STUDIES OF THE ADDITION OF VIABLE YEAST CELL SUSPENSIONS TO BEEF CATTLE RATIONS

by

OLLIE MONROE BOWMAN

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INTRODUCTION

For more than a century it has been known that the rumen of cattle and sheep contains a vast population of microflora and microfauna that digest complex food substances and change them into substances that are of a nutritive benefit to the host animal. It has also been known that without a normal ruminal population the host animal is unable to produce maximum returns in the form of meat, milk and/or wool.

The major functions of these microorganisms seem to be the release of energy by the decomposition of complex carbohydrates that occur in roughages, the synthesis of protein from simple nitrogen compounds and the synthesis of B-complex vitamins. Recognition of these facts has resulted in extensive research programs directed toward elucidating the environmental and nutritive requirements of the rumen microorganisms. The ultimate goal of such programs is to develop supplements which enhance the activities and functions of the microorganisms and result in more efficient conversion of roughages and feed grains to edible meat.

Reports from livestock producers and certain representatives of the feed industry have suggested beneficial effects from the introduction of viable yeast preparations into ruminant rations. These reported effects included substantial increases in rate and efficiency of gain of cattle on either wintering or fattening rations. However, to date research workers at several experiment stations have observed no marked

differences between the performance of ruminant animals fed rations fortified with live yeast preparations and those fed the same rations without the addition of yeast.

The experiments reported herein were designed to study the value of viable yeast preparations in rations commonly used to winter and fatten cattle in Kansas.

REVIEW OF LITERATURE

The literature has been reviewed only to the extent of the isolation and identification of rumen microorganisms, the morphology and physiology of the two subject varieties of yeast, and the feeding of viable cell yeast to cattle and sheep with some notes on the deleterious effects of feeding the subject varieties to rats. It has been divided into three general groups: the physiology of the rumen and its microorganisms; the morphology and physiology of Saccharomyces cerevisiae and Torula utilis yeasts; and the feeding experiments that have been conducted relative to the feeding of viable yeast cells to ruminants and a summary of the feeding value of dry non-viable yeast.

Rumen Physiology and Microbiology

Digestion of feed and forage by ruminant animals such as cattle and sheep involves an intricate integration of physical, mechanical and chemical forces. These herbivorous animals possess a compound stomach composed of four compartments, the rumen, the reticulum, the omasum, and the abomasum. The rumen and reticulum function as a storage compartment for bulky, fibrous food following prehension, mastication and deglutition. After being mixed with the rumen fluids, the coarse feedstuffs are formed into boluses regurgitated, re-chewed, re-insalivated, and re-swallowed. This process of rumination increases the surface area exposed to attack by the microorganisms as the food re-enters the rumen where it is stirred by strong muscular

contractions of the walls of the rumen and reticulum in a fluid medium constantly renewed by the inflow of saliva. The entire mass of food is held here for considerable time under anaerobic conditions and at a pH favorable to the growth and multiplication of microorganisms. The heat of the animal and the heat of fermentation of the mass of food contribute to establish optimum conditions for microbial action (Dukes, 1947).

Recognizing that there are no enzymes present in the alimentary secretions which are capable of hydrolyzing complex carbohydrates such as cellulose, Mc Anally and Phillipson (1944) stated that the presence of microorganisms appears to be necessary for the digestion of these substances by ruminant animals.

Baker (1942) stated that a digestive process may be unconditionally or only conditionally dependent upon microbial activity, unconditionally if cooperation of microorganisms is essential to discharge of the function, conditionally if the nature and extent of their contribution is variable and determined by a wide range of factors. Unconditional dependence is illustrated by the digestion of cellulosic materials in ruminant herbivora.

Van der Wath (1941) reported there were indications that if these microorganisms of the rumen are destroyed, the host animal perishes soon after, so that a form of symbiosis exists between host and microorganisms.

He further stated that since the discovery of ruminal infusoria by Gruby and Delanfond in 1843, these organisms have interested research workers in a two-fold way. Firstly, as a

source of complicated morphological and evolutionary studies and secondly, as a biological problem.

Hastings (1944) estimated that there will be in each milliliter of the liquid of the rumen 100 billion cubic microns of bacteria. He further summarizes that it is not at all impossible that ten per cent of the volume of the rumen contents at the peak of a digestive cycle consists of bacteria and protozoa.

Among the many early researchers that attempted to elucidate the rumen microorganisms Crawley (1923) and Dogiel (1927) and many others have labored incessantly to describe and classify the family Ophryoscolecidae. Van der Wath (1941) quoting Feber stated that these animals convert plant protein into easily digestible animal protein, namely that of their own bodies, and that they serve as an important source of animal protein to the herbivorous hosts. In addition he also listed the following functions of the microorganisms: (a) they assist in the digestion of starch, (b) they assist in the digestion of cellulose, and (c) they are mechanical and physical aids in digestion.

Some of the rumen microorganisms that have been identified physiologically and morphologically are listed below.

As early as 1928 Bechde, et al. isolated an organism which was identified as Flavobacterium vitarumen, a gram-negative bacteria capable of synthesizing certain vitamins of the B-complex.

Schieblick (1929) noted that the decomposition of structural cellulose and starch is associated with rapid multiplication of the iodophile microorganisms concerned. Substances giving a

red instead of a blue reaction may be formed, as in the rumen ciliates and the yeast Schizosaccharomyces ovis.

The morphological characteristics of a free iodophile and a fixed iodophile population were studied in detail by Baker and Martin (1937, 1939) and Baker (1939, 1943) who distinguished the following forms: curved rods and vibrios; very small coccoids; larger coccoids; giant coccoids; and giant ellipsoidal and other elongated forms.

By microscopic examination Baker (1942) concluded that normal microflora and microfauna of the ruminant always include Oscellospira guillermondi; a giant spirillum; large sarcina packets; a rosette-shaped organism made up of five to thirty units; and coccoid chains. In 1943 he recognized iodophilic and aniodophilic organisms in the rumen. The iodophilic forms were classified further as free or fixed. Starch and cellulose were decomposed by the fixed forms and usually were associated with starch and vegetable fragments. The free forms were found in suspension in the rumen liquid.

Smith and Baker (1944) identified the iodophilic bacteria of the rumen as follows: (a) large bacteria which they classified as members of the genera Amylococcus, Amylosarcina, Amylobacterium, and Amylospirillum; (b) small bacteria with no specifically distinct morphological characteristics. These bacteria are also responsible for protein and polysaccharide synthesis.

Elsden (1946) isolated in pure culture an organism that digested starch and stained blue with iodine, this organism

also fermented glucose. Along with the fermentation of both glucose and starch there was the production of undetermined acidic products. He concluded that it was the same organism, Schizosaccharomyces ovis, isolated by Quinn. Elsden also reported that members of the genus Propionibacterium have been isolated from the rumen, and presented evidence to show that these organisms are responsible for the production of the propionic acid in the rumen.

In studies conducted by Quinn (1943) with fistulated sheep it was demonstrated that acute gas production in the forestomach immediately after the consumption of certain foods is associated with a process of oxidative assimilation. By this process variable proportions of such sugars as glucose, fructose, and sucrose are rapidly oxidized through the agency of a strain of false yeast Schizosaccharomyces ovis, which is present in the rumen of sheep in large quantities, especially when such animals are kept on a diet of lucrene. These yeast cells store excess sugar in their cells in the form of glycogen.

Baker (1943) found similar results while working with rumen contents in vitro of the ox.

Elsden, et al. (1946) reversed the sequence by feeding sheep first on poor meadow hay without the presence of neither iodophile cocci nor yeast in the rumen, and later on good clover hay, when iodophile cocci appeared first, followed by yeast in approximately fourteen days. He concluded that the better quality roughages are necessary for the establishment of a yeast fraction in the ruminant population.

Sypestyn (1949) described Ruminococcus flavofacions in the rumen of the cow which is an anaerobic, gram-positive streptococcus that attacks cellulose and cellibiose, but not maltose, glucose, lactose, or xylose.

The isolation of Clostridium cellobioparus and Bacteroides succinogenes was reported by Hungate (1950). The isolation of bacterium producing propionic acid from the rumen of sheep has been reported by Johns (1951).

Huhtanen and Gall (1953) described three main groups of rumen microorganisms based on morphology, designated as: (a) RO-H types which are very tiny, thin, curved motile rods which might resemble spirilla or very thin vibrios; (b) RO-HD types are distinguished easily because they are gram-negative, large, fat, curved, motile rods usually occurring singly; (c) RO-TRC types which appear as a short, thin, straight rod occurring chains. They concluded that all of the organisms were non-spore forming, obligate anaerobic rods which attacked fiber producing the short-chain fatty acids, propionic, butyric, and acetic, and lactic acid as the main end products. It was postulated that these organisms play an important role in roughage digestion in the ruminant.

In subsequent studies by Huhtanen and Gall (1953) they isolated some "miscellaneous" groups of microorganisms which perform varied functions. The RO-C1 and RO-C8 groups have the ability to metabolize lactic acid, producing the short-chain fatty acids. In addition, RO-C1 produces folic acid, pyridoxine, and considerable quantities of a microbiologically active

vitamin B_{12}, whereas RO-C8 produces pantothenic acid, folic acid, riboflavin, and vitamin B_{12}. RO-L5 and RO-CR are strongly amylolytic in vitro which indicates that their possible function in the rumen might be the break-down of the starches contained in grain. Since RO-LCC possesses the ability to break-down fiber and this characteristic also may be possessed by RO-PSO, these organisms may be involved in fiber break-down in the rumen. RO-SCC produces riboflavin and folic acid and metabolizes simple carbohydrates while RO-PR groups of organisms metabolize monoses and maltose.

RO-C1 and RO-PSO characteristically are found largely in the rumen of calves or adult animals eating roughages, whereas the other organisms are found largely in the rumen of calves or adult animals eating large quantities of grain. The RO-PR group of organisms is found about equally in all types of animals.

The nitrogen requirements (of bacteria and host) have secured attention largely through the demonstrated ability of ruminants to utilize non-protein nitrogen in the form of urea (Baker, 1946). Thus he concluded that: (a) the microorganisms concerned are the self-same iodophile and aniodophile species responsible for the decomposition of starch and sugars; (b) they are unable directly to utilize non-protein nitrogen; (c) urea is utilized as ammonia, through the action of rumen urease; but (d) in the absence of carbohydrate intensive decomposition of protein can also occur.

Gall, et al. (1948) reported greater numbers of coccciform organisms in animals on high grain rations. Also animals on

pasture showed the presence of sarcina and star-shaped organisms, which were seldom, if ever, found in animals on winter rations.

It is axiomatic that the maintenance of digestive processes in the rumen presupposes the satisfaction of the requirements for growth of the microorganisms responsible. Since the rumen supports a variety of microbial species, it is a reasonable inference that the conditions of reciprocal dependence are established among several microorganisms (Baker, 1946).

The Morphology and Physiology of Saccharomyces cerevisiae and Torula utilis

Yeasts are found in nature wherever sugar is present, in the nectar of flowers, on the leaves of plants, and in the soil (Skinner, et al. 1947).

In this review two genus' of yeasts were investigated, namely Saccharomyces and Torula. The genus Saccharomyces includes most of the yeasts of industrial importance, and is a typical diplobiontic yeast. The spores are round and two to four are found per ascus. Torula, Torulopsis, or Cryptococcus, are all names given to one genus of yeast. It is essentially very much like Saccharomyces except that ascospores are never formed and there are non-fermenting species as well as fermenting. The fermenting species are nearly, if not quite, as active as species of Saccharomyces. They ferment glucose and sucrose and utilize nitrates. The cells are spherical or nearly so, but in some cases they are ovid or elongated (Skinner, et al. 1947).

The varieties, Saccharomyces cerevisiae and Torula utilis

are the members of the above named genus' that were investigated in this review. Skinner, et al. (1947) stated that Saccharomyces cerevisiae is the common ale and bakery yeast, a top yeast that does not ferment melibiose, but does ferment about one-third of the raffinose, and in addition to its strong fermenting action it is also oxidative. Torula utilis yeasts, these workers proposed, are especially suited as a source of vitamin D, members of the B-complex, protein, fats, and mineral salts.

Chapman (1925) stated that the ordinary Saccharomyces cerevisiae normally decomposes sugar with the production of alcohol and carbon dioxide, and about 3 per cent of glycerine. However, he concluded that it has been found that when fermentation is conducted in the presence of a considerable quantity of sodium sulfite the main products of the fermentation consists of acetaldehyde and glycerine in roughly equal molecular proportions, and that instead of the normal 3 per cent as much as 36 per cent glycerine is produced.

Sheffner and Grahow (1953) presented evidence for the presence of a growth factor in Saccharomyces cerevisiae hydrolyzates which could replace partially the growth requirements for magnesium ions or amide compounds. They also reported that transamination occurs readily during the growth of this organism.

The synthesis of riboflavin is accomplished by microorganisms one of which is Saccharomyces cerevisiae, but very little is known about the mechanism involved (Giri and Krishnaswamy, 1954). They concluded that adenine, guanine, xanthine, hypoxanthine, thiamine, and uracil are effective in increasing riboflavin

production by this organism while uric acid exerted an inhibitory action. The amino acids tryptophane, phenylalanine, and serine inhibited growth as well as riboflavin production by this organism. This strain of yeast requires both thiamin and pyridoxine as indispensable for maximum growth with pyrimidine as the key intermediate (Moses and Joslyn, 1953).

This organism is also concerned in the synthesis of vitamin B_{12} (Perlman, et al. 1954), and in the oxidation of glucose, ethanol, and acetate (Eaton and Klein, 1954).

Tremaine and Miller (1954) listed 6 vitamins that are required for the growth of yeast. They are: biotin, calcium pantothenate, inositol, niacin, pyridoxine hydrochloride, and thiamine hydrochloride.

The organism, Torulopsis utilis synthesizes the branched chained amino acids valine, isoleucine, and leucine (Strassman, et al. 1955).

Schwarz (1951) and Seeley, et al. (1952) noted a gross hepatic necrosis when rats were fed a vitamin E-free diet with Torula utilis as the sole source of protein. Goyco and Asenjo (1954) noted this liver degeneration in rats on the same type deficient diet, but with DL-methionine and vitamin B_{12} supplementation there was an increased protein intake and efficiency, and increased growth.

Seeley, et al. (1952) concluded that the incidence of hepatic necrosis could probably be due to the lower level of the sulfur amino acids contained in the Torula utilis as com-

pared with the Saccharomyces cerevisiae, but did offer this as a definite statement.

Skinner, et al. (1947) listed the following commercial uses for the above varieties of yeasts: (1) the hydrolysis of sucrose to invert sugar, glucose and fructose; (2) the conversion of carbohydrates to lipoidal materials; (3) microbiological assay of certain vitamins; (4) alcoholic fermentation from corn, wheat and potato starch, and cellulose; (5) baking; (6) brewing of beer and ale; (7) wine manufacture, and; (8) vinegar manufacture.

Feeding Experiments

Before reviewing the literature on the feeding experiments involving viable yeast suspensions the author deems it wise to summarize the value of dry non-viable yeast.

According to Flour and Feed (Feb. 1955) brewers' dried yeast is the dried non-fermentative non-extracted yeast resulting as a by-product from the brewing of beer and ale and shall contain not less than 46 per cent of crude protein on the moisture free basis. Producers claim the product's potent antioxidant activity is of great significance in feeds and foods of high animal fat content as a deterrent of peroxide formation as well as in the preservation of vitamins A, E, and D. Brewers' yeast contains approximately 45 per cent protein, 2½ per cent fat and one per cent fiber. The product offers approximately 50 milligrams of thiamine, 16 milligrams of riboflavin, 230 milligrams of niacin, 50 milligrams of pantothenic acid, and 1500 milligrams of choline per pound.

Funk, et al. (1916) stated that a large part of the yeast nitrogen apparently has no food value. However, Osborne and Mendel (1919) reported that the use of yeast as a source of food protein for man and higher animals is not a new one.

Briggs (1940) stated that yeast is commonly associated with a source of the B-complex vitamins. The past few years have seen renewed attempts to sell various yeast compounds to culture farm feeds. But he concluded that work with these products at the Iowa, Kansas, and Oklahoma Stations have shown no advantage in culturing oats or corn with these preparations.

Tosic (1949) reported a possible theapeutic action of yeast. In a flock of 15 sheep fitted with permanent rumen fistulas and wholly maintained indoors on hay, only three animals showed a marked fall in appetite as measured by the average daily intake of hay. In two of the three animals the reduced hay intake was accompanied by a marked fall in body weight. Both of these detrimental changes were successfully arrested and normal appetite and weight restored simply by dosing the sheep with a small quantity of yeast-extract preparation. He thereby concluded that a possible deficiency in some sheep of some accessory food factors or trace elements which are supplied by the yeast caused the syndrome.

Beeson and Perry (1951), working with Hereford and Shorthorn steer calves, attempted to determine the most suitable supplement for poor quality roughages. The supplements, added to Purdue Supplement A were: urea, fish meal, live cell yeast, vitamin B_{12}, distillers' dried solubles, brewers' yeast, and

alfalfa meal. All of the supplements produced a daily gain as high or higher than the control lot except urea, and distillers' dried solubles. The daily gain produced by the live cell yeast was superceded by the alfalfa meal.

These same workers, in 1952, continued this series of experiments to study the growth responses of steer calves and yearlings to various roughage supplementation programs. The roughage used was corn cobs fed ad libitum.

They concluded that corn cobs were successfully used as the sole source of roughage, when supplemented to make good their nutritional deficiencies, in the wintering ration of growing steers. The active cell yeast as a supplement contained 20 billion cells per gram. These data from this experiment indicate that fish meal, active cell yeast, or vitamin B_{12} tend to contribute factors towards the growth of steers, being wintered on corn cobs, over that supplied in Purdue Supplement A, or in the urea substituted supplements. Although the addition of live cell yeast gave an apparent growth stimulation, the addition of neither live cell yeast nor brewers' yeast resulted in a significantly increased growth rate. The addition of 2 pounds of alfalfa meal - replacing 2 pounds of corn - resulted in significantly increased growth.

Beeson (1954) reported that there are many nutritional factors which are added to beef supplements which may or may not be beneficial. One of these is live cell yeast, sometimes called active cell yeast, which is a product that contains 20 billion cells per gram. This product was added to Purdue

Supplement A at the rate of 10 pounds per ton of Supplement. In the first 2 trials, live cell yeast improved growth rate slightly, but in the third trial where alfalfa meal was included in the Supplement, there was no beneficial effect. These results, he concluded, indicated that maybe the same factor(s) that improves roughage utilization are present in alfalfa meal and live cell yeast.

Similarly Perry, et al. (1954) reported that the addition of five tenths per cent of live cell yeast did not improve rate of gain or feeding efficiency. This was in contrast to the results of two previous experiments in which the addition of live cell yeast to a corn cob-Supplement A ration resulted in increased rate of gain. The results, they concluded, indicate that there may be no additive effect from feeding both live cell yeast and dehydrated alfalfa, both of which have been shown to be beneficial when fed separately.

Iowa Supplement Three-a (3a) contains the live cell yeast, Torula. Burroughs, et al. (1954), initiated an experiment with one of its objectives to determine suitable cattle supplements to feed with cornstalk silage. The addition of live cell Torula to the supplement did not result in any significant weight gains.

In a lamb feeding trial using a semi-purified ration to determine the significance of a growth factor in stimulating appetite and weight gains, Ruff, et al. (1953) offered the following conclusions. The factor is rather widespread in common feeds fed to cattle and sheep, both concentrates and roughages. Yeast (Torula, live dried bakers' yeast, autoclaved

dried bakers' yeast, ash of bakers' yeast, aqueous extract of bakers' yeast, and ash from bacto yeast) and manure extract were particularly rich sources of the material.

METHODS AND MATERIALS

Experimental Procedure - Wintering Phase

The purpose of this experiment was to determine the effects on rate of gain and feed efficiency on a wintering ration of Atlas sorghum silage, ground milo grain, and soybean oil meal by two different varieties of yeast.

Allocation of Steers. Forty head of choice-quality Hereford steers were used in this phase of the experiment. The calves were portions of shipments from the Lonker Ranch, Medicine Lodge, Kansas, and the Curry Ranch, Westmoreland, Kansas.

The calves were kept at the Kansas State College Grass Utilization pastures until November 1, 1954 when they were brought to the Beef Cattle Experimental Barn. They were alloted into 4 lots of 10 animals each, 8 steers in each lot were from the Lonker Ranch and 2 were from the Curry Ranch. The assignments per lot were made on the basis of uniformity of weight and conformation. All lots were immediately put on a basal ration of Atlas sorghum silage ad libitum, 4 pounds of ground milo grain, 1 pound of soybean oil meal, and salt and minerals ad libitum. Lots 1 and 2 served as the controls and 3 and 4 were the experimental animals. The 2 experimental lots, 3 and 4, received Torula utilis and Saccharomyces cerevisiae, respectively. The average initial weights of the calves in each lot were: lot 1, 454 pounds; lot 2, 456 pounds; lot 3, 454 pounds; lot 4, 456 pounds. The study officially

began 16 November 1954 and ended 3 May 1955 for a period of 168 days.

Preparation of Viable Yeast Cell Suspensions. The two varieties of yeast that were used in this study were Saccharomyces cerevisiae and Torula utilis. The suspensions were prepared weekly by the Bacteriology department, and stored under refrigeration until used. The suspensions were prepared by adding one pound of peeled potatoes to a liter of water which was steamed for one hour, and then filtered through cheesecloth. To this filtrate was then added two per cent commercial sucrose. Sterilization was accomplished by autoclaving. The cells were grown for 48 hours on this potato-sucrose broth on a shaking machine at 30 degrees Centigrade.

After growth of the cells, they were adjusted by photoelectric turbidity measurements to give 3,000,000,000 cells per steer per day. The cells were not washed, but were diluted with sterile water to adjust the count to the desired level. This seemingly high level of feeding is approximately 13⅓ times higher than the recommended commercial level (287,000,000 cells per head per day).

The steers were fed once daily in the morning. The yeast suspensions were mixed with ½ pint of water and sprinkled over the ration in the feed bunk at feeding time.

Experimental Procedure - Digestion Phase

In this phase of the study 11 yearling Hereford steers, weighing 700 pounds each, were used. The ration fed these

steers consisted of one part of chopped alfalfa hay and three parts of ground milo grain. The steers received 2400 grams of milo and 800 grams of chopped alfalfa (Tables 13, 14 and 15 in the Appendix) unless individual differences prevented such a high level of intake, however, the ratio was maintained at three to one. The live cell yeast suspensions were fed at the same concentration as was in the wintering phase, 3,000,000,000 cells per head per day.

The steers were allowed an adjustment period or pre-experimental period of 15 days in the case of the Torula utilis because of the Christmas holidays vacation. The adjustment period was six days in the case of the Saccharomyces cerevisiae. The steers were fed and watered twice daily, but received the yeast suspensions at the morning feeding.

Collection of the Feces. The steers were kept in stanchions, and the method of collection was the same as that outlined by Garrigus and Rusk (1939) with the exception of using web straps instead of leather ones.

Feces were collected at six o'clock each morning for the seven day collection period prior to the administration of the morning's feeding and watering.

The collection bags were weighed twice before each study and an average of the two weights was used. The total daily fecal excretion was weighed (in the bag, and a 2 per cent composite sample was taken) each morning. The daily samples were kept in pans and under refrigeration until the study was ended. After which the samples were dried in an oven between 90 and

100 degrees Centigrade for three days, or for 24 hours after the temperature reached 100 degrees Centigrade. This drying removed all except approximately 1½ per cent of the moisture. Then they were placed in tightly sealed glass quart jars and taken to the Chemistry department for protein, ether extract, nitrogen-free-extract, and crude fiber determinations on a moisture-free basis.

Fecal Yeast Cell Counts. To determine the presence of the two varieties of yeast in the rumen of the subject steers in this study fecal yeast cell counts were made. The samples for these counts were obtained on the last morning of the subject digestion study with the exception of the controls. This count was taken after the study was ended without regard to identification of the individual steer. The counts were obtained by diluting 10 grams of moist feces in sterile water blanks and plating using appropriate dilutions. The growth medium was potato-dextrose-agar acidified to pH 4.5 by the addition of one milliliter of sterile 10 per cent lactic acid to each 100 milliliters of agar.

RESULTS AND DISCUSSION

Wintering Phase

The results of the wintering phase are shown in Table 1. From this table it will be noted that the average daily ration, the total or daily gains, the feed required per hundred pounds of gain, the feed cost per hundred pounds of gain, and the net return per head do not differ significantly from lot to lot.

Figure 1 shows the average gains per lot as divided into 28 day weigh periods. The increase in rate of gain was not significantly different between lots, in fact there existed a linear relationship between the lots. The average initial weights were 454 pounds for lots 1 and 3, and 456 pounds for lots 2 and 4. The average final weights were 761.5 pounds for lot 1, 760 pounds for lot 2, 762.5 pounds for lot 3, and 757.5 pounds for lot 4. The greatest difference in average weights for all lots was noted on 10 January 1955 when the weights ranged from 538 pounds (lot 3) to 560.5 pounds (lot 4). The individual weights for each lot for each weigh period are shown in Tables 7, 8, 9, and 10 of the Appendix.

It was observed that lot 3 did not clean up its feed as readily as did lot 4, but the difference between this lot and the controls in total and daily gains and total feed consumed are not significantly different.

The water in the tank of lot 4 would begin to develop a milky appearance about three days after filling. A sample of this water and regular tap water revealed no pathological bacteria.

The net return per steer as shown in Table 1 does not include the cost of the yeast cell suspensions for lots 3 and 4 nor labor for any of the lots.

The over-all picture as revealed by the feed required per 100 pounds of gain, and the total and daily gains as shown in Table 1 are in agreement with the results obtained by Beeson

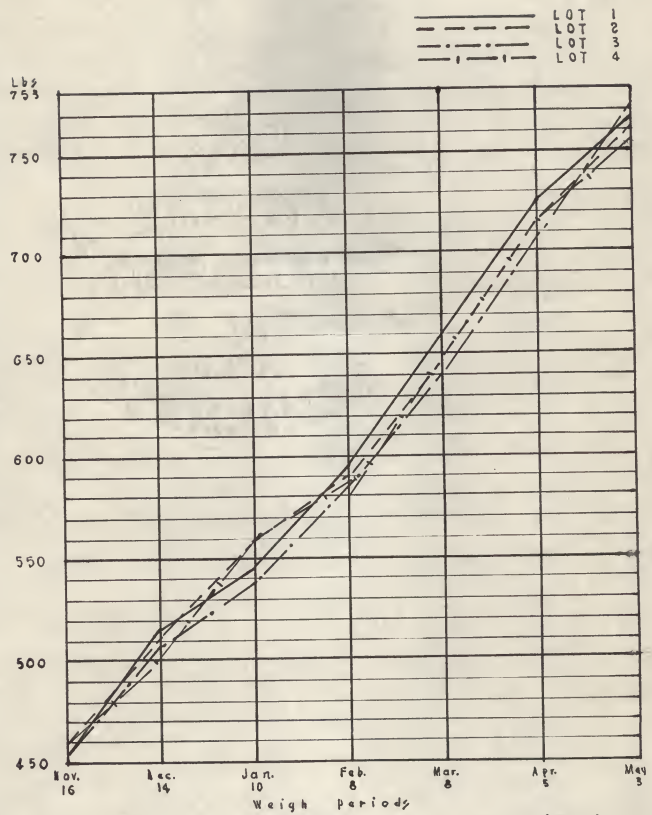

Figure 1. Average Gains Per 28 Day Weigh Period For All Lots.

(1954), Beeson and Perry (1951, 1952), Perry, et al. (1954), and Burroughs, et al. (1954) which indicate that the addition of live cell yeast to beef cattle rations did not result in significantly increased gains, even if the roughage were corn cobs along with alfalfa meal.

Tosic (1949) stated that yeast preparations have a stimulatory effect on appetite, but as shown in Table 1 the amount of silage, which was fed ad libitum, did not differ significantly from lot to lot. The stimulatory factor contained in yeast, noted Ruff, et al. (1953), is rather wide spread in common feeds fed to cattle and sheep, both concentrates and roughages.

Table 1. Data of steer calves fed viable yeast suspensions in wintering ration for 168 days.

Item	Lot 1	Lot 2	Lot 3	Lot 4
Experimental treatment	None	None	Torula Utilis	Saccharomyces Cerevisiae
Number of steers per lot	10	10	10	10
Average daily ration (lbs)				
Soybean oil meal	1.00	1.00	1.00	1.00
Ground milo grain	4.00	4.00	4.00	4.00
Atlas Sorgo silage	30.57	30.69	30.61	30.69
Salt	0.09	0.096	0.095	0.11
Mineral	0.085	0.094	0.095	0.098
Average weight data (lbs)				
Initial weight	454.00	456.00	454.00	456.00
Final weight	761.50	760.00	762.50	757.50
Total gain	307.50	304.00	308.50	301.50
Average daily gain	1.83	1.81	1.84	1.79
Feed required per cwt gain (lbs)				
Soybean oil meal	54.63	55.26	54.46	55.72
Ground milo grain	218.54	221.05	217.83	222.89
Atlas sorgo silage	1670.16	1696.52	1666.93	1710.61
Salt	5.01	5.31	5.15	5.87
Mineral	4.64	5.19	5.15	5.47
Feed cost per cwt gain ($)	14.66	14.89	14.66	15.01
Average financial return ($)				
Initial cost per head[1]	102.47	102.91	102.47	102.91
Feed cost per head	45.08	45.24	45.18	45.28
Total cost (steer plus feed)	147.55	148.15	147.65	148.19
Value at end of winter	167.53	167.20	167.75	166.65
Net return per head[2]	19.98	19.05	20.10	18.46

Average feed prices

Milo grain, cwt	$ 2.50
Soybean oil meal, ton	84.00
Atlas sorgo silage, ton	8.00
Salt, ton	15.00
Mineral (2 parts steamed bone meal, 1 part salt), ton	80.00

[1] Includes transportation costs - $2.59 per head
[2] Selling price - $22.00 per cwt.

Several investigators (Seeley, et al. 1952, Schwarz, 1951) have reported pathological conditions in rats when Torula utilis was fed as the sole source of protein. Since this experiment was designed to determine the additive effect of these yeast preparations autopsies were not performed. However, no physical deleterious effects were noted as a result of this feeding which lasted for 168 days.

As early as 1940 Briggs showed that there was no advantage in culturing oats or corn with yeast compounds. In the work of Perry, et al. (1954), Burroughs, et al. (1954), Beeson and Perry (1951, 1952), and Beeson (1954) there does not appear to be any effect from the feeding of viable cell yeast suspensions to beef cattle.

Going back to the symbiotic relationship that exists between the host and the microorganisms and the "balance" that exists between the different types of organisms it would seem that the rumen, under normal conditions, contains adequate yeast cells or organisms that display physiological characteristics similar to those of yeast. That the rumen normally contains yeast is shown in Table 16 of the Appendix which is a count of yeast cells per gram of feces. This table also illustrates the usage of some of the yeast fed as determined by fecal yeast cell counts. However, this study was not designed to show what effect, if any, the feeding of these yeast cells may have had on the normal rumen population once they were withdrawn from the ration.

Quinn (1943) using sheep on a ration of lucrene and Baker (1943) working with cattle isolated a strain of yeast in the normal rumen, to which Quinn gave the name Schizosaccharomyces ovis.

Digestion Phase

The complete data of the digestion studies are given in Tables 11, 12, 13, 14, 15, 16, and 17 in the Appendix. A summary of these tables is given in Tables 2, 3, 4, and 5. It will be noted from these tables that the digestion coefficients for both of the experimental trials are lower than those of the control study for protein. This is not in agreement with the observation made by Tosic (1949) that yeast preparations have a stimulatory effect on appetite thereby causing increased consumption. It is postulated that since the rumen normally contains yeast (Quinn, 1943; Baker, 1943; and Elsden, 1946), and since yeast are to be found abundantly in nature (Skinner, et al., 1947) beef cattle would have a sufficient supply of said organisms. That the rumen contains yeast is attested by Table 6 which gives an average of the number of the two subject varieties found in the feces of the steers used in this study (Table 18 in the Appendix).

Table 2. Individual digestion coefficients for the steers on the physical balance digestion study.

Steer Number	Protein	Ether Extract	Fiber	N.F.E.	T.D.N.
39 Hip	65.60	70.00	57.30	77.90	68.30
22 Hip	70.20	65.40	60.90	86.70	74.50
48 Rib	70.10	70.70	65.80	82.20	72.40
11 Rib	68.20	72.50	60.70	77.50	68.90
79 Hip	61.30	63.70	55.10	75.60	65.60
31 Rib	61.40	55.40	55.40	77.10	66.00
11 Hip	66.10	62.60	58.20	83.20	71.30
84 Hip	67.20	60.50	56.90	80.30	69.40
61 Hip	67.20	69.00	54.70	81.30	70.40
39 Rib	66.20	65.10	51.20	77.00	66.90
1 Rib	62.30	50.70	56.20	75.50	64.90

Table 3. Individual digestion coefficients for steers on Torula Utilis digestion study.

Steer Number	Protein	Ether Extract	Fiber	N.F.E.	T.D.N.
39 Hip	62.30	52.65	52.67	83.66	70.02
22 Hip	64.24	54.23	51.15	86.00	71.75
48 Rib	69.40	59.53	62.93	87.03	74.33
11 Rib	60.11	65.27	55.52	79.28	67.88
79 Hip	50.19	50.78	36.17	77.18	62.87
31 Rib	58.45	70.74	58.31	77.24	66.91
11 Hip	59.95	61.18	51.86	79.50	67.45
84 Hip	61.81	65.03	53.83	74.94	65.04
61 Hip	62.90	71.05	52.32	82.64	70.50
39 Rib	62.50	66.75	45.99	79.01	67.26
1 Rib	57.10	46.73	48.04	79.16	65.71

Table 4. Individual digestion coefficients for the steers on the Saccharomyces Cerevisiae digestion study.

Steer Number	Protein	Ether Extract	Fiber	N.F.E.	T.D.N.
39 Hip	56.95	66.97	59.96	74.83	65.06
22 Hip	57.36	66.36	51.13	77.77	66.27
48 Rib	60.14	68.24	59.32	82.14	70.28
11 Rib	67.24	74.61	73.81	78.89	70.53
79 Hip	59.52	51.25	53.99	73.84	63.24
31 Rib	51.51	56.87	48.64	71.68	60.79
11 Hip	56.12	61.64	53.23	76.08	64.90
84 Hip	60.70	62.00	50.97	72.13	62.63
61 Rib	59.78	65.21	49.15	77.18	65.91
39 Rib	56.31	63.46	55.89	72.27	62.73
1 Rib	58.12	54.60	57.45	75.98	64.99

Table 5. Average digestion coefficients.

Treatment	Protein	Ether Extract	Fiber	N.F.E.	T.D.N.
None	66.10	64.00	57.50	79.60	69.00
T. Utilis	61.31	60.38	52.54	80.82	68.49
S. Cerevisiae	58.34	62.92	55.30	75.70	65.17

Table 6. Average yeast counts in feces of steers used in the digestion studies (cells per milliliter).

Control	Torula Utilis	Saccharomyces Cerevisiae
1122.22	1575.45	9631.82

There was observed a scouring condition exhibited by numbers 39 hip and 22 hip, also on one occasion number 22 hip failed to get up for the morning's feed or water. There were a number of factors, other than yeast, that could have been the causative agents - the design of the experiment, the environmental conditions,

the difference in weather conditions at the time of experimentation, the time lag between trials, and the individual differences of the steers. The control study was conducted in late November 1954 whereas the experimental studies were delayed until January and February 1955. Such factors as temperature, moisture, draft, and stress could have been responsible for the scouring, or could have been predisposing factors. In either case the condition did not last for more than two days.

It was observed that the feces in both experimental studies were much more turbid and moist than in the control study. The percentage of undigested grain that appeared in the feces did not seem to be reduced over that of the control study. As shown in Tables 2, 3, 4, and 5 the digestibility of protein was significantly lower than the controls, whereas ether extract, fiber, nitrogen-free-extract, and total digestible nutrients were not significantly affected.

SUMMARY

An experiment consisting of two phases was conducted with steers to determine the effects of viable cell yeast suspensions on rate of gain, feed efficiency, and digestibility. In the wintering phase, 40 head of choice Hereford steer calves were used. The basal ration consisted of four pounds of ground milo grain, one pound of soybean oil meal, and atlas sorgo silage, ad libitum. In the digestion phase, 11 yearling Hereford steers were fed a fattening-type ration consisting of ground milo grain and chopped alfalfa hay in a 3 to 1 ratio. The individual tests

in this phase were conducted separately, i.e. control, Torula utilis, and Saccharomyces cerevisiae, thereby using each steer as his own control.

The addition of 3,000,000,000 viable cells of Torula utilis or Saccharomyces cerevisiae to the wintering-type (basal) ration resulted in no significant increase in average daily gains or feed efficiency for the 168 day feeding period.

In the digestion trial the two varieties of yeast, which were fed at the same level as in the wintering ration, produced no significant difference in nitrogen-free-extract, total digestible nutrients, ether extract or fiber. However, a significant decrease in protein digestion was observed.

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APPENDIX

Table 7. Weight data for lot 1. Steer calves wintered on sorgo silage, soybean oil meal and milo grain.

Steer Number	Nov 16	Dec 14	Jan 10	Feb 8	Mar 8	Apr 5	May 3
82	505.00	550.00	610.00	670.00	740.00	822.00	865.00
95	485.00	545.00	560.00	610.00	680.00	735.00	765.00
64	475.00	555.00	595.00	645.00	695.00	770.00	825.00
69	455.00	525.00	545.00	605.00	650.00	717.00	750.00
23	445.00	470.00	510.00	550.00	640.00	707.00	750.00
74	425.00	500.00	520.00	560.00	640.00	710.00	760.00
18	420.00	470.00	500.00	530.00	600.00	652.00	675.00
77	385.00	455.00	465.00	525.00	580.00	635.00	670.00
R11c	430.00	500.00	520.00	570.00	625.00	702.00	750.00
R 8c	515.00	585.00	600.00	650.00	705.00	775.00	805.00
Total	4540.00	5155.00	5425.00	5915.00	6555.00	7225.00	7615.00
Average	454.00	515.50	542.50	591.50	655.50	722.50	761.50
Total gain		62.00	88.50	138.00	201.50	268.50	307.50
Average gain per period		62.00	26.50	49.50	63.50	67.00	39.00
Average daily gain per period		2.21	0.98	1.71	2.27	2.39	1.39
Total number of days		28.00	55.00	84.00	112.00	140.00	168.00
Average daily gain		2.21	1.61	1.64	1.80	1.92	1.83

Table 8. Weight data for lot 2. Steer calves wintered on sorgo silage, soybean oil meal and milo grain.

Steer Number	Nov 16	Dec 14	Jan 10	Feb 8	Mar 8	Apr 5	May 3
78	490.00	540.00	580.00	605.00	670.00	735.00	780.00
2	487.00	540.00	600.00	630.00	680.00	757.00	800.00
91	465.00	530.00	550.00	605.00	680.00	752.00	795.00
72	465.00	505.00	570.00	630.00	685.00	750.00	795.00
54	440.00	505.00	555.00	580.00	635.00	710.00	745.00
44	435.00	500.00	545.00	580.00	635.00	697.00	735.00
30	405.00	445.00	470.00	500.00	555.00	617.00	675.00
43	402.00	470.00	495.00	535.00	580.00	650.00	690.00
R00c	490.00	545.00	575.00	620.00	655.00	715.00	785.00
R 1c	485.00	540.00	580.00	605.00	680.00	752.00	800.00
Total	4564.00	5120.00	5520.00	5890.00	6455.00	7135.00	7600.00
Average	456.40	512.00	552.00	589.00	645.50	713.50	760.00
Total gain		56.00	96.00	133.00	189.50	257.00	304.00
Average gain per period		56.00	40.00	37.00	56.50	68.00	46.50
Average daily gain per period		2.00	1.48	1.28	2.02	2.43	1.66
Total number of days		28.00	55.00	84.00	112.00	140.00	168.00
Average daily gain		2.00	1.74	1.58	1.69	1.84	1.81

Table 9. Weight data for lot 3. Steer calves wintered on sorgo silage, soybean oil meal, milo grain, and Torula Utilis yeast.

Steer Number	Nov 16	Dec 14	Jan 10	Feb 8	Mar 8	Apr 5	May 3
28	520.00	545.00	590.00	645.00	700.00	780.00	820.00
21	480.00	530.00	560.00	620.00	705.00	782.00	850.00
57	480.00	560.00	605.00	665.00	735.00	807.00	860.00
25	450.00	490.00	515.00	565.00	620.00	672.00	705.00
12	450.00	505.00	525.00	585.00	630.00	697.00	745.00
86	425.00	505.00	550.00	585.00	645.00	722.00	785.00
87	420.00	480.00	500.00	550.00	585.00	672.00	730.00
59	375.00	425.00	455.00	490.00	525.00	582.00	635.00
R 9c	585.00	655.00	680.00	720.00	780.00	845.00	880.00
R14c	355.00	385.00	400.00	445.00	490.00	562.00	615.00
Total	4540.00	5080.00	5380.00	5870.00	6415.00	7121.00	7625.00
Average	454.00	508.00	538.00	587.00	641.50	712.10	762.50
Total gain		54.00	84.00	133.00	187.50	258.10	308.50
Average gain per period		54.00	30.00	49.00	54.50	70.60	50.40
Average daily gain per period		1.93	1.11	1.69	1.95	2.52	1.80
Total number of days		28.00	55.00	84.00	112.00	140.00	168.00
Average daily gain		1.93	1.53	1.58	1.67	1.84	1.84

Table 10. Weight data for lot 4. Steer calves wintered on sorgo silage, soybean oil meal, milo grain, and Saccharomyces Cerevisiae yeast.

Steer Number	Nov 16	Dec 14	Jan 10	Feb 8	Mar 8	Apr 5	May 3
88	490.00	535.00	580.00	600.00	675.00	760.00	790.00
70	485.00	515.00	565.00	600.00	660.00	712.00	765.00
32	465.00	500.00	550.00	550.00	625.00	692.00	740.00
22	460.00	520.00	580.00	620.00	680.00	760.00	800.00
46	440.00	515.00	570.00	575.00	655.00	712.00	755.00
61	435.00	470.00	530.00	530.00	600.00	680.00	720.00
42	410.00	470.00	535.00	580.00	625.00	685.00	730.00
94	400.00	445.00	540.00	565.00	615.00	672.00	720.00
R12c	500.00	535.00	570.00	575.00	655.00	710.00	765.00
R 2c	475.00	545.00	585.00	620.00	695.00	745.00	790.00
Total	4560.00	5050.00	5605.00	5815.00	6485.00	7128.00	7575.00
Average	456.00	505.00	560.50	581.50	648.50	712.80	757.50
Total gain		49.00	104.50	125.50	192.50	256.80	301.50
Average gain per period		49.00	55.50	21.50	66.50	64.30	44.70
Average daily gain per period		1.75	2.06	0.74	2.38	2.30	1.60
Total number of days		28.00	55.00	84.00	112.00	140.00	168.00
Average daily gain		1.75	1.90	1.50	1.72	1.83	1.79

Table 11. Chemical analysis of feeds used in all three digestion studies.

Feed	% Protein	% Ether Extract	% Fiber	% N. F. E.
Torula Utilis and Saccharomyces Cerevisiae digestion studies				
Alfalfa hay	16.50	1.69	29.16	37.91
Milo grain	9.44	3.04	1.54	75.64
Control (physical balance) digestion study				
Alfalfa hay	16.50	1.69	29.16	37.91
Milo grain	13.00	3.62	1.89	71.73

Table 12. Chemical composition of feces collected from steers on physical balance digestion study.

Steer Number	% Protein	% Ether Extract	% Fiber	% N. F. E.
39 Hip	18.94	3.73	14.76	55.64
22 Hip	21.81	5.73	17.95	44.36
48 Rib	19.94	4.43	14.34	54.26
11 Rib	17.81	3.48	13.80	57.47
79 Hip	19.19	4.07	13.98	55.24
31 Rib	19.69	5.15	14.29	53.43
11 Hip	21.13	5.27	16.33	47.65
84 Hip	18.88	5.14	15.59	51.69
61 Hip	19.81	4.24	17.17	51.50
39 Rib	17.56	4.10	15.91	54.49
1 Rib	18.56	5.48	13.52	54.86

Table 13. Chemical composition of feces collected from steers on Turula Utilis digestion study.

Steer Number	% Protein	% Ether Extract	% Fiber	% N. F. E.
39 Hip	19.31	5.85	18.27	49.44
22 Hip	19.31	5.96	19.88	44.66
48 Rib	19.31	6.16	17.63	48.37
11 Rib	18.00	3.78	15.13	55.25
79 Hip	18.38	4.38	17.75	49.95
31 Rib	18.13	3.08	13.71	58.69
11 Hip	17.75	4.15	16.08	53.68
84 Hip	15.44	3.41	14.07	59.87
61 Hip	18.81	3.54	18.22	51.99
39 Rib	16.50	3.53	17.92	54.59
1 Rib	18.13	5.43	16.55	52.04

Table 14. Chemical composition of feces collected from steers on Saccharomyces Cerevisiae digestion study.

Steer Number	% Protein	% Ether Extract	% Fiber	% N. F. E.
39 Hip	17.56	3.25	12.31	60.68
22 Hip	18.13	3.45	15.66	55.84
48 Rib	20.19	3.88	15.53	53.46
11 Rib	16.69	3.12	10.06	63.56
79 Hip	15.63	4.54	13.39	59.68
31 Rib	17.06	3.66	13.62	58.88
11 Hip	17.69	3.73	14.21	56.99
84 Hip	14.75	3.44	13.87	61.82
61 Hip	17.88	3.73	17.04	59.94
39 Rib	16.31	3.29	12.41	61.17
1 Rib	17.25	4.51	13.21	58.45

Table 15. Physical balance digestion study. 3:1 ratio alfalfa hay to milo grain.

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
39	Alfalfa	10800.00	1782.00	182.50		3149.30	4094.30		
Hip	Milo	32400.00	4212.00	1172.90		612.40	23240.50		
	Total	43200.00	5994.00	1355.40		3761.70	27334.80		
	Feces	10877.00	2060.10	405.70		1605.40	6052.00		
	Amount digested		3933.90	949.70	2136.80	2156.30	21282.80	29509.80	68.30
	Dig.coefficient		65.60	70.00		57.30	77.90		
22									
Hip	Alfalfa	10800.00	1782.00	182.50		3149.30	4094.30		
	Milo	32400.00	4212.00	1172.90		612.40	23240.50		
	Total	43200.00	5994.00	1355.40		3761.70	27334.80		
	Feces	8194.40	1787.20	469.50		1470.90	3635.00		
	Amount digested		4206.80	885.90	1993.30	2290.80	23699.80	32190.70	74.50
	Dig.coefficient		70.20	65.40		60.90	86.70		
48	Alfalfa	10800.00	1782.00	182.50		3149.30	4094.30		
Rib	Milo	32400.00	4212.00	1172.90		612.40	23240.50		
	Total	43200.00	5994.00	1355.40		3761.70	27334.80		
	Feces	8976.80	1790.00	397.70		1287.30	4870.80		
	Amount digested		4204.00	957.70	2474.80	2474.40	22464.00	31297.20	72.40
	Dig.coefficient		70.10	70.70		65.80	82.20		
11	Alfalfa	8400.00	1386.00	142.00		2449.40	3184.40		
Rib	Milo	25200.00	3276.00	912.20		476.30	18076.00		
	Total	33600.00	4662.00	1054.20		2925.70	21260.40		
	Feces	8335.00	1484.50	290.10		1150.20	4790.10		
	Amount digested		3177.50	764.10	1719.20	1775.50	16470.30	23142.50	68.90
	Dig.coefficient		68.20	72.50		60.70	77.50		

Table 15. (Cont'd.)

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
79	Alfalfa	7000.00	1155.00	118.30		2041.20	2653.70		
Hip	Milo	21000.00	2730.00	760.20		396.90	16063.30		
	Total	28000.00	3885.00	878.50		2438.10	17717.00		
	Feces	7827.20	1502.00	318.60		1094.20	4323.70		
	Amount digested		2383.00	559.90	1259.80	1343.90	13393.30	18380.00	65.60
	Dig.coefficient		61.30	63.70		55.10	75.60		
31	Alfalfa	10500.00	1732.50	177.40		3061.80	3980.50		
Rib	Milo	31500.00	4095.00	1140.30		595.30	22594.90		
	Total	42000.00	5827.50	1317.70		3657.10	26575.40		
	Feces	11410.90	2246.80	587.70		1630.60	6096.80		
	Amount digested		3580.70	730.00	1642.50	2026.50	20478.60	27728.30	66.00
	Dig.coefficient		61.40	55.40		55.40	77.10		
11	Alfalfa	8000.00	1320.00	135.20		2332.80	3032.80		
Hip	Milo	24000.00	3120.00	868.80		453.60	17215.20		
	Total	32000.00	4440.00	1004.00		2786.40	20248.00		
	Feces	7128.90	1506.30	375.70		1164.10	3396.90		
	Amount digested		2933.70	628.30	1413.70	1622.30	16851.10	22820.80	71.30
	Dig.coefficient		66.10	62.60		58.20	83.20		
84	Alfalfa	10800.00	1782.00	182.50		3149.30	4094.30		
Hip	Milo	32400.00	4212.00	1172.90		612.40	23240.50		
	Total	43200.00	5994.00	1355.40		3761.70	27334.80		
	Feces	10402.40	1964.00	534.70		1621.70	5377.00		
	Amount digested		4030.00	820.70	1846.60	2140.00	21957.80	29974.40	69.40
	Dig.coefficient		67.20	60.50		56.90	80.30		

Table 15. (Concl.)

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
61	Alfalfa	10800.00	1782.00	182.50		3149.30	4094.30		
Hip	Milo	32400.00	4212.00	1172.90		612.40	23240.50		
	Total	43200.00	5994.00	1355.40		3761.70	27334.80		
	Feces	9923.10	1965.80	420.70		1703.80	5110.40		
	Amount digested		4028.20	934.70	2103.10	2057.90	22224.40	30413.60	70.40
	Dig.coefficient		67.20	69.00		54.70	81.30		
39	Alfalfa	10800.00	1782.00	182.50		3149.30	4094.30		
Rib	Milo	32400.00	4212.00	1172.90		612.40	23240.50		
	Total	43200.00	5994.00	1355.40		3761.70	27334.80		
	Feces	11540.60	2026.50	473.20		1836.10	6288.50		
	Amount digested		3967.50	882.20	1984.90	1925.60	21046.30	28924.30	66.90
	Dig.coefficient		66.20	65.10		51.20	77.00		
1	Alfalfa	10800.00	1782.00	182.50		3149.30	4094.30		
Rib	Milo	32400.00	4212.00	1172.90		612.40	23240.50		
	Total	43200.00	5994.00	1355.40		3761.70	27334.80		
	Feces	12185.70	2261.70	667.80		1647.50	6685.10		
	Amount digested		3732.30	687.60	1547.10	2114.20	20649.70	28043.30	64.90
	Dig.coefficient		62.30	50.70		56.20	75.50		
Total fed		438000.00	60772.50	13742.20		38139.20	277144.40		
Total digested			40177.60	8800.80	19801.80	21927.40	220518.10	302424.90	69.00
Digestion coefficient			66.10	64.00		57.50	79.60		

Table 16. Torula Utilis digestion study.

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
39	Alfalfa	12800.00	2112.00	216.32		3732.50	4852.50		
Hip	Milo	38400.00	3624.96	1167.36		591.36	29045.80		
	Total	51200.00	5736.96	1383.68		4323.86	33898.30		
	Feces	11199.40	2162.60	655.16		2046.10	5536.98		
	Amount digested		3574.36	728.52	1639.17	2277.76	28361.32	35852.61	70.02
	Dig.coefficient		62.30	52.65		52.67	83.66		
22	Alfalfa	12800.00	2112.00	216.32		3732.50	4852.50		
Hip	Milo	38400.00	3624.96	1167.36		591.36	29045.80		
	Total	51200.00	5736.96	1383.68		4323.86	33898.30		
	Feces	10625.60	2051.80	633.29		2112.37	4745.39		
	Amount digested		3685.16	750.39	1688.38	2211.49	29152.91	36737.94	71.75
	Dig.coefficient		64.24	54.23		51.15	86.00		
48	Alfalfa	12000.00	1980.00	202.80		3499.20	4549.20		
Rib	Milo	36000.00	3398.40	1094.40		554.40	27230.40		
	Total	48000.00	5378.40	1297.20		4053.60	31779.60		
	Feces	8522.20	1645.64	524.97		1502.50	4122.18		
	Amount digested		3732.76	772.23	1737.52	2551.10	27657.42	35678.80	74.33
	Dig. coefficient		69.40	59.53		62.93	87.03		
11	Alfalfa	6531.25	1077.66	110.38		1904.51	2475.00		
Rib	Milo	19593.75	1849.65	595.65		301.74	14820.71		
	Total	26125.00	2927.31	706.03		2206.25	17296.70		
	Feces	6486.80	1167.62	245.20		981.45	3583.96		
	Amount digested		1759.69	460.83	1036.87	1224.40	13712.74	17734.10	67.88
	Dig.coefficient		60.11	65.27		55.52	79.28		

Table 16. (Cont'd.)

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
79 Hip	Alfalfa	6900.00	1138.50	116.61		2012.04	2615.79		
	Milo	20700.00	1954.08	629.28		318.78	15657.48		
	Total	27600.00	3092.58	745.89		2330.82	18273.27		
	Feces	8381.70	1540.56	367.12		1487.75	4168.66		
	Amount digested		1552.02	378.77	852.23	843.07	14104.61	17351.89	62.87
	Dig. coefficient		50.19	50.78		36.17	77.18		
31 Rib	Alfalfa	12800.00	2112.00	216.32		3732.50	4852.50		
	Milo	38400.00	3624.96	1167.36		591.36	29045.80		
	Total	51200.00	5736.96	1383.68		4323.86	33898.30		
	Feces	13147.40	2383.62	404.94		1802.51	7716.21		
	Amount digested		3353.34	978.74	2202.17	2521.35	26182.09	34258.95	66.91
	Dig. coefficient		58.45	70.74		58.31	77.24		
11 Hip	Alfalfa	9500.00	1567.50	160.55		2770.20	3601.45		
	Milo	28500.00	2690.40	866.40		438.90	21557.40		
	Total	38000.00	4257.90	1026.95		3209.10	25158.85		
	Feces	9607.10	1705.26	398.69		1544.82	5157.09		
	Amount digested		2552.64	628.26	1413.59	1664.28	20001.76	25632.27	67.45
	Dig. coefficient		59.95	61.18		51.86	79.50		
84 Hip	Alfalfa	12800.00	2112.00	216.32		3732.50	4852.50		
	Milo	38400.00	3624.96	1167.36		591.36	29045.80		
	Total	51200.00	5736.96	1383.68		4323.86	33898.30		
	Feces	14189.50	2190.86	483.86		1996.46	8495.25		
	Amount digested		3546.10	899.82	2024.59	2327.40	25403.05	33301.14	65.04

Table 16. (Concl.)

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
61 Hip	Alfalfa	12800.00	2112.00	216.32		3732.50	4852.50		
	Milo	38400.00	3624.96	1167.36		591.36	29045.80		
	Total	51200.00	5736.96	1383.68		4323.86	33898.30		
	Feces	11316.20	2128.58	400.59		2061.81	5883.29		
	Amount digested		3608.38	983.09	2211.95	2262.05	28015.01	36097.39	70.50
	Dig. coefficient		62.90	71.05		52.32	82.64		
39	Alfalfa	6800.00	1122.00	114.92		1982.88	2577.88		
	Milo	20400.00	1925.76	620.16		314.16	15430.56		
	Total	27200.00	3047.76	735.08		2297.04	18008.44		
	Feces	6923.50	1142.38	244.40		1240.69	3779.54		
	Amount digested		1905.38	490.68	1104.03	1056.35	14228.90	18294.66	67.26
	Dig. coefficient		62.52	66.75		45.99	79.01		
1 Rib	Alfalfa	11500.00	1897.50	194.35		3353.40	4359.65		
	Milo	34500.00	3256.80	1048.80		531.30	26095.80		
	Total	46000.00	5154.30	1243.15		3884.70	30455.45		
	Feces	12196.80	2211.28	662.29		2018.57	6347.21		
	Amount digested		2943.02	580.86	1306.94	1866.13	24108.24	30224.33	65.71
	Dig. coefficient		57.10	46.73		48.04	79.16		
Total fed		468925.00	52543.05	12572.70		39600.81	310463.81		
Total digested			32212.85	7652.19	17217.43	20805.78	250928.05	321164.08	68.49
Digestion coefficient			61.31	60.38		52.54	80.82		

Table 17. Saccharomyces Cerevisiae digestion study.

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
39 Hip	Alfalfa	11200.00	1848.00	189.28		3265.90	4245.90		
	Milo	33600.00	3171.84	1021.44		517.44	25415.04		
	Total	44800.00	5019.84	1210.72		3783.34	29660.94		
	Feces	12305.50	2160.85	399.93		1514.81	7466.98		
	Amount digested		2858.99	810.79	1824.28	2268.53	22193.96	29145.76	65.06
	Dig. coefficient		56.95	66.97		59.96	74.83		
22 Hip	Alfalfa	11100.00	1831.50	187.59		3236.76	4208.01		
	Milo	33300.00	3143.52	1012.30		512.82	25188.12		
	Total	44400.00	4975.02	1199.89		3749.58	29396.13		
	Feces	11700.00	2121.25	403.66		1832.25	6533.39		
	Amount digested		2853.77	796.23	1791.52	1917.33	22862.74	29425.34	66.27
	Dig. coefficient		57.36	66.36		51.13	77.77		
48 Rib	Alfalfa	11200.00	1848.00	189.28		3265.90	4245.90		
	Milo	33600.00	3171.84	1021.44		517.44	25415.04		
	Total	44800.00	5019.84	1210.72		3783.34	29660.94		
	Feces	9909.76	2000.78	384.50		1538.99	5297.76		
	Amount digested		3019.06	826.22	1858.99	2244.35	24363.18	31485.58	70.28
	Dig. coefficient		60.14	68.24		59.32	82.14		
79 Hip	Alfalfa	8200.00	1353.00	138.58		2391.12	3108.62		
	Milo	24600.00	2322.24	747.84		378.84	18607.44		
	Total	32800.00	3675.24	886.42		2769.96	21716.06		
	Feces	9517.80	1487.63	432.11		1274.43	5680.22		
	Amount digested		2187.61	454.31	1022.20	1495.53	16035.84	20741.18	63.24
	Dig. coefficient		59.52	51.25		53.99	73.84		

Table 17. (Cont'd.)

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
11	Alfalfa	7700.00	1270.50	130.13		2245.32	2919.07		
Rib	Milo	23100.00	2180.64	702.24		355.74	17472.84		
	Total	30800.00	3451.14	832.37		2601.06	20391.91		
	Feces	6773.30	1130.46	211.33		681.35	4305.11		
	Amount digested		2320.68	621.04	1397.34	1919.71	16086.80	21724.54	70.53
	Dig. coefficient		67.24	74.61		73.81	78.89		
31	Alfalfa	11200.00	1848.00	189.28		3265.90	4245.90		
Rib	Milo	33600.00	3171.84	1021.44		517.44	25415.04		
	Total	44800.00	5019.84	1210.72		3783.34	29660.94		
	Feces	11267.10	2433.97	522.18		1943.18	8400.47		
	Amount digested		2585.87	688.54	1549.22	1840.16	21260.47	27235.72	60.79
	Dig. coefficient		51.51	56.87		48.64	71.68		
11	Alfalfa	8400.00	1386.00	141.96		2449.44	3184.44		
Hip	Milo	25200.00	2378.88	766.08		388.08	19061.28		
	Total	33600.00	3764.88	908.04		2837.52	22245.72		
	Feces	9338.70	1652.02	348.33		1327.03	5322.13		
	Amount digested		2112.86	559.71	1259.35	1510.49	16923.59	21806.29	64.90
	Dig. coefficient		56.12	61.64		53.23	76.08		
84	Alfalfa	11200.00	1848.00	189.28		3265.90	4245.90		
Hip	Milo	33600.00	3171.84	1021.44		517.44	25415.04		
	Total	44800.00	5019.84	1210.72		3783.34	29660.94		
	Feces	13374.10	1972.68	460.07		1854.99	8267.87		
	Amount digested		3047.16	750.65	1688.96	1928.35	21393.07	28057.54	62.63
	Dig. coefficient		60.70	62.00		50.97	72.13		

Table 17. (Concl.)

Steer No.	Ration	Total gm fed	Gm crude protein	Gm ether extract	X 2.25	Gm crude fiber	Grams N.F.E.	Total digested	Per cent T.D.N.
61	Alfalfa	10900.00	1798.50	184.21		3178.44	4132.19		
Hip	Milo	32700.00	3086.88	994.08		503.58	24734.28		
	Total	43600.00	4885.38	1176.29		3682.02	28866.47		
	Feces	10988.80	1964.80	409.88		1872.49	6586.69		
	Amount digested		2920.58	768.41	1728.92	1809.53	22279.78	28738.81	65.91
	Dig. coefficient		59.78	65.21		49.15	77.18		
39	Alfalfa	8400.00	1386.00	141.96		2449.44	3184.44		
Rib	Milo	25200.00	2378.88	766.08		388.08	19061.28		
	Total	33600.00	3764.88	908.04		2837.52	22245.72		
	Feces	10085.80	1644.99	331.82		1251.65	6169.48		
	Amount digested		2119.89	576.22	1296.49	1585.87	16076.24	21078.49	62.73
	Dig. coefficient		56.31	63.46		55.89	72.27		
1	Alfalfa	9400.00	1551.00	158.86		2741.04	3563.54		
Rib	Milo	28200.00	2662.08	857.28		434.28	21330.48		
	Total	37600.00	4213.08	1016.14		3175.32	24894.02		
	Feces	10228.60	1764.43	461.31		1351.20	5978.62		
	Amount digested		2448.65	554.83	1248.37	1824.12	18915.40	24436.54	64.99
	Dig. coefficient		58.12	54.60		57.45	75.98		
Total fed		435600.00	48808.98	11772.07		36786.22	288399.79		
Total digested			28475.10	7406.95	16665.64	20343.97	218319.07	283875.79	65.17
Digestion coefficient			58.34	62.92		55.30	75.70		

Table 18. Summary of yeast cell counts in feces.

Steer Number	Control*	Torula Utilis	Saccharomyces Cerevisiae
31 Hip	800	880	21800
11 Hip	600	360	4900
84 Hip	100	3200	6900
61 Hip	1100	2200	4800
39 Rib	100	490	5100
39 Hip	0	250	1730
22 Hip	1300	350	15300
48 Rib	1700	930	1820
11 Rib	1700	1440	5700
79 Hip	3400	6900	12800
1 Rib	1000	330	25100

* These counts were taken from undesignated steers.

STUDIES OF THE ADDITION OF VIABLE YEAST CELL SUSPENSIONS TO BEEF CATTLE RATIONS

by

OLLIE MONROE BOWMAN

B. S., Hampton Institute, 1951

AN ABSTRACT OF A THESIS

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Reports from livestock producers and certain representatives of the feed industry have suggested beneficial effects from the introduction of viable yeast preparations into ruminant rations. These reported effects included substantial increases in rate and efficiency of gain of cattle on either wintering and fattening rations. However, to date research workers at several experiment stations have observed no marked differences between the performance of ruminant animals fed rations without the addition of yeast. Thus to study this problem further, an experiment was designed to study the value of viable yeast cell suspensions in rations commonly used to winter and fatten cattle in Kansas.

Viable cell suspensions of Saccharomyces cerevisiae and Torula utilis were used in the two phases of this study. Each steer, whether on the wintering or the fattening ration received three billion viable cells per day. These suspensions were prepared weekly by the Bacteriology Department and were refrigerated at optimum temperature until used.

In the wintering phase of this study 40 head of choice Hereford steer calves were used. They were fed, daily, one pound of soybean oil meal, four pounds of ground milo grain, and sorgo silage ad libitum for 168 days. The calves were divided into four lots of ten each, based on uniformity in size and conformation. Lots one and two served as controls while lots three and four received three billion viable cells of Torula utilis and Saccharomyces cerevisiae respectively. Salt and minerals were

supplied ad libitum.

In the digestion phase of this study 11 yearling Hereford steers were used. They were fed ground milo grain and chopped alfalfa hay in a ratio of three to one. They were fed and watered twice daily, but received the viable yeast suspensions only at the morning feeding. The feces were collected each morning prior to feeding and watering for the seven day collection period. The fecal samples were placed in pans and kept under refrigeration until the collection period ended. After which time they were dried and chemical analyses were made by the Chemistry Department.

The results obtained from the wintering phase showed that the addition of three billion viable cells of Torula utilis or Saccharomyces cerevisiae to the basal ration resulted in no significant increase in average daily gains or feed efficiency for the 168 day feeding period.

In the digestion trial the two species of yeast, which were fed at the same level as in the wintering ration, produced no significant differences in nitrogen-free-extract, total digestible nutrients, ether extract or fiber. However, a significant decrease in protein digestion was observed.