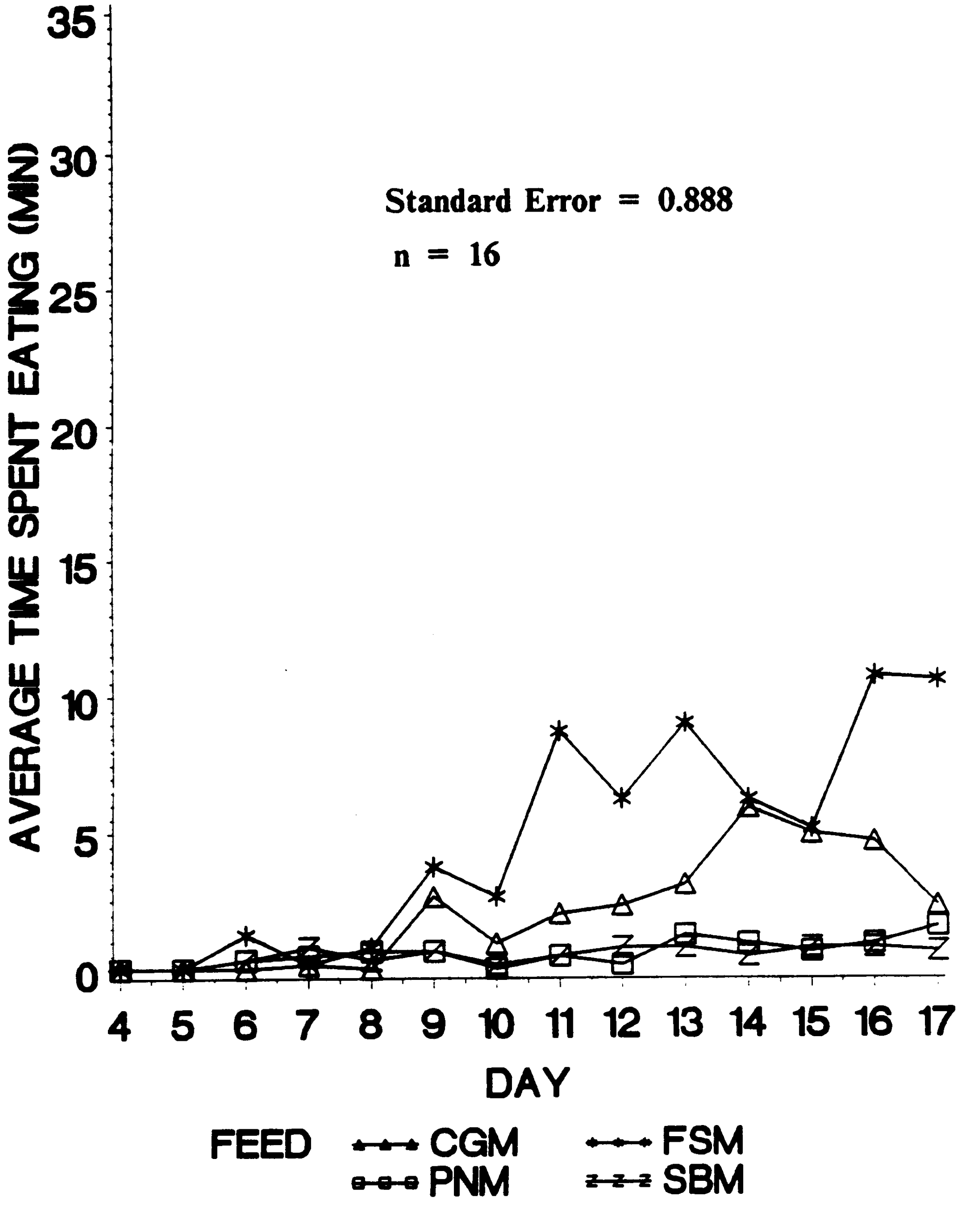

Figure 14. Average time calves spent eating each feed, each day during interval 5.

to be eaten last. Thus, preference for FSM changed the most over time in that though FSM was preferred over PNM and CGM early in the experiment, PNM was preferred to FSM by the fourth day and CGM was eaten longer in the first 30 min by the last three days of the trials. This adjustment may have been due to the taste of FSM which became less desirable to the calves over time for reasons not examined in this study. However, such a conclusion is not supported by the number of days which were required for the calves to possibly develop an aversion to this taste. The apparent change in preference away from FSM was considered more probably to be due to an unidentified negative metabolic affect caused by FSM. Calves may have been able to associate such an affect with the FSM and, therefore, they may have learned to avoid this feed. The association would have been made more slowly, however, than an association of a 'bad' taste with FSM, because the metabolic affect would probably have developed over time.

Chi-Square analysis of frequency of feed eaten first (Table 9) may suggest that the first feed chosen was the preference. SBM was the most preferred feed with PNM second and the frequency with which these feeds were selected first agrees with such findings. These data also indicate, though, that CGM, which was selected first more times than FSM, was preferred over FSM. The importance of the first feed chosen in indicating preference is also demonstrated in Figure 15 where the mean length of time calves continuously ate the first feed chosen is plotted. These results agree with those of Table 9. Calves continued to eat SMB for the longest period when it was chosen first and, again, PNM was second. Both SBM and PNM were eaten considerably longer when selected first as compared to CGM and FSM. Though the length of time calves continued to consume CGM when it was chosen first was greater than the time calves continued to consume FSM, both values were so low as compared to the values for SBM and PNM that a conclusion, based on these data, concerning preferences for CGM and FSM were not possible.

Table 9. Effect of Feed on First Box Calves Selected

Feed	Frequency of Each Feed Chosen First (days 4-17)
Fish meal	34
Corn gluten meal	48
Peanut meal	61
Soybean meal	81

Chi-Square analysis showed that feeds were chosen first a significantly different ($P < .01$) number of times than expected (expected frequency = 56).

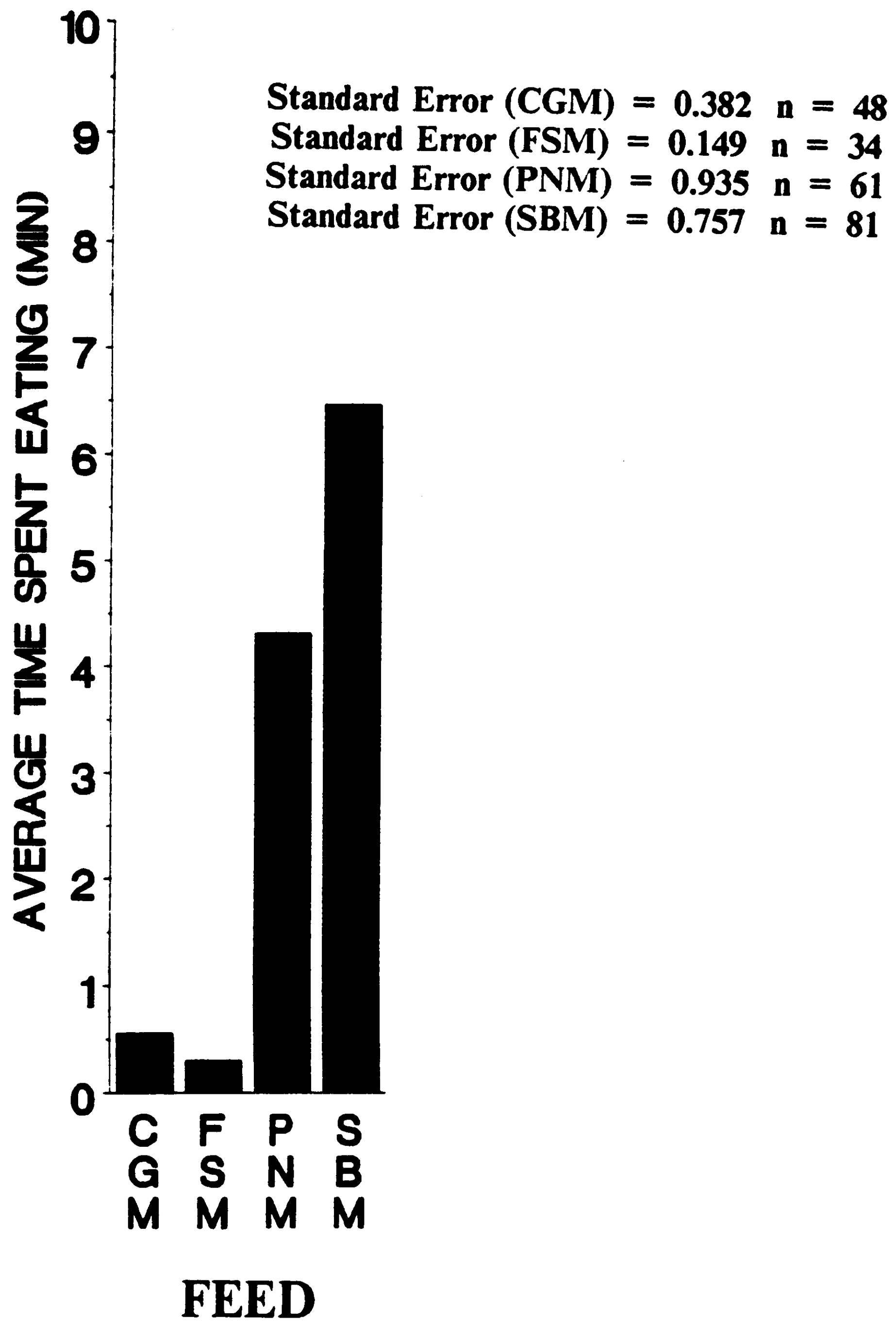

Figure 15. Average time calves spent continuously eating the first feed chosen.

General Discussion of Experiment 1

The preference of calves for the four protein sources was:

SBM > PNM > FSM > CGM

for the majority of the trial periods, with a possible adjustment of preference to:

SBM > PNM > CGM > FSM.

Because the apparent reversal between CGM and FSM occured only near the end of the trial periods, a definite conclusion concerning this preference change cannot be drawn. Reasons for the preference order were not examined but were thought to be largely due to taste differences because taste is the sense which has been determined to be most influential in directing forage and concentrate preference (34, 44, 47, 49). Sight and smell were believed to be important in directing the animals to SBM and PNM over FSM and CGM once preference was firmly established because of the significant difference among the feeds for the first one selected, even though the feeds were randomly placed each day. Smell may have been more influential than sight because while visually the feeds varied only in shades of color from brown to yellow, each feed, particularly FSM, had a strong, distinctive smell. Texture of the protein feeds was probably not a determinate in preference. Though SBM was the dustiest feed and cattle have been shown to prefer feeds that are pelleted in order to decrease the amount of dust (2, 41, 47), all four of the protein sources were from 88-92.5% dry and were finely ground. Therefore, differences in moisture content and particle size were likely not sufficient to be the basis for preference between the feeds. The preference order determined in this study generally agrees with statements made by Etgen and Reaves (28) that PNM was thought to be palatable to dairy cows while CGM and FSM were not.

Preference for SBM was not affected by its presence or absence in weaned calf feed because calves which did not receive SBM in their weaned calf feed preferred SBM as strongly as calves which did receive SBM previously. Though Matthews and Kilgour (49) found that when young sheep have experience with particular feeds these feeds are preferred in subsequent tests, preference was not determined using the same feeds with sheep that did not have the same previous experience.

Marten (48), however, did show that regardless of preconditioning, sheep preferred bromegrass to reed canarygrass, while preconditioning to reed canarygrass reduced preference for orchardgrass. Therefore, though feeding experience may increase the preference for some feeds, other feeds will be highly preferred regardless of previous experience.

The fact that the variable 'group' was not significant for average length of time calves spent eating and average amount eaten indicates that season, which varied from summer to fall with an approximate temperature decrease of 10 C as the experiment was conducted, did not effect feed preference. Perera et al (55) found that for lactating cows, eating activity and drinking were increased in winter versus summer. However, Wilson and Flynn (65) found, using dairy steers, that the shorter length of daylight in winter did not effect total time spent eating or rate of liveweight gain as compared to the longer daylight length in summer. Neither study, though, examined the effect of season on feed preference.

Experiment 2

The acceptability of each protein feed used in Experiment 1 was determined. As measured by length of time required by calves to eat each feed, acceptability was greatest for SBM, followed closely by PNM and CGM. Though calves fed FSM consumed all of this concentrate and therefore accepted it, much more time was required to consume FSM than the other groups took to eat SBM, PNM and CGM. Calves began eating SBM, PNM and CGM as soon as it was offered, except for the first day when the group fed PNM hesitated to finish after trying it, and SBM was consistently finished first with PNM then CGM finished soon after SBM, and in that order. Calves offered FSM often waited several minutes before eating began and these animals stopped to look around, drink water and eat hay much more frequently than those in the other groups. Analysis of weight gain of the calves showed no differences for feeds, individual calves or periods, with

PR > .22, PR > .40 and PR > .10, respectively. The lack of difference in weight gain according to feeds indicates that the speed with which calves finished their given concentrate did not effect their growth. Slower consumption of FSM, though it implies lower acceptability of this feed, may not be negative from a nutritional viewpoint. A rapid decrease in rumen pH, and any accompanying problems with acidosis, which are associated with large amounts of concentrate intake over short periods of time, may be avoided by feeding less palatable feeds which are conusmed at a slower rate. However, if feeding time is limited, then slow feeding rate for feeds with low acceptance may cause decreased intake.

Greater acceptance of CGM as compared to FSM, when animals were not given a choice of feeds, is not consistent with previous results obtained by C. E. Polan and his coworkers at Virginia Tech. For example, cows were fed individually in a Calan door feeding system and those animals receiving a mixed ration containing CGM were more likely to steal from cows receiving feed containing another protein source (personal communication). In addition, Spain (unpublished Masters thesis) fed lactating cows individually. He reported nonsignificant depressed intake of the complete mixed ration containing 20% CP as CGM compared to the diets containing 13% CP as SBM, 20% CP as SBM and 20% CP as FSM. Reasons for the difference in results between the greater acceptability of CGM concentrate over FSM concentrate found in this study as compared to results of studies showing lack of acceptance of CGM, are not clear. One may speculate that the different results were due to the test situation of group feeding in this study as compared to individual feeding in the other studies cited. Social facilitation may have occured under the group feeding situation such that animals which did not "like" CGM ate it more readily than they would have if they were fed individually, because they observed other calves in the group begin eating immediately and continue eating steadily.

Summary and Conclusions

The results of this thesis show that dairy farmers using SBM as their primary protein supplement are using a feed dairy calves preferred over PNM, FSM and CGM when these concentrates were mixed with corn and fed separately from forage. Therefore, high intake of concentrate containing SBM at a rapid rate by dairy cattle would not be unexpected. PNM also would be a good protein source in terms of acceptability if time for cattle to develop a preference for it was not a restriction and if economic conditions warranted its purchase. Though the merits of CGM and FSM may be high in terms of bypass protein, dairy cattle may be reluctant to consume these feeds. Future work evaluating the effect of previous experience with FSM and/or CGM on preference of the feeds tested in this study would be valuable. Also, other protein sources such as cottonseed meal, dried brewers grains and dried distillers grains should be tested for preference and acceptability, with some or all of the feeds used in this study.

REFERENCES

1. Arave, C. W. and J. L. Albright. 1981. Cattle Behavior. J. Dairy Sci. 64:1318.

2. Arave, C. W., W. Temple, R. Kilgour, L. R. Matthews., and J. L. Walters. 1983. Effect on heifer feeding preference of adding flavor or pelleting a dairy meal. J. Dairy Sci. 66:107.

3. Arave, C. W., W. Temple, J. V. Leman, and R. Kilgour. 1984. Discriminability and preference among milking machine functions by dairy cows. Appl. Anim. Behav. 12:313.

4. Arnold, G. W. and R. A. Maller. 1977. Effects of nutritional experience in early and adult life on the performance and dietary habits of sheep. Appl. Anim. Ethol. 3:5.

5. Aseltine, M. S. 1987. Several factors can affect feed intake of dairy cows. Feedstuffs. 59:12.

6. Baile, C.A. 1975. Control of feed intake in ruminants. *In* Digestion and metabolism in the ruminant. I. W. McDonald and A. C. I. Warner, eds. University of New England Publishing Unit, Armidale, New South Wales.

7. Baile, C. A. and M. A. Della-Fera. 1981. Nature of hunger and satiety control systems in ruminants. J. Dairy Sci. 64:1140.

8. Bell, F. R. 1959. Preference thresholds for taste discrimination in goats. J. Agric. Sci. 52:125.

9. Bell, F. R. 1984. Aspects of ingestive behavior in cattle. J. Anim. Sci. 59:1369.

10. Bell, F. R. and R. L. Kitchell. 1966. Taste reception in the goat, sheep and calf. J. Physiol. 183:145.

11. Bell, F. R. and J. Sly. 1983. The olfactory detection of sodium and lithium salts by sodium deficient cattle. Physiol. Behav. 31:307.

12. Bell, F. R. and H. L. Williams. 1960. The effect of sodium depletion on the threshold of calves. J. Physiol. 151:42P.

13. Bines, J. A. and W. F. Davey. 1970. Voluntary intake, digestion, rate of passage, amount of material in alimentary tract and behavior in cows receiving complete diets containing straw and concentrates in different proportions. Br. J. Nutr. 24:1013.

14. Blohowiak, C. C. and P. B. Siegel. 1985a. Mate choice by males from lines of Japanese quail selected for male mating frequency; 1 Preference among lines. Biol. Behav. 10:87.

15. Blohowiak, C. C. and P. B. Siegel. 1985b. Mate choice by males from lines of Japanese quail selected for male mating frequency; 2 Preference among plumage colors. Biol. Behav. 10:97.

16. Burghardi, S. R., R. D. Goodrich, J. C. Meiske, M. L. Thonney, D. H. Theuninck, T. S. Kahlon, D. E. Pamp and K. Kraiem. 1982. Free choice consumption of minerals by lambs fed calcium-adequate or calcium deficient diets. J. Anim. Sci. 54:410.

17. Campbell, R. G. 1976. A note on the use of a feed flavour to stimulate the feed intake of weaner pigs. Anim. Prod. 23:417.

18. Capretta, P. J. and L. H. Rawls, III. 1974. Establishment of a flavor preference in rats: importance of nursing and weaning experiment. J. Comp. Physiol. Psychol. 86:670.

19. Cate, L. R., M Mullord, W. Temple, and L. R. Matthews. 1978. A feed delivery system for the study of choice behavior in cows. Behav. Res. Meth. Instru. 10:27.

20. Chalupa, W. and C. A. Baile. 1978. Development of palatable diets for food-producing animals. *In* Flavor chemistry of animal foods. R. W. Bullard, ed. American Chemical Society. Washington, D. C.

21. Chalupa, W., C. A. Baile, C. L. McLaughlin and J. G. Brand. 1979. Effect of introduction of urea on feeding behavior of Holstein heifers. J. Dairy Sci. 62:1278.

22. Church, D. C. and R. P. Randall. 1979. Effects of diet and feeding level on taste responses of sheep and calves to sucrose solutions. J. Anim. Sci. 48:1177.

23. Coppock, C. E., R. W. Everett, N. E. Smith, S. T. Slack and J. P. Harner. 1974. Variation in forage preference in dairy cattle. J. Anim. Sci. 39:1170.

24. Coppock, C. E., D. L. Bath, and B. Harris, Jr. 1981. From feeding to feeding systems. J. Dairy Sci. 64:1230.

25. Curtis, S. E. and J. H. McGlone. 1982. Status of farm animal behavior research in North America. J Anim. Sci. 54:450.

26. Curtis, S. E. and K. A. Houpt. 1983. Animal ethology: Its emergence in animal science. J. Anim. Sci. 57(Suppl. 2):234.

27. Dulphy, J. P., B. Remond and M. Theriez. 1980. Ingestive behavior and related activities in ruminants. *In* Digestive physiology and metabolism in ruminants. Y. Ruckebusch and P. Thivend, eds. MTP Press Limited, Lancaster, England.

28. Etgen, W. M. and P. M. Reaves. 1978. Dairy Cattle Feeding and Management. Sixth Edition. John Wiley and Sons. N. Y., N. Y.

29. Galef, B. G. Jr. and D. F. Sherry. 1973. Mother's milk: a medium for transmission of cues reflecting the flavor of mother's diet. J. Comp. Physiol. Psychol. 83:374.

30. Goatcher, W. D. and D. C. Church. 1970a. Taste responses in ruminants I. Reactions of sheep to sugars, saccharin, sthanol and salts. J. Anim. Sci. 30:777.

31. Goatcher, W. D. and D. C. Church. 1970b. Taste responses in ruminants II. Reactions of sheep to acids, quinine, urea and sodium hydroxide. J. Anim. Sci. 30:784.

32. Goatcher, W. D. and D. C. Church. 1970c. Taste responses in ruminants III. Reactions of pygmy goats, normal goats, sheep and cattle to sucrose and sodium chloride. J. Anim. Sci. 31:364.

33. Goatcher, W. D. and D. C. Church. 1970d. Taste responses in ruminants IV. Reactions of pygmy goats, normal goats, sheep and cattle to acetic acid and quinine hydrochloride. J. Anim. Sci. 31:373.

34. Goatcher, W. D. and D. C. Church. 1970. Review of some nutritional aspects of the sense of taste. J. Anim. Sci. 31:973.

35. Grier, J. W. 1984. Biology of Animal Behavior. Times Mirror/Mosby College Publishing, St. Louis, Missouri.

36. Hafez, E. S. E. and M. F. Bouissou. 1975. The behavior of cattle. *In* The behavior of domestic animals. E. S. E. Hafez, ed. The Williams and Wilkins Company, Baltimore.

37. Hatton, G. I. 1975. Ingestive mechanisms and behaviors. *In* The behavior of domestic animals. E. S. E. Hafez, ed. The Williams and Wilkins Company, Baltimore.

38. Huey, D. F., J. A. Cherry, P. B. Siegel, D. M. Denbow, and H. P. VanKrey. 1982. Self-selection of dietary protein and energy by diverse populations of chickens. Nutr. Behav. 1:55.

39. Jones, G. M. 1972. Chemical factors and their relation to feed intake regulation in ruminants: a review. Can. J. Anim. Sci. 52:207.

40. Kare, M. R., W. C. Pond and J. Campbell. 1965. Observations on the taste reactions in pigs. Anim. Behav. 13:265.

41. Kilgour, R. and C. Dalton. 1984. Livestock Behavior. Westview Press, Boulder, Colorado.

42. Klopfer, F. D., R. Kilgour, and L. R. Matthews. 1981. Paired comparison analysis of palatabilities of twenty foods to dairy cows. Proc. N. Z. Soc. Anim. Prod. 41:242.

43. Krueger, W. C. 1972. Evaluating animal forage preference. J. Range Manage. 25:471.

44. Krueger, W. C., W. A. Laycock and D. A. Price. 1974. Relationships of taste, smell, sight and touch to forage selection. J. Range Manage. 27:258.

45. Lehner, P. N. 1987. Design and execution of animal behavior research: an overview. J. Anim. Sci. 65:1213.

46. Marnane, N. J., L. R. Matthews, R. Kilgour and M. Hawke. 1982. Prevention of bark chewing of pine trees by cattle: the effectiveness of repellents. Proc. N. Z. Soc. Anim. Prod. 42:61.

47. Marten, G. C. 1970. Measurement and significance of forage palatability. *In* Proceedings of the national conference on forage quality evaluation and utilization. Lincoln: Nebraska Center for Continuing Education.

48. Marten, G. C. 1978. The animal-plant complex in forage palatability phenomena. J. Anim. Sci. 46:1470.

49. Matthews, L. R. and R. Kilgour. 1980. Learning and associated factors in ruminant feeding behavior. *In* Digestive physiology and metabolism in ruminants. Y. Ruckebusch and P. Thivend, eds. MTP Press Limited, Lancaster, England.

50. Matthews, L. R. and W. Temple. 1979. Concurrent schedule assessment of food preference in cows. J. Exp. Anal. Behav. 32:245.

51. Miller, W. J., J. L. Carmon and H. L. Dalton. 1959. Influence of high levels of plant and animal fats in calf starters on growth, feed consumption, and palatability. J. Dairy Sci. 42:153.

52. Moore, C. L., W. G. Whittlestone, M. Mullord, P. N. Priest, R. Kilgour, and J. L. Albright. 1975. Behavior responses of dairy cows trained to activate a feeding device. J. Dairy Sci. 58:1531.

53. Morrill, J. L. and A. D. Dayton. 1978. Effect of feed flavor in milk and calf starter on feed consumption and growth. J. Dairy Sci. 61:229.

54. Muller, L. D., L. V. Schaffer, L. C. Ham and M. J. Owens. 1977. Cafeteria style free-choice mineral feeder for lactating dairy cows. J. Dairy Sci. 60:1574.

55. Perera, K. S., F. C. Gwazdauskas, R. E. Pearson and T. B. Brumback, Jr. 1986. Effect of season and stage of lactation on performance of Holsteins. J. Dairy Sci. 69:228.

56. Ray, M. L. and C. L. Drake. 1959. Effects of grain preparation on preferences shown by beef cattle. J. Anim. Sci. 18:1333.

57. Schuh, J. D. and T. N. Wegner. 1979. Evaluation of a feed preference agent for dairy calves. J. Dairy Sci. 62:1951.

58. Shumake, S. A. 1978. Food preference behavior in birds and mammals. In Flavor chemistry of animal foods. R. W. Bullard, ed. American Chemical Society, Washington, D. C.

59. Stricklin, W. R. and C. C. Kautz-Scanavy. 1984. The role of behavior in cattle production: a review of research. Appl. Anim. Ethol. 11:359.

60. Stubbs, D. J. and M. R. Kare. 1958. Taste preferences of cattle. J. Anim. Sci. 17:1162.

61. Truax , R. E. and P. B. Siegel. 1982. Plumage phenotypes and mating proferences in Japanese quail. Behav. Processes. 7:211.

62. Vasilatos, R. and P. J. Wangness. 1980. Feeding behavior of lactating dairy cows as measured by time-lapse photography. J. Dairy Sci. 63:412.

63. Waldern, D. E. and G. Cedeno. 1970. Comparative acceptability and nutritive value of barley, wheat mixed feed, and a mixed concentrate ration in meal and pelleted forms for lactation cows. J. Dairy Sci. 53:317.

64. Whittlestone, W. G., M. M. Mullord, L. R. Cate and T. Waite. 1975. Operant conditioning as a technique for the solution of practical problems in animal husbandry. Proc. N. Z. Anim. Prod. 35:238.

65. Wilson, R. K. and A. V. Flynn. 1979. Feeding behavior of cattle when offered grass silage in troughs during winter and summer. Appl. Anim. Ethol. 5:35.

66. Wing, J. M. 1961. Preference of claves for a concentrate feed with and without artificial flavors. J. Dairy Sci. 44:725.

67. Zerbini, E. and C. E. Polan. 1985. Protein sources evaluated for ruminating Holstein calves. J. Dairy Sci. 68:1416.

APPENDIX A. ANALYSIS OF VARIANCE EXAMPLES

Below is the ANOVA used to test significance of the independent variables effecting the length of time calves ate from any given box (equation [2] on page 25):

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
DAY	14	4 5 6 7 8 9 10 11 12 13 14 15 16 17
GROUP	4	1 2 3 4
FEED	4	CGM FSM PNM SBM
CALFID	16	1066 1067 1068 1073 1079 1080 1084 1672 1677 1678 1679 1681 1695 2346 2347 2348
POS	4	1 2 3 4
INTERVAL	5	1 2 3 4 5
SET	2	1 2

NUMBER OF OBSERVATIONS IN DATA SET = 4480

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LENGTH

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	399	50265.35125486	125.97832395	9.98
ERROR	4080	51510.08602192	12.62502108	PR > F
CORRECTED TOTAL	4479	101775.43727679		0.0001

R-SQUARE	C.V.	ROOT MSE	LENGTH MEAN
0.493885	131.8933	3.55317057	2.69397321

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SET	1	213.42974163	16.91	0.0001
GROUP(SET)	2	171.53594646	6.79	0.0011
CALFID(GROUP*SET)	12	1754.04844780	11.58	0.0001
FEED	3	2786.41742254	73.57	0.0001
FEED*SET	3	812.29971431	21.45	0.0001
GROUP*FEED(SET)	6	772.97297343	10.20	0.0001
FEED*CALF(GROU*SET)	36	3740.70769630	8.23	0.0001
INTERVAL	4	7756.03883929	153.58	0.0001
GROUP*INTERVAL(SET)	12	288.98258929	1.91	0.0290
FEED*INTERVAL	12	17479.59330357	115.38	0.0001
GROU*FEED*INTE(SET)	36	3497.14241071	7.69	0.0001
POS	3	8.75721186	0.23	0.8747

FEED*POS	9	70.93706355	0.62	0.7773
DAY	13	3453.49372915	21.04	0.0001
DAY*FEED	39	1251.98354118	2.54	0.0001
DAY*FEED*INTERVAL	208	6117.24285714	2.33	0.0001

CONTRAST	DF	SS	F VALUE	PR > F
FEED PNM VS SBM	1	0.44030579	0.03	0.8519
FEED CGM VS FSM	1	120.22756247	9.52	0.0020
FEED CGM AND FSM VS	1	2670.85047044	211.55	0.0001

TESTS OF HYPOTHESES USING THE TYPE III MS FOR GROUP(SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SET	1	213.42974163	2.49	0.2554

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LENGTH

TESTS OF HYPOTHESES USING THE TYPE III MS FOR CALFID(GROUP*SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
GROUP(SET)	2	171.53594646	0.59	0.5713

TESTS OF HYPOTHESES USING THE TYPE III MS FOR GROUP*FEED(SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
FEED	3	2786.41742254	7.21	0.0205

TESTS OF HYPOTHESES USING THE TYPE III MS FOR GROUP*INTERVAL(SET)
AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
INTERVAL	4	7756.03883929	80.52	0.0001

TESTS OF HYPOTHESES USING THE TYPE III MS FOR GROU*FEED*INTE(SET)
AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
FEED*INTERVAL	12	17479.59330357	14.99	0.0001

TESTS OF HYPOTHESES USING THE TYPE III MS FOR GROUP*FEED(SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
FEED*SET	3	812.29971431	2.10	0.2014

TESTS OF HYPOTHESES USING THE TYPE III MS FOR FEED*CALF(GROU*SET)
AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
GROUP*FEED(SET)	6	772.97297343	1.24	0.3094

Below is the ANOVA used to test significance of the independent variables effecting the amount of any given feed eaten (equation [3] on page 25):

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
FEED	4	CGM FSM PNM SBM
CALFID	16	1066 1067 1068 1073 1079 1080 1084 1672 1677 1678 1679 1681 1695 2346 2347 2348
GROUP	4	1 2 3 4
SET	2	1 2
DAY	14	4 5 6 7 8 9 10 11 12 13 14 15 16 17

NUMBER OF OBSERVATIONS IN DATA SET = 896

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: AE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	115	28.17186347	0.24497273	17.05
ERROR	780	11.20686061	0.01436777	PR > F
CORRECTED TOTAL	895	39.37872408		0.0001

R-SQUARE	C.V.	ROOT MSE	AE MEAN
0.715408	47.7042	0.11986563	0.25126826

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SET	1	0.28409322	19.77	0.0001
GROUP(SET)	2	0.69051155	24.03	0.0001
CALFID(GROUP*SET)	12	2.69680674	15.64	0.0001
FEED	3	6.96643254	161.62	0.0001
FEED*SET	3	0.68717486	15.94	0.0001
FEED*GROUP(SET)	6	1.51574952	17.58	0.0001
FEED*CALF(GROU*SET)	36	4.53928387	8.78	0.0001
DAY	13	9.15774655	49.03	0.0001
FEED*DAY	39	1.63406462	2.92	0.0001

CONTRAST	DF	SS	F VALUE	PR > F
FEED PNM VS SBM	1	1.28084877	89.15	0.0001
FEEC CGM VS FSM	1	0.00892857	0.62	0.4308
FEED CGM AND FSM VS	1	5.67665520	395.10	0.0001

TESTS OF HYPOTHESES USING THE TYPE III MS FOR GROUP(SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F

SET	1	0.28409322	0.82	0.4601

TESTS OF HYPOTHESES USING THE TYPE III MS FOR CALFID(GROUP*SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
GROUP(SET)	2	0.69051155	1.54	0.2547

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: AE

TESTS OF HYPOTHESES USING THE TYPE III MS FOR FEED*GROUP(SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
FEED	3	6.96643254	9.19	0.0116

TESTS OF HYPOTHESES USING THE TYPE III MS FOR FEED*GROUP(SET) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
FEED*SET	3	0.68717486	0.91	0.4913

TESTS OF HYPOTHESES USING THE TYPE III MS FOR FEED*CALF(GROU*SET)
AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
FEED*GROUP(SET)	6	1.51574952	2.00	0.0907