THE USE OF AUTOLYZED LIQUID BREWERS YEAST AND BREWERS' WET GRAINS AS A SOLE SOURCE OF SUPPLEMENTAL PROTEIN FOR DAIRY HEIFERS

By

Edgar Omar Bautista

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Dairy Science

1978

ABSTRACT

THE USE OF AUTOLYZED LIQUID BREWERS YEAST AND BREWERS' WET GRAINS AS A SOLE SOURCE OF SUPPLEMENTAL PROTEIN FOR DAIRY HEIFERS

by

Edgar Omar Bautista

Studies were conducted during the summer of 1977 to determine the feeding value of liquid brewers yeast and brewers' wet grains as a sole source of supplemental protein. Five groups of ten Holstein heifers were fed during a period of 90 days one of the following rations: positive control 11.5% C.P.; low level of yeast 11.0% C.P.; high level of yeast 13.1% C.P.; brewers' wet grains 12.4% C.P.; and negative control 8.5% C.P.

Values for rumen fluid ammonia and VFA, plasma urea and plasma glucose were not affected by the different rations. It was found that autolyzed liquid brewers yeast can be used as a sole source of supplemental protein in a ration 13.1% C.P. Heifers in this ration gave as good or better performance than heifers in the positive control ration, when soybean meal was used as a sole source of protein in a ration containing 11.5% C.P.

To my Wife, **Cecilia**, who generously encouraged
me during my studies,

To my Son Omar

To my Daughter Erika

ACKNOWLEDGMENTS

The author extends his sincere appreciation to his major professor, Dr. Robert M. Cook, for his guidance, and encouragement throughout the pursuit of this degree.

Sincere appreciation is extended to Dr. J. William Thomas for his valuable assistance during the trial. The author is grateful to Dr. Roger Neitzel for his valuable assistance of the computer analysis, and Dr. John Gill for his assistance in the statistical design.

Thanks are extended to Laurie J. Allinson, Carlos Godoy and Bill Neppach for their help in feeding the cattle, and Bill Wheeler for his assistance in technical analysis.

This work was made possible by a grant from the Stroh Brewery Company. The author's graduate studies at Michigan State University were financed by the Foundation "Gran Mariscal de Ayacucho" of the Republic of Venezuela.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

INTRODUCTION

As a large processor of farm-grown grain, the brewing industry is an important source of income for the farmer. By converting its by-products into feed ingredients, it fully utilizes this grain without waste. In fact, approximately 25% of the grain by volume and a much higher percentage by nutritive value is returned to the farm in the form of feedstuff with properties and nutrients not possessed by the raw grain. Water soluble vitamins and other nutrients are developed in the barley during germination, while the proteins are modified into more readily assimilable and, therefore, more efficient nutrients for animal feeding, (Anonymous, 1950).

In the United States all brewers yeast are strains of the genus Saccharomyces cerevisiae, a single-cell, egg shaped microorganism consisting of an outer membrane which protects the protoplasm in the cell and its constituents. This membrane is of selective permeability and plays an important part in the nutrition of the yeast cell as well as in the assimilability of its nutrients, (Anonymous, 1950).

Brewers yeast represents the richest natural source of the highly important vitamins of the B-complex group. It contains ergosterol or pro-vitamin D, which upon irradiation with ultra-violet rays, is transformed into vitamin D. Brewers yeast is also an important source of proteins of high biological value and of minerals such as phosphoric acid, potassium, magnesium, calcium, and iron, (Fischer, 1944).

The use of brewers yeast in veterinary medicine antedates the discovery of vitamins. The application of yeast was exterior for the treatment of eczema, as well as internal as a purgative, as a preventive of hoof and mouth disease and distemper in dogs, (Fischer, 1944).

The National Academy of Sciences (1971) defined brewers' grains as the course, insoluble residue from brewed malt, and calssified them as protein supplements.

It is apparent that brewers dried grains contribute a wide variety of essential nutrients which are considered in feed formulations for livestock and poultry rations. Brewers dried grains contribute primarily to the protein, amino acid, and energy content of feeds when this ingredient is used in formulation. The ingredient also furnishes trace minerals, B-vitamins and vitamin E.

Linoleic acid in brewers' dried grains can furnish a significant percentage of this essential fatty acid for poultry and swine, (Couch, 1976).

The objective of the work in this thesis was to determine the feeding value of liquid brewers yeast and brewers' wet grains as a source of natural protein, when compared with soybean meal which is the standard source of supplemental protein in most dairy cattle rations.

LITERATURE REVIEW

Brewers' Grains in Animal Feeding

Limited investigations on wet brewers' grains indicate that this product varies in nutrient composition, particularly in the moisture, copper and calcium content. The variable copper content is probably related to the type of tank lining in which the beer is prepared or to some other source of contamination in the manufacturing plant. The calcium level is determined largely by the calcium content of the water used by a particular brewery producing the grains, (Maclean, 1969).

Spoiled wet brewers' grains can cause serious health problems when fed to animals. Oleas, (1977) recommends the use of propionic acid at the level of 2% or a mixture of formic acid (1.4%) and paraformaldehyde (0.1%) in order to avoid spoilage of wet brewers' grains when stored in silos.

Some research on the nutritional value of brewers' grains for livestock has been conducted.

Chickens

Ademosun, (1973) found in growing chickens that increasing levels of brewers dried grains (BDG) resulted in significant increase in food intake. He also found that both the control diet (21.9% C.P.) and the 10% BDG diet (22.3% C.P.) supported a similar growth rate. However, higher levels of BDG in the diet significantly reduced growth rate.

Couch, (1976) reported that BDG can be used at a level as high as 40% in commercial layer rations. Fertility and hatchability were improved when BDG were included in breeder and in turkey breeder rations.

Eldred et al (1975 b) showed that cumulative egg production was significantly improved by the addition of 5% BDG to the diet. The addition of 10% BDG and 5% BDG plus yeast to the diet containing 0.528% sulfur amino acids significantly improved egg weights. The addition of 10% BDG or 10% BDG plus yeast to any diet resulted in a numerical increase of Haugh units when compared to the 5% level of ingredients.

Eldred et al (1975 a) found that the presence of 10% BDG in diets containing 0.470% sulfur containing amino acids resulted in a significant decrease in egg weights.

Some studies indicate that the inclusion of up to 10% BDG or a grain-yeast mixture in the diet is acceptable to the laying hen if the diet formulation is based on the nutrient composition of BDG (Damron and Harms, 1973 and Eldred et al 1975 a).

Pigs

Young and Ingram, (1968) found that there was a consistent decrease in average daily gain as the level of BDG in the diet supplied, from 50 to 100% of the supplemental protein in a corn-based diet for market hogs. They also indicate that BDG may supply up to 50% of the supplemental protein in a swine diet based on corn, without affecting rate of gain or carcass quality.

BDG were reported to replace all of the soybean meal without significantly reducing reproductive performance, (Harmon et al 1975).

Wahlstrom and Libal, (1977) found that sows fed 20% BDG gained more and those fed 40% BDG gained less than control sows when all were fed diets calculated to be equal in energy and lysine content. The data reported showed that reproductive performance was very acceptable when either 20 or 40% of the total diet was BDG.

Ademosun, (1976) stated that the high crude fibre content of the diets containing BDG has been responsible for low feed digestibility and; therefore, poor performance in terms of average daily weight gain or the quantity of feed required per unit of gain in finishing pigs. In one trial with pigs back-fat thickness and percent ham and loin decreased as the levels of BDG increased in the test rations.

Rabbits

Omole and Ajayi, (1976) fed white rabbits with diets containing 0%, 15%, 30% or 45% BDG. BDG significantly improved food consumption in all the treatments, but the 30% and 45% BDG significantly depressed efficiency of feed utilization. While the 15% dietary BDG gave the highest rate of growth, the 45% dietary BDG treatment depressed daily body gains. Kidney fat significantly increased with increases in BDG levels of the diets. Dietary levels of BDG did not seem to have any significant effect on the weight of offals, skin and dressing value.

Cattle

Preston et al (1973) improved feedlot performance by adding brewers grains to the rations of finishing cattle at either the 25 or 50% level. Problems associated with rumen keratosis when a high corn ration was fed were overcome by feeding brewers grains; liver abscesses were also markedly reduced. The net energy value of brewers grains was nearly the same as corn grain.

Loosli and Warner (1958) showed that cows receiving BDG produced more milk and more fat-corrected milk than those on the low-protein diet. They also gained more weight. In the same trial urea apparently was not as efficient as the nitrogen in BDG for milk yield or weight gain.

Griffiths, (1971) working with dairy heifers found that levels of total fatty acids were depressed by the introduction of BDG to diets containing hay and BDG and BDG containing 5% molasses plus silage. Addition of BDG to either hay or silage depressed the digestibility of the total dry matter in the diet, but increased the digestibility of the oil fraction. In these experiments an increasing percentage of grains in the diets was associated with a decreasing calcium retention, which suggest that calcium supplementation is desirable, particularly for lactating animals. An extensive review of published reports show that BDG can be used effectively in dairy rations in levels ranging from 30-40% of the grain mixture, (Couch, 1976).

Trials performed at Cornell University showed that BDG was an excellent source of protein for the lactating cow and was superior to urea, (Couch, 1976).

Hatch et al (1972) found that the effects of adding a mixture of 95% BDG and 5% brewers dried yeast as 5% of a semipurified, high-urea type ration for hereford steers produced significantly increased nitrogen retention. There was also decreased rumen ammonia and plasma urea concentrations. These results point to increase urea utilization and its conversion to animal protein.

Yeast in Animal Feeding

Yeast was formerly evaluated according to its fermentation power. It was assumed that a yeast which had retained its ability to ferment had also retained unchanged all of its other characteristics. It was overlooked, however, that in the living yeast cell reciprocal activities occur among the very labile and unstable substances. These activities continue during the storage of living yeast, with the result that the uninterrupted activities of the fermentative and other enzymes bring about a degradation or even destruction of primary cell constituents. Live yeast has no advantage over dried dead yeast from a therapeutic view point. With proper drying of live yeast vitamin losses do not occur. It should also be mentioned that the animal organism can utilize only 60% of the living yeast cells, while dried dead yeast is completely utilized. It should be noted that the enzyme zimase is damaged by the digestive enzymes and consequently is without effect in metabolism, (Fischer, 1942).

Chickens

Balloun and Khajarern, (1974) reported that dried brewers'

yeast did not improve feather meal protein utilization in poults. Yeast levels of 2.5 and 5.0% caused no significant effect on weight gain or feed utilization, nitrogen retention or protein digestibility.

Waldroup et al (1971) observed that broiler chicks fed diets with hydrocarbon yeast protein at levels of up to 15% in all mash-diets or up to 25% in pelleted diets grew as well as chicks fed the basal diet with no yeast (29.75% soybean meal). When the experimental diets were offered to the chicks on an ad libitum basis, there were no significant differences in body weight gains, average feed intake, or feed:gain ratios between chicks fed the diet with no yeast and those fed the diet with 15% yeast protein. It seems that the problems associated with high level feeding of hydrocarbon yeast protein are due primarily to problems associated with feed intake, such as appearance, dustiness, or other factors.

Waldroup and Hazen, (1975 b) found that the rate of egg production of hens fed diets containing up to 15% yeast derived from high pure alkane fractions was equal or superior to that of hens fed either an all-vegetable corn-soybean meal diet or a diet containing 5% peruvian fish-meal.

Waldroup and Flynn, (1975 a) observed that chicks fed the diet containing the reference soybean protein had significantly greater body weight gain, consumed more nitrogen, and had superior nitrogen efficiency ratios and net protein utilization scores than chicks fed

any of the diets containing yeast grown on hydrocarbon feed stocks under varying processing conditions. Significant differences were observed among the various yeast samples indicating that the conditions under which these organisms are grown or stored may influence their subsequent nutritional value. Thus, standardization of processing and storage conditions should be established for the production of yeast grown on hydrocarbon fractions to obtain maximum nutritional value. Short-term experiments with poultry have consisted of evaluating various levels of both gas oil and n-alkane grown yeast, ranging from 7.5 to 15% of the rations for broiler birds. The general finding is that levels of yeast up to 10% of the diet are invariably satisfactory. Above this level, results are somewhat variable as they are for fish meal, (Shacklady, 1972).

Van Weerden and Shacklady, (1970) working with hydrocarbon grown yeast in rations for chicks found that growth rates of chicks were not adversely affected until the percentage of the L-type yeast reached 15% in contrast to the poorer growth rate observed when similar amount of torula yeast were fed. General results indicate that, 7.5% and possibly 10% of L-type yeast may be used to replace fish meal of equivalent protein content on a weight basis in the rations of broilers.

Beck and Gropp, (1974) reported that alkane grown yeast can be used in quantities of 10% in broiler rations and 20% in rations for laying birds.

Tiews et al, (1974) found that both the alkane grown yeast Lavera and Toprina supplemented with methionine could replace effectively fishmeal or soybean oil meal in diets for broiler chicks when used at about 15% of the diet.

Shannon et al, (1972) studying the effect of a n-paraffin grown yeast plus methionine on the growth and food intake of broiler chicks at 4 and 8 weeks of age found that the broiler chicks on the 20% yeast diet gained significantly less body weight than those on the control, 5 or 10% yeast diets at 4 and 8 weeks of age. At 8 weeks of age chicks fed the 5% yeast diet weighed significantly more than chicks fed any of the other diets. Food intake was significantly higher for birds given 10% yeast than for birds receiving the control diet at 4 weeks of age or the 20% yeast diet at 4 and 8 weeks of age.

Paliev et al, (1972) found broilers averaged 1300g when 8 weeks by feeding a well-balanced mash composed of 18% torula yeast plus 16% fishmeal plus 44% of raw sugar, or 14% of torula yeast plus 13% of fish meal plus 52% yellow corn.

Yoshida et al, (1972 a), (1974 b), (1974 c), (1974 d) and (1975 e) observed in a multigeneration feeding experiment of hens fed either a control diet or a diet containing 15% of yeast grown on n-paraffin that there was a consistent trend of slower growth with less feed intake for chicks fed the yeast diet in all of the five generations. These authors suggest that the delay in growth of the chicks on the yeast diet was mainly due to the unbalance of nutrients in the yeast diet.

Yoshida et al, (1972) obtained excellent viability during growing and laying stages, high egg production with good feed conversion, normal egg size and adult body size, high fertility and hatchability when a diet containing 15% of hydrocarbon yeast was fed to chicks.

Fertility of the yeast group of the fourth and fifth generations and hatchability of fertile eggs of the yeast group of the fourth generation were higher and that of the fifth generation was lower than those on the control diet. The egg production and feed conversion by hens from the third generation fed a diet containing 15% of yeast grown on n-paraffin were higher than that on the control diet. Daily feed intake, average body weight, egg weight, fertility and hatchability were similar between those fed the yeast diet and the control group, (Yoshida et al 1974).

Yoshida et al, (1975 e) observed that feed conversion and viability during the growing stage was almost identical between the hens on both the yeast and control diets. Both fertility and hatchability of fertile eggs was better on the yeast diet than those on the control diet. In the same trial no evidence was obtained indicating that the yeast contained a large quantity of heavy metals and polycyclic aromatic compounds to be injurious to human health through the meat and egg produced by the yeast feeding.

Yoshida, (1974) showed during a test panel integrated for 116 people that the difference in the flavor of both meat and eggs from

hens fed either the control or yeast diet was so small that most of the people could not distinguish one from the other.

Pigs

Veum and Bowman, (1973) determined the effects of supplementing the diets with Saccharomyces cervisiae yeast culture (S.C.Y.C.) as measured by the performance of piglets fed individually. At the 1.5 or 2.0% level S.C.Y.C. fed from 20 to 23 days of age did not produce any significant effect on the average daily gain and gain/feed of the piglets compared to the control diet. S.C.Y.C. fed at the 2.5% level from 2 to 23 days of age significantly depressed performance of the piglets compared to the control and 1.5% S.C.Y.C. diets. S.C.Y.C. fed at 1.5, 2.0 or 2.5% of the diet from 23 to 65 or 72 days of age did not have any significant effect on the performance of the pigs.

Bowman and Veum, (1973) showed that the supplementation of swine diets with 2.0 or 1.5% S.C.Y.C. from 14 to 34 kgs. or 34 to 100 kgs. respectively did not significantly affect the performance or carcass characteristics of swine.

Beck and Gropp, (1974) reported that 15, 20, and 10% of the yeast can be incorporated in rations for piglets, growing-fattening pigs and breeding sows, respectively without negative effects.

Février et al, (1973) showed that 13% sulphite yeast or 25% yeasted-whey could replace 16.20% of the soybean meal in the ration for growing-finishing pigs.

Barber et al, (1971) concluded that, in general, paraffin-grown yeast plus methionine and white fish meal are equally effective as protein supplements in cereal-based diets for growing pigs.

Pigs fed barley meal plus yeast grown on hydrocarbon has as good a growth rate and feed conversion as pigs fed barley plus fish meal.

There was a trend for the treatment in which half the protein added was from fish meal and half from yeast to give a better daily live weight gain and better food conversion, (Kneale, 1972).

Rats

There were neither deleterious effects of feeding rats on diets containing up to 30% of yeast grown on gas-oil or yeast growing on pure n-paraffins as long as 1 year nor on rats fed diets containing up to 30% of yeast grown on gas-oil for a 2 year period (Groot de, et al., 1970 a, b, and c).

Yeast grown on gas-oil diets had no effect on mortality, general condition or behaviour of the animals. Haematological values were not affected, liver and kidney function tests showed no unfavorable effects. There were no significant changes in the weight of the major organs nor in the gross and histological appearance (Groot de, et al, 1970 a and c).

Sheep

Lambs receiving the ration containing yeast as a source of unidentified factors stimulatory to cellulose digestion in the rumen

consumed 2.24 lb. of feed daily per lamb and made daily liveweight gains of 0.21 lb. compared with 1.58 lb. of feed consumed and 0.05 lb. daily gain made by lambs not receiving yeast (Ruf, et al., 1953).

From preliminary experiments, dried "fodder yeast" given as a supplement in relatively small quantities (about 3% of dry matter of the diet), greatly increased the utilization of poor quality hay (0.73%N) as measure by the hay intake and steady gain in the body weight, (Thomson and Tosic, 1949).

Cattle

Mimura et al., (1973) showed that cattle fed hydrocarbon grown yeast as a substitution for fish soluble, fish meal and soybean meal had carcass grades which were a little higher than those of the control group. The cattle here was in good health throughout the experiment. There were no abnormalities in urine or internal organs. Results indicated that hydrocarbon grown yeast may be substituted for fish or soybean meal.

Two different alkane yeast meal preparations (particle size 50 or 200 microns) plus methionine, or soybean meal plus methionine were incorporated into a milk replacer for calves to provide 70-75% of the total protein. The live weight gains obtained with the diet containing yeast particles of 50 microns were satisfactory, whereas they were unsatisfactory with the other two diets (Parvelle et., 1972).

Skimmed milk powder was replaced by 5.0, 7.5 and 10% alkane-yeast in isonitrogenous and isocaloric milk replacer diets for male

calves. Weight gains and feed conversion were unfavorable influenced by 10% alkane yeast in the diet. There were no differences between treatments in carcass grading or serum urea content at the end of the experiment, (Kirchgessner and Roth, 1973).

Beck and Gropp, (1974) reported that in calf rearing 20% skim milk powder could be replaced by 10% of toprina yeast plus 10% of whey powder.

Hereford steers approximately 10 months old were used in a series of three digestion and nitrogen balance trials. In these studies, nitrogen retention expressed either as a percentage of the intake or as a percentage of the digestible nitrogren was not improved significantly by addition of the live-yeast cells to low quality roughage, high quality roughage or fattening rations, (Legendre, 1957).

Lifestock sometimes consumes high levels of nitrates from high-nitrate water or feed such as drouth-stricken, high-nitrate silage. According to the University of Missouri (Feedstuffs, 1977), a yeast culture that has been termed a "lifesaving" feed ingredient will counteract the effect of nitrate poisoning.

Baker et al, (1955) and Richardson et al, (1956) working with live yeast suspensions of Torula utilis and Saccharomyces cerevisiae feeding fattening rations for beef cattle found that the rate of gain and feed efficiency were essentially the same for the yeast groups as for the control group, the same results were found when

the digestibility of the rations were determined.

Richardson et al. (1956) working with live yeast suspension of Torula utilis and Saccharomyces cerevisiae in beef cattle rations showed that animals that had been fed yeast did not gain as well as those that did not receive yeast during the grazing phase of the experiment. Also animals receiving Torula utilis did not gain so well in the fattening phase as the others. The workers concluded that the addition of live yeast suspensions (3 billion live yeast cells/head/day) to beef cattle rations is not desirable.

In Canadian experiments brewers' dried yeast equalled linseed meal for dairy cows. In Hawaiian trials, dried yeast fed as 25 to 35% of the concentrate mixture for dairy cows gave as nearly as good results as soybean oil meal, (Morrison, 1957).

In summary, most of the research using yeast and brewers' grains have been done in chickens, pigs, rats, sheep and cattle. Workers have used hydrocarbon yeast, brewers yeast and brewers' grains in their experiments. Results indicate that both yeast and brewers' grains can be used in animal feeding without causing any negative effect on the productive life or health of the animal. More research needs to be performed on the toxic effects of people consuming products from animals which have been fed with yeast grown on pure n-paraffins.

EXPERIMENTAL PROCEDURE

The experiment was conducted at the Michigan State University's dairy farm, from July 23 to October 21 of 1977. The objective was to test autolyzed liquid brewers' yeast and brewers' wet grains as a supplemental protein source in corn silage rations for dairy heifers.

Experimental Design

Fifty Holstein heifers from 10 to 22 months of age and from 827 to 940 lb. of body weight were assigned in ten blocks of five animals each (one animal per treatment per block) in a complete block design with three covariates. The heifers were blocked by breeding group and the covariates were: age of the heifers, days of pregnancy at the beginning of the experiment and initial body weight of the heifers. There were 16 pregnant heifers at the beginning of the experiment and 24 at the end of it. According to the breeding group* there were four blocks catalogued as Worst, four as Best and two as Control.

Treatments

The experiment consisted of five treatments with ten heifers each. The treatments were designed to consist of five rations as follows:

---

* M.S.U. Dairy Farm participates in a project where the sires are classified into three groups termed Control, Worst and Best according to the predicted differences in milk (PD milk). Offspring are also classified according to these three groups of sire which artificial inseminates or mate them.

1. Positive Control. 12.0% crude protein (C.P.) from corn silage and soybean meal.
2. Negative Control. 8.5% C.P. from corn silage.
3. Autolyzed liquid yeast. 12.0% from corn silage and liquid yeast.
4. Autolyzed liquid yeast. 14.75% C.P. from corn silage and liquid yeast.
5. Brewers' wet grains (B W G). 12.0% C.P. from corn silage and B W G.

After the analysis for crude protein and dry matter were done on each of the rations the crude protein content for the treatments were as follows: (Table 1)

1. Positive Control. 11.5% C.P. from corn silage and soybean meal.
2. Negative Control. 8.5% C.P. from corn silage.
3. Autolyzed liquid yeast. 11.0% C.P. from corn silage and liquid yeast.
4. Autolyzed liquid yeast. 13.1% C.P. from corn silage and liquid yeast.
5. Brewers' wet grains. 12.4% C.P. from corn silage and brewers' wet grains.

All rations were balanced for calcium and phosphorus at a ratio of 1.5 : 1. The crude protein is expressed on a dry matter basis.

Feeding and General Mangement

The live liquid yeast was autolyzed by steam at 140° F for four hours. Immediately after this process the autolyzed liquid yeast was transported in 55-gallon metal drums from Stroh Brewery in

Detroit, Michigan to M.S.U. dairy farm where they were kept under roof. The liquid yeast was stored in the drums for varying lengths of time up to 15 days.

The brewers' wet grains from Stroh Brewery were also stored in drums for the same period of time as the yeast. There was no spoilage of yeast when stored for 15 days as observed by its physical aspect and odor, but there was some spoilage of brewers' wet grains during the same period of time.

Four groups of 10 dairy heifers were located at the dairy heifer barn and the fifth group (negative control) was located at the loose housing barn. Of the four pens at the dairy heifer barn two had doors allowing access to exercise pens outside. Therefore, the heifers in the pens with doors were changed to the pens without doors at about every fifteen days in order to remove variation due to arrangement of pens. The animals were given water and blocks of trace mineral salt ad libitum. The rations were prepared daily using a mixer wagon.* The rations were balanced with calcium and phosphorus at a ratio of 1.5 : 1, using defluorinated rock phosphate and limestone. The rations were balanced in all ingredients each time that the heifers were weighed. The heifers were fed once a day. The amount of the ration fed was calculated on a dry matter basis at a 2.0-2.3% of body weight plus 10% excess. In this way the heifers always had feed available.

---

* Ensilmixer trailer mount Model 180-H. Oswalt Division. Butler Manufacturing Company.

Sample Collection

The amount of feed offered to each group of heifers and the amount refused was weighed and recorded every other day in order to determine feed intake. During the first 45 days of the trial there was an innaccuracy in the scale on the mixer wagon. The values for average daily feed intake and efficiency of gain during this period are estimated from these innaccurate weights.

All the heifers were weighed at 15 to 19 days intervals. Blood and rumen fluid samples were taken monthly from five randomly selected heifers from each treatment. Blood was sampled from the coccygeal vein and the rumen contents were sampled by stomach tube and strained immediately through four layers of cheesecloth prior to placement in an icebath. At the time of sampling, rumen fluid was also prepared for ammonia determinations by adding 2 ml. rumen fluid to 1 ml. 10% sodium tungstate followed by the addition of 1 ml. of 0.1 N H_2SO_4. Feed samples were taken every other day from each ration and the ingredients of the rations and composites of the samples were made at two week intervals and analysis performed on each composite.

Analytical Methods

Approximately four hours after sampling, whole blood was centrifuged at 8500 x g(0-5C) for 20 minutes, then the plasma was separated and stored in a freezer until analysis for plasma urea and blood glucose. Plasma urea and rumen ammonia were determined as described by Okuda (1965) and Kulasek (1972). Blood glucose was

determined using a modified glucose oxidase method (Anonymous, 1972) where plasma was deproteinized using a 2% $ZnSO_4$ and 1.8% $B_2(OH)_2$ solutions previously titrated to equivalency. Three milliliters of glucostat reagent was added to 0.5 ml. of the protein-free supernatant. The reaction was allowed to proceed for 45 minutes at 37°C and stopped by adding 1 ml. of 0.1 N HCl. Absorbance was determined at a wavelength of 400 nm using a Coleman Junior II Spectrophotometer model 6/20.

Upon arriving in the laboratory about four hours after sampling, ice cold rumen fluid samples were brought to room temperature and the pH was measured. The samples were then centrifuged at 15,000 x g(0-5C) for 15 minutes. The supernatant was stored in a freezer until analysis for volatile fatty acids. Rumen ammonia nitrogen was determined in fresh samples within 18 hours of sampling.

Volatile fatty acids (acetic, propionic, iso-butyric, butyric, 2-methyl butyrate, isovaleric and valeric) were measured by using a Hewlet-Packard gas liquid chromatograph model 5730 A with flame ionization detector. A glass column (6 ft. x 2 mm ID) was packed with 3% carbowax 20M, 0.5% H_3PO_4 on 60/80 carbopack B (Supelco, Inc. 1-1825). Nitrogen was the carrier gas at a flow rate of 60 ml/min. The temperature program used was 2 minutes beginning at 140°C with a temperature increase of 4°C per minute, and finally 180°C at 16 minutes. Prior to the injection the samples were acidified with two drops of 9N H_2SO_4. Injection volume was 3 microliters. Concentrations were computed and printed using the

Hewlet-Packard 3380 A integrator and the external standard method. Total nitrogen was determined on the wet samples using the macro Kjeldahl method (A.O.A.C., 1965). Copper sulfate was used as the catalyst. Nitrogen readings were made using an ammonia electrode model 95-10. Dry matter was determined by drying samples in an oven at 105°C overnight.

Statistical Analysis

Analysis of variance for a completely randomized block design was calculated for body weight, blood glucose, plasma urea, rumen ammonia, volatile fatty acids and rumen pH after 90 days trial. Means were compared using Tukey's test. Body weight was analyzed using three covariates in order to adjust for differences in age of the heifers, days of pregnancy and initial body weight.

The daily feed intake (Table 2) was determined using the weigh-back determined every other day. There were 39 weigh-backs during the whole experiment. These weigh-backs were a total for each treatment. It was not possible to measure feed intake for individual heifers. For the statistical analysis the dates when the weigh-backs were taken were used as blocks and the rations as treatments. Thirty nine blocks and 5 treatments were used. This is not a proper statistical analysis for feed intake. This analysis compares on effect of time rather than on effect of treatment or intake.

The dry matter intake per gain (Table 2) was determined using the dry matter percentage of the different rations. The average daily feed intake value was multiplied by the percentage of dry matter in the ration and the resulting value was divided by one hundred. This last value was divided by the average daily gain. This gives an accurate measure of efficiency but the data can not be statistically analyzed.

RESULTS AND DISCUSSION

For purposes of discussion the 11.0% and 13.1% Crude Protein (C.P.) rations containing autolyzed liquid yeast will be called low yeast and high yeast respectively and the 12.4% C.P. ration containing brewers' wet grains will be called B.W.G.

The data were analyzed for the following treatments: a) Positive Control (SBM), b) Low Yeast, c) High Yeast and d) B.W.G. The Negative Control group was not analyzed because of withdrawal of seven heifers out of ten for exhibition purposes at M.S.U. during the last week of the trial. It was felt that the final body weights for the negative control group were not representative of the experimental treatment. Therefore, the final body weights for this group were calculated using a linear regression equation based on all previous weights during the trial.

Average body weight gains indicate that heifers in the high yeast diet gained significantly ($P<0.05$) more than heifers in both the low yeast and BWG diets, 2.43 vs. 1.91 and 1.92 lb/day respectively, (Table 2). There was no significant difference between any group and the positive control group (SBM).

Differences in body weight gain between the positive control group and both the low yeast and BWG groups were not significant ($P<0.05$). The average body weight gain of heifers in the low yeast and BWG groups was identical, (1.92 lb/day). The projected weight gain for the negative control group was the lowest of any

of the treatments. This indicates that autolyzed liquid yeast when fed at the higher amount (15.7 parts yeast to 84.3 corn silage)was as good or better than SBM and much more efficient as a protein source than BWG and the low amount of autolyzed liquid yeast.

Although there was no significant difference between the high yeast diet and the positive control, heifers fed the former gained an average of 22.9 lb. more than heifers fed the latter diet. The high yeast group gained an average of 46.0 lb. more than heifers fed either the low yeast or the BWG diets, and an average of 52.5 lb. more than heifers in the negative control group. These results (Table 2) indicate the value of the brewers yeast as a supplement to corn silage. Similar possibilities may exist for yeast as a feed for finishing beef cattle and possibly for milking cows.

Analysis of Variance for body weight at 90 days (Table 16) shows that the three covariates; age, body weight and days of pregnancy at the beginning of the experiment did not affect significantly the body weights within treatments. The differences among heifers in initial body weight, age and days of pregnancy at the beginning of the trial did not affect significantly the final body weights of the heifers within treatments at the end of the trial. The superior nutritive value of the high brewers yeast ration may be demonstrated by comparing the differences in average daily gains among treatments (Table 2). Heifers in the high yeast

diet gained 0.26, 0.52, and 0.51 lb/day more than positive control group (SBM), low yeast and BWG diets respectively. This improvement in gain would represent a major economic advantage for the beef industry, specially during the finishing period.

Average daily feed intake (Table 2) indicates that there were significant differences among treatments. Daily intake for the positive control diet was significantly lower ($P<0.01$) than intake for the high yeast diet and BWG diet. This difference in intake may be because the dry matter for the high yeast diet (29.9% DM) and for the BWG diet (32.7% DM) was lower than the positive control diet (37.0% DM) (Table 3). There was a significant difference ($P<0.05$) in daily feed intake between the positive control and the negative control group (Table 2). Heifers fed the high yeast diet tended to consume less feed during the first two weeks of the trial. This indicates that an adaptation period of about two weeks is required to obtain maximum intake when this amount of liquid yeast is fed. After this period of adaptation, the heifers did not reject the liquid yeast diets even when the high yeast ration was very wet. The high yeast diet tended to have some mold and unpleasant odor when residues of feed were left in the feeder from the day before.

Feed efficiency measurements (Table 2) show that brewers yeast at a level of 13.1% C.P. was more efficient than SBM, BWG or the same brewers yeast used at a level of 11.0% C.P. The feed conversion

values ranked from low to high are as follows: high yeast, SBM (positive control), low yeast, BWG and negative control. Actual values being 7.52, 8.58, 9.51, 9.90 and 11.18, respectively.

Table 3 shows the percentage of crude protein which each feed ingredient contributed to the ration. For the positive control, 63% of the C.P. came from corn silage and 37% from SBM. For the high yeast diet, 51% of the C.P. came from corn silage and 49% from autolyzed brewers yeast. Since SBM contributed less protein to the diet than did high yeast diet and since there were no significant differences between these two treatments, may be that the protein in SBM is utilized more efficiently than the protein from yeast. For the low yeast diet, 66% of the C.P. came from the corn silage and 34% from brewers yeast. This further supports the hypothesis that brewers yeast is less efficient than SBM (Table 3). In general for brewers yeast to be as efficient as SBM in a corn silage ration that has 11.5% C.P., the yeast must contribute 49% of the C.P. in a ration that is 13.1% C.P.

Brewers yeast protein was utilized more efficiently than protein from BWG (Table 3), even when brewers yeast contributed 34% of the total protein in the low yeast ration (11.0% C.P.) as compared with 45% of the total protein contributed by BWG (12.4% C.P.). These results agree with other work showing that protein from SBM is more digestible and better utilized for ruminants than protein from brewers yeast or BWG, (The National Academy of Sciences).

There was not a significant difference in rumen ammonia levels among treatments at days 0 and 90 of the trial, but there were significant differences among treatments at days 30 and 60 of the experiment (Table 4).

At day 30, (Table 4) rumen ammonia levels from heifers in the high yeast diet were significantly greater ($P<0.05$) than levels from heifers in the negative control diet (5.6 vs. 2.2mg% $N\text{-}NH_4$). The other comparisons were not different. At day 60, rumen ammonia levels from heifers fed the positive control, high yeast and BWG were not significantly different. Rumen ammonia levels from the positive control group were significantly greater ($P<0.01$) than the low yeast and negative control diets. Rumen ammonia concentrations from the high yeast diet were significantly greater ($P<0.01$) than levels from the negative control group (7.5 vs 2.9mg% $N\text{-}NH_4$). There was a significant difference ($P<0.05$) between values from heifers fed the positive control diet and the BWG diet.

The differences among treatments observed at day 30 and 60 of the experiment were not consistent throughout the whole trial. In general rumen ammonia levels (Table 4) increased in all treatments from day 0 to 60. Ammonia levels in the rumen at day 90 were found to be the same as those found at day 30 of the trial. There was no data for the negative control group at 90 days of the trial. Results in Table 4 indicate that larger amounts of ammonia may be produced by the action of rumen microbes on the high yeast protein diet than on

any other of the treatments. The action of the microbes is greater on the high yeast diet than on the low yeast diet as indicated by higher amounts of NH_4 produced from the high yeast diet. Production of rumen ammonia was also high in the positive control group and BWG group, and very low in the negative control group. These levels of ammonia indicate the capacity of the microbes to utilize protein from yeast, SBM and BWG to produce ammonia in the rumen.

Alternatively, the data may indicate a lower ruminal protein synthesis and a higher urea synthesis by the liver. This would mean lower utilization of nitrogen by the animal.

There were no significant differences among blocks in rumen ammonia levels at days 0, 30, and 90 of the trial, but there were at day 60 of the trial.

At day 60 of the trial, rumen ammonia levels from blocks* 3 and 4 (worse) were significantly lower ($P<0.05$) than rumen ammonia levels from block 9 (control). As expected these results show that a lower relation exists between blocks (breeding groups) and rumen ammonia levels.

There were no differences among treatments in plasma urea concentrations at days 0, and 90 of the trial, but there were significant differences at days 30 and 60 (Table 5). At day 30, plasma urea concentrations from heifers fed the high yeast diet

---

* There were a total of ten blocks. They were divided as follows: blocks 1-4 worst, blocks 5-8 best and blocks 9-10 control.

were significantly higher ($P<0.01$) than concentrations from heifers fed the positive control and negative control diets. There were not differences between the low yeast and BWG diets. Plasma urea concentrations from the positive control group were also significantly greater than the negative control group. Both the low yeast and BWG plasma urea concentrations were significantly greater ($P<0.01$) than the negative control diet. There were no significant differences among plasma urea concentrations from the positive control, low yeast and BWG diets. At day 30 of the trial, there was a significant difference in plasma urea concentrations ($P<0.05$) between the positive control group and the BWG group and between low yeast concentrations and high yeast concentrations.

At 60 days of the trial, plasma urea concentrations from the positive control, low yeast, high yeast and BWG groups were significantly greater ($P<0.01$) than the negative control group. There were no significant differences ($P<0.01$) among plasma urea concentrations between the positive control, low yeast, high yeast and BWG groups. In general the results at day 60 were similar to those observed at day 30.

At day 90 of the trial, there were no significant differences in plasma urea concentrations among treatments. Plasma urea concentrations from the negative control group were the lowest throughout the experiment. Plasma urea concentrations increased in all treatments from day 0 to day 90, except in the negative control

group where concentrations were found to be constant up to 60 days, (Table 5). Plasma urea concentrations were in general higher at day 90 than at any other sampling day during the experiment. On day 60 of the experiment, plasma urea concentrations for the positive control changed abruptly from 6.5 on day 30 to 9.7 mg% $N\text{-}NH_4$ on day 60. These results indicate that the formation of urea by the liver is significantly greater in the groups fed a nitrogen supplement compared to the negative control group. This indicates that there was a greater production of rumen ammonia in the supplemented groups.

There were no significant differences in plasma urea values among blocks. This indicates that there was no relationship among blocks (breeding groups) and plasma urea levels.

Blood glucose concentrations for the different treatments are presented in Table 6. There were no significant differences among treatments in blood glucose concentrations at days 0, 30, and 90 of the trial. There were significant differences among treatments in blood glucose concentrations at day 60 of the trial. At this time, there was a significant difference ($P<0.01$) between the positive control and negative control groups. Blood glucose concentrations from heifers in the positive control group were significantly different ($P<0.05$) from values in the low yeast, BWG and negative control diets. There were no significant differences ($P<0.05$) in blood glucose values among low yeast, high yeast, BWG and negative control groups. During the trial, all the values fell within the normal range for blood glucose.

There were no significant differences among blocks for blood glucose values at any sampling day of the trial. This also indicates the lack of relationship between blocks (breeding groups) and blood glucose levels.

Rumen pH values are shown in Table 7. The pH values are somewhat higher than the normal rumen pH values. This variation may be due to some contamination of rumen fluid with saliva. As expected there were no significant differences among treatments at day 0 of the trial (Table 7).

At day 30, pH values from the positive control group were significantly greater ($P<0.01$) than values from the BWG group. Low yeast and BWG values were significantly different ($P<0.01$) from those in the negative control group. PH values for the high yeast group were significantly different ($P<0.01$) from values from the BWG group. The positive control, low yeast and high yeast pH values were not significantly different. There was also a significant difference ($P<0.05$) between pH values from low yeast and BWG groups.

At day 60 of the trial, the only significant difference ($P<0.01$) in rumen pH values was between high yeast and negative control values. The other groups were not significantly different.

At day 90 of the trial, the only significant difference ($P<0.05$) was between pH values from the low yeast and high yeast diets. There were no other significant differences among the other treatments.

There were no significant differences among blocks for rumen pH at days 0, 60, and 90 of the trial, but there was a significant difference among blocks at day 30. The results from block 2 (worst) were significantly lower ($P<0.05$) when compared with blocks 4 (worst), 5 (best) and 9 (control). The block 2 (worst) was also significantly lower ($P<0.01$) when compared with blocks 1, 3, (worst) 6, 7, 8, (best) and block 10 (control). These results indicate that block 2 (worst) was significantly lower from the other 9 blocks. There were no significant differences between blocks 1, 3 and 4 (worse) and the others. Rumen pH results show the lack of relationship between blocks (breeding groups) and this parameter.

The volatile fatty acid (VFA) concentration in rumen fluid at day 0 of the experiment is shown in Table 8. As expected, there were no significant differences among both total VFA or specific VFA among treatments.

Data in Table 9 shows VFA concentration in rumen fluid at day 30 of the experiment. There was a significant difference ($P<0.05$) in propionic acid between values from heifers in BWG group and heifers in the negative control group. 2-methyl butyric acid values from heifers in the low yeast group were significantly greater ($P<0.05$) than values from heifers in the positive control group. Valeric acid values from heifers in the BWG group were significantly greater ($P<0.05$) than values from heifers in the negative control group. At day 30 of the experiment, there were no

significant differences among treatments in acetic acid, iso-butyric acid, butyric acid, iso-valeric acid and total VFA.

In general VFA values (Table 9) for the negative control group were the lowest among treatments in acetic acid, propionic acid, iso-butyric acid, butyric acid, valeric acid and total VFA. The high yeast diet had the lowest value for iso-valeric acid. The positive control group had the lowest value for 2-methyl butyric acid and a low value for iso-butyric acid. BWG had the greatest value in total rumen VFA, propionic acid, iso-butyric acid, butyric acid, iso-valeric acid and valeric acid.

Data in Table 10 shows VFA concentration of rumen fluid at day 60 of the experiment. There was a significant difference ($P<0.05$) in propionic acid between the high yeast and negative control groups. Iso-butyric concentrations were greater ($P<0.01$) for the low yeast diet compared to those from the high yeast, BWG, positive control or negative control groups. Butyric acid values from the high yeast group (Table 10) were significantly greater ($P<0.05$) than negative control values. Valeric acid values from the high yeast group were significantly greater ($P<0.05$) than values from the negative control group.

At 60 days there were not significant differences among treatments in acetic acid, 2-methyl butyric acid, iso-valeric acid and total VFA.

In general the negative control group had the lowest VFA values among treatments in propionic acid, iso-butyric acid,

butyric acid, valeric acid and total VFA (Table 10). The high yeast diet had the highest values among treatments in acetic acid, propionic acid, butyric acid, valeric acid and total VFA. The positive control had a slightly greater value among treatments in iso-butyric acid. BWG had the lowest value among treatments in acetic acid and iso-butyric acid.

At day 60 of the experiment, there were significant differences among blocks in iso-butyric acid. Block 5 (best) was significantly greater ($P<0.05$) from block 10 (control). Block 8 (best) was significantly greater ($P<0.05$) than blocks 90 and 10 (control).

Data in Table 11 shows VFA concentrations of rumen fluid at 90 days of the experiment. 2-methyl butyric acid values from the high yeast group were significantly greater ($P<0.05$) than values from the positive control group. Values from low yeast group were significantly greater ($P<0.01$) than values from the positive control group. At day 90, there were no significant differences among treatments in acetic acid concentrations, propionic acid, iso-butyric acid, butyric acid, iso-valeric acid, valeric acid and total VFA.

In general VFA values (Table 11) for the high yeast were the highest in acetic acid, butyric acid, valeric acid and total VFA among treatments. The positive control gave the lowest values among treatments in acetic acid, propionic acid, butyric acid, 2-methyl butyric acid, valeric acid, and total VFA. The positive

control group always had the least 2-methyl butyric acid concentrations during the entire trial and the greatest value was for the low yeast group.

At 90 days of the experiment, there was a significant difference in 2-methyl butyric acid among blocks. Block 2 (worse) was significantly greater ($P<0.05$) than block 3 (worst). Block 4 (worst) was significantly ($P<0.01$) lower than blocks 2 and 7 (worst and best respectively).

Data in Tables 12, 13, 14 and 15 show the molar percent of rumen fluid VFA within treatments at days 0, 30, 60 and 90 respectively. These tables are presented in order to aid interpretation of the results in Tables 8-11. These tables show that the negative control group gave the lowest percentages for propionic acid among treatments at days 0, 30 and 60 of the trial. BWG group gave the highest percentages for propionic acid at days 30, 60 and 90 of the trial.

In summary the data obtained from this investigation showed the following:

1. Brewers liquid yeast plus corn silage (13.1% C.P.) gave as good or better average body weight gain when compared to soybean meal plus corn silage (11.5% C.P.). The daily body gain for heifers fed brewers yeast (13.1% C.P.) was 0.26 lb/day more than heifers fed the positive control (SBM).
2. The brewers liquid yeast diet (13.1% C.P.) was more efficient in feed conversion to body gain than the

positive control (SBM), BWG (12.4% C.P.), brewers yeast (11.0% C.P.) or negative control (corn silage 8.5% C.P.).

3. Efficiency of gain figures also indicate that the protein from brewers yeast when used as in the high yeast ration is readily utilyzed by the rumen microorganisms. The same occurred with the protein from SBM and to a lesser extent with BWG and brewers yeast (11.0% C.P.).

4. There were no health problems observed related to consumption of autolyzed liquid yeast or BWG by the animals.

5. There was no relationhip between blocks (breeding groups) and rumen ammonia, plasma urea, blood glucose, pH and VFA.

6. Rumen ammonia levels were higher for brewers yeast (13.1% C.P.) positive control (SBM) and BWG rations. These results indicate that these sources of protein were readily degraded by rumen microorganisms to produce ammonia which might be used in the synthesis of microbial protein. In contrast the negative control diet produced the least concentrations of rumen ammonia.

7. Plasma urea levels were greater for the positive control (SBM), high yeast and BWG diets. These results suggest that some ammonia was absorbed through the rumen wall and then converted to urea by the liver. The plasma urea levels for the negative control were very low as compared to the other rations throughout the whole experiment.

8. Plasma glucose results fell in the normal range for this metabolite in all rations throughout the whole experiment.

9. Rumen pH values were somewhat higher than the expected values presumably because of contamination of rumen fluid with saliva.

10. VFA values were affected by diets within a given sampling day (specially for propionic acid, 2-methyl butyric acid, iso-butyric, butyric and valeric acid), but they were not affected consistently throughout the whole experiment. Therefore, it is not possible to conclude that the different diets affected VFA production.

These results suggest that autolyzed brewers yeast is a good protein supplement for dairy and beef cattle. Therefore, it is recommended to promote the use of liquid brewers yeast and brewers' wet grains in feeding cattle in order to take advantage of the high production of these products and their low price.

More research is needed for milking cows, beef cattle and the effect that both brewer liquid yeast and brewers' wet grains could have on the taste of final products, milk and meat.

CONCLUSIONS

From this work it can be concluded that autolyzed liquid brewers yeast can be used in feeding dairy heifers as a sole source of supplemental protein.

Feeding yeast in this experiment showed that autolyzed liquid brewers yeast at a level of 13.1% C.P. gave as good or better results than when soybean meal is used at a level of 11.5% C.P. as a sole source of supplemental protein.

Brewers' wet grains fed at a level of 12.4% C.P. produced less body gain than yeast used at a level of 13.1% C.P., or soybean meal used at a level of 11.5% C.P., but gave the same results as yeast fed at 11.0% C.P.

Even when the body gain produced by feeding brewers' wet grains as a sole source of supplemental protein was lower than high yeast or soybean meal, it can be concluded that brewers' wet grains give a good body gain rate for dairy heifers.

APPENDIX

TABLE 1

RATIONS USED IN BREWERS' WET GRAINS AND AUTOLYZED LIQUID YEAST STUDY[a]

Constituents	Positive Control %	Low Yeast %	High Yeast %	B.W.G. %	Negative Control %
Corn Silage	90.6	90.8	84.3	85.0	100.0
Brewers' Wet Grains	----	----	----	15.0	-----
Autolyzed Liquid Yeast	----	9.2	15.7	----	-----
Soybean Meal (S.B.M.)	9.4	----	----	----	-----
Trace Mineral Salt	ad-lib*	ad-lib*	ad-lib*	ad-lib*	ad-lib*
Protein Content (% dry basis)	11.5	11.0	13.1	12.4	8.5

a The rations were calculated according to the requirements reported in Extension Bulletin E-702, June 1973.

* Ca : P ration 1.5 : 1 and blocks of trace mineral salt.

1 Crude Protein on dry matter basis.

TABLE 2

THE EFFECTS OF THREE DIFFERENT PROTEIN SUPPLEMENTS ON GROWTH AND FEED CONSUMPTION IN DAIRY HEIFERS

(soybean meal, autolyzed yeast, brewers' wet grains)

ITEM	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	B.W.G. (12.4% C.P.)	Negative Control (8.5% C.P.)
No. of heifers	10	10	10	10	10
Days on feed	90	90	90	90	90
Adjusted avg. body wt. gain (lb.)	ab 195.7	aA 172.2	bB 218.6	a 172.5	** 166.1
Avg. daily gain (lb.)	ab 2.17	a 1.91	b 2.43	a 1.92	** 1.85
Avg. daily feed intake (lb.)	*Aa 50.3	*AB 56.0	*B 61.1	*B 58.2	*ABb 57.1
Dry matter intake/ gain (lb.)	* 8.58	* 9.51	* 7.52	* 9.90	* 11.18

* Estimated Values ** Projected Values

1 Figures within a row followed by the same small letter superscript are not significantly different ($P<0.05$). Figures within a row followed by the same capital letter superscript are not significantly different ($P<0.01$).

TABLE 3

PERCENTAGE OF TOTAL PROTEIN FROM EACH FEED WITHIN A DIET AND DRY MATTER CONTENT OF THE RATIONS

CONSTITUENTS	Positive Control (11.5% C.P.) %	Low Yeast (11.0% C.P.) %	High Yeast (13.1% C.P.) %	B.W.G. 12.4% C.P.) %	Negative Control (8.5% C.P.) %
Corn Silage	63	66	51	55	100
Brewers' Wet Grains	—	—	—	45	—
Autolyzed Liq. Yeast	—	34	49	—	—
Soybean Meal (SBM)	37	—	—	—	—
Dry Matter	37.0	32.4	29.9	32.7	36.2

TABLE 4

EFFECTS OF DIETS ON RUMEN AMMONIA LEVELS (mg% $N\text{-}NH_4$)

Treatment Group	Time of Experimental Period (days)			
	0	30	60	90
Positive Control 11.5% C.P.	1.0 a	3.2 ab	9.7 Aa	4.1 a
Low Yeast 11.0% C.P.	1.1 a	4.2 ab	4.5 BCD	3.5 a
High Yeast 13.1% C.P.	1.6 a	5.6 a	7.5 AC	4.2 a
BWG 12.4% C.P.	1.2 a	4.7 ab	5.7 ABCDb	3.9 a
Negative Control 8.5% C.P.	1.3 a	2.2 b	2.9 BD	---

* Figures within a column followed by the same capital letter superscript are not significantly different ($P<0.01$). Figures within a column followed by the same small letter superscript are not significantly different ($P<0.05$).

TABLE 5

EFFECTS ON DIETS ON PLASMA UREA LEVELS (mg% $N\text{-}NH_4$)

Treatment Group	Time of Experimental Period (days)			
	0	30	60	90
Positive Control 11.5% C.P.	3.0^{a}	6.5^{A}	9.7^{A}	11.0^{a}
Low Yeast 11.0% C.P.	2.9^{a}	7.2^{AB}	8.0^{AB}	9.6^{a}
High Yeast 13.1% C.P.	3.2^{a}	9.6^{BC}	9.2^{ABC}	10.4^{a}
BWG 12.4% C.P.	3.5^{a}	9.0^{ABC}	9.0^{ABC}	11.3^{a}
Negative Control 8.5% C.P.	3.0^{a}	3.4^{D}	3.2^{D}	---

* Figures within a column followed by the same capital letter superscript are not significantly different ($P<0.01$). Figures within a column followed by the same small letter superscript are not significantly different ($P<0.05$).

TABLE 6

EFFECTS OF DIETS ON PLASMA GLUCOSE LEVELS (mg%)

Treatment Group	Time of Experimental Period (days)			
	0	30	60	90
Positive Control 11.5% C.P.	57.0^{a}	60.7^{a}	51.1^{Aa}	63.9^{a}
Low Yeast 11.0% C.P.	57.0^{a}	59.0^{a}	60.7^{b}	61.5^{a}
High Yeast 13.1% C.P.	58.3^{a}	62.5^{a}	57.7^{ab}	68.0^{a}
BWG 12.4% C.P.	56.8^{a}	61.1^{a}	60.0^{b}	63.7^{a}
Negative Control 8.5% C.P.	57.0^{a}	52.1^{a}	62.4^{Bb}	———

* Figures within a column followed by the same capital letter superscript are not significantly different ($P<0.01$). Figures within a column followed by the same small letter superscript are not significantly different ($P<0.05$).

TABLE 7

EFFECTS OF DIETS ON RUMEN PH VALUES

Treatment Group	Time of Experimental Period (days)			
	0	30	60	90
Positive Control 11.5% C.P.	7.5^{a}	7.4^{AC}	7.1^{AB}	7.6^{ab}
Low Yeast 11.0% C.P.	7.5^{a}	7.3^{ABa}	7.0^{AB}	7.7^{a}
High Yeast 13.1% C.P.	7.5^{a}	7.4^{ACD}	6.6^{A}	7.2^{b}
BWG 12.4% C.P.	7.4^{a}	7.1^{Bb}	7.1^{AB}	7.4^{ab}
Negative Control 8.5% C.P.	7.3^{a}	7.5^{CD}	7.4^{B}	7.6^{ab}

* Figures within a column followed by the same capital letter superscript are not significantly different ($P<0.01$). Figures within a column followed by the same small letter superscript are not significantly different ($P<0.05$).

TABLE 8

THE CONCENTRATION OF RUMEN FLUID VFA (μmoles%) WITHIN TREATMENTS AT DAY 0 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)	Negative Control (8.5% C.P.)
Acetic	4.089	3.920	4.052	4.470	4.649
Propionic	1.052	1.068	1.065	1.143	1.084
Iso-butyric	0.075	0.065	0.072	0.077	0.088
Butyric	0.647	0.664	0.702	0.808	0.716
2-methyl butyric	0.101	0.077	0.077	0.089	0.111
Iso-valeric	0.058	0.048	0.049	0.054	0.060
Valeric	0.071	0.071	0.066	0.072	0.075
Total	6.093	5.913	6.083	6.713	6.783

TABLE 9

THE CONCENTRATION OF RUMEN FLUID VFA (μ moles%) WITHIN TREATMENTS AT DAY 30 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)	Negative Control (8.5% C.P.)
Acetic	4.883 ab	5.309 ab	4.534 ab	5.070 a	4.382 b
Propionic	1.264	1.353	1.229	1.564	1.107
Iso-butyric	0.067	0.072	0.078	0.115	0.064
Butyric	0.963 a	0.937 b	1.025 ab	1.057 ab	0.853 ab
2-methyl butyric	0.064	0.150	0.092	0.089	0.100
Iso-valeric	0.048 ab	0.050 ab	0.040 ab	0.057 a	0.047 b
Valeric	0.091	0.115	1.102	0.122	0.084
Total	7.380	7.986	7.100	8.074	6.637

1 Figures within a row followed by the same letter superscript are not significantly different ($P<0.05$).

TABLE 10

THE CONCENTRATION OF RUMEN FLUID VFA (μmoles%) WITHIN TREATMENTS AT DAY 60 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)	Negative Control (8.5% C.P.)
Acetic	6.183 ab	5.686 ab	7.047 a	4.881 ab	5.245 b
Propionic	1.613 A	1.372 B	1.752 A	1.536 A	1.121 A
Iso-butyric	0.080 ab	0.121 ab	0.087 a	0.086 ab	0.074 b
Butyric	1.479	1.109	1.624	1.074	1.009
2-methyl butyric	0.079	0.116	0.080	0.086	0.097
Iso-valeric	0.060 ab	0.059 ab	0.057 a	0.050 ab	0.053 b
Valeric	0.141	1.129	0.161	0.132	0.085
Total	9.635	8.592	10.808	7.845	7.684

1 Figures within a row followed by the same capital letter superscript are not significantly different ($P<0.01$). Figures within a row followed by the same small letter superscript are not significantly different ($P<0.05$).

TABLE 11

THE CONCENTRATION OF RUMEN FLUID VFA (μmoles%) WITHIN TREATMENTS AT DAY 90 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)
Acetic	4.672	5.117	5.597	5.021
Propionic	1.074	1.093	1.278	1.338
Iso-butyric	0.088	0.087	0.087	0.091
Butyric	0.764 Aa	0.764 Bab	0.943 ABb	0.799 ABab
2-methyl butyric	0.079	0.157	0.134	0.117
Iso-valeric	0.057	0.056	0.049	0.065
Valeric	0.077	0.092	0.129	0.106
Total	6.811	7.366	8.217	7.537

1 Figures within a row followed by the same capital letter superscript are not significantly different ($P<0.01$). Figures within a row followed by the same small letter superscript are not significantly different ($P<0.05$).

TABLE 12

THE MOLAR PERCENT OF RUMEN FLUID VFA WITHIN TREATMENTS

AT DAY 0 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)	Negative Control (8.5% C.P.)
Acetic	67.15	66.49	66.90	66.26	68.45
Propionic	17.26	17.85	17.21	17.06	15.88
Iso-butyric	1.24	1.10	1.19	1.14	1.31
Butyric	10.62	11.28	11.60	12.27	10.76
2-methyl butyric	1.63	1.30	1.23	1.38	1.63
Iso-valeric	0.95	0.80	0.79	0.81	0.89
Valeric	1.15	1.18	1.04	1.08	1.08

TABLE 13

THE MOLAR PERCENT OF RUMEN FLUID VFA WITHIN TREATMENTS AT DAY 30 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)	Negative Control (8.5% C.P.)
Acetic	66.15	66.47	63.88	62.86	66.09
Propionic	17.19	16.91	17.44	19.23	16.61
Iso-butyric	0.90	0.90	1.11	1.44	0.97
Butyric	13.00	11.75	14.33	13.16	12.93
2-methyl butyric	0.86	1.90	1.23	1.11	1.47
Iso-valeric	0.65	0.63	0.56	0.70	0.70
Valeric	1.23	1.43	1.44	1.50	1.25

TABLE 14

THE MOLAR PERCENT OF RUMEN FLUID VFA WITHIN TREATMENTS AT DAY 60 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)	Negative Control (8.5% C.P.)
Acetic	64.28	66.03	65.35	62.29	67.96
Propionic	16.69	16.01	16.17	19.21	14.58
Iso-butyric	0.85	1.43	0.83	1.19	0.99
Butyric	15.30	12.98	14.88	13.92	13.41
2-methyl butyric	0.83	1.35	0.76	1.09	1.26
Iso-valeric	0.62	0.69	0.53	0.64	0.69
Valeric	1.45	1.51	1.49	1.65	1.12

TABLE 15

THE MOLAR PERCENT OF RUMEN FLUID VFA WITHIN TREATMENTS AT DAY 90 OF THE EXPERIMENT

VFA	Positive Control (11.5% C.P.)	Low Yeast (11.0% C.P.)	High Yeast (13.1% C.P.)	BWG (12.4% C.P.)
Acetic	68.67	69.27	68.36	66.54
Propionic	15.72	14.78	15.47	17.75
Iso-butyric	1.25	1.18	1.07	1.26
Butyric	11.36	10.32	11.36	10.62
2-methyl butyric	1.15	2.12	1.67	1.57
Iso-valeric	0.85	0.75	0.60	0.86
Valeric	1.10	1.26	1.57	1.42

TABLE 16

ANALYSIS OF VARIANCE FOR BODY WEIGHT AT 90 DAYS

Source of Variance	Sum of Squares	D.F.	Mean Square	F	Signif. of F
Within + Residual	22792.83755	24	949.70156		
Regression	2589.36245	3	863.12082	0.90883	0.45141
Blocks	9468.78914	9	1052.08768	1.10781	0.39433
Treatments	9563.20806	3	3187.73602	3.35657	0.03550

TABLE 17

CRUDE PROTEIN (% dry matter basis) AND DRY MATTER COMPOSITION OF BREWERS LIQUID YEAST, BREWERS' WET GRAINS AND SOYBEAN MEAL

Ingredient	C.P. %	D.M. %
Brewers Liquid Yeast	40.5	15.6
Brewers' Wet Grains	34.0	22.1
Soybean Meal	45.4	90.0

TABLE 18

UNADJUSTED AVERAGE BODY WEIGHT (lbs.) PER TREATMENT AT DIFFERENT PERIODS DURING THE TRIAL

Treatment	Period (day)				
	0	31	49	77	90
Positive Control	837.4	906.7	927.8	995.2	1029.1
Low Yeast	910.5	997.8	1012.2	1066.0	1087.9
High Yeast	901.5	1004.6	1041.4	1092.4	1116.1
BWG	872.4	964.4	981.8	1022.4	1047.1
Negative Control	953.1	1023.2	1030.6	1095.7	1119.2*

* Estimated Value

LITERATURE CITED

LITERATURE CITED

Ademosun, A.A. 1973. Evaluation of brewers' dried grains in the diets of growing chickens. Brit. Poult. Sci., 14:463-468.

Ademosun, A.A. 1976. The effect of energy dilution on feed utilization and carcass quality of finishing pigs. Nut Rep. International. 13 (5):449-461.

Anonymous, 1950. Better feeds with brewers dried yeast. Brewer Yeast Council. p. 3.

Anonymous, 1972. Glucostat: For the enzymatic determination of glucose. Worthington Biochemical Corporation. Freehold, New Jersey.

Anonymous, 1977. Yeast culture found to fight high nitrates. Feedstuffs, Jan.

A.O.A.C. 1965. Official methods of analysis (10th ed.). Association of Official Agricultural Chemist. Washington, D.C.

Atlas of Nutritional Data on United States and Canadian Feeds, 1971. National Academy of Sciences. Washington, D.C.

Baker, F.H., D. Richardson, J.O. Harris, R.F. Cox, and O.M. Bowman, 1955. The use of live-cell yeast suspensions in beef cattle rations. Kan. Agr. Exp. Sta. Circ. p. 52-54.

Balloun, S.L., and J.K. Khajarern, 1974. The effects of whey and yeast on digestibility of nutrients in feather meal. Poult. Sci. 53:1084-1095.

Barber, R.S., R. Braude, K.G. Mitchell and A.W. Myres, 1971. The value of hydrocarbon-grown yeast as a source of protein for growing pigs. Br. J. Nutr. 25:285-294.

Beck, V.H. and J. Gropp, 1974. Alkanhefen in der Geflugelernahrung. 2. Bisherige Erfahrungen mit Alkanhefen in der Tierernahrung. Z. Tierphysiol. Tierernahrg. u. Futtermittelkde. 33 (6):305-323.

Bowman, G.L. and T.L. Veum, 1973. Saccharomyces cer visiae yeast culture in growing-finishing swine diets. J. Anim. Sci. 37 (1):72-74.

Couch, J.R., 1976. Brewers dried grains as an ingredient in formula feeds. Feedstuffs, Dec. p. 11-12.

Damron, B.L. and R.H. Harms, 1973. Evaluation of dried brewers grains and yeast in layer diets. Poult. Sci. 52:2018. (abstract).

Eldred, A.R., B.L. Damron and R.H. Harms, 1975 (a). Evaluation of dried brewers grains and yeast in laying hen diets containing various sulfur amino acid levels. Poult. Sci. 54:856-860.

Eldred, A.R., B.L. Damron and R.H. Harms, 1975 (b). Improvement of interior egg quality from the feeding of brewers dried grains. Poult. Sci. 54:1337. (abstract).

Février, C., F. Colomer-Rocher and B. Seve, 1973. Valeur comparée des proteines de levure sulfitique et de lactoserum levuré dans une ration a base d'orge, chez le porc en croissance-finition. Effet d'une supplementation en DL-methionine. Ann. Zootech., 22 (1):61-72.

Fischer, A.M., 1942. Dried brewers yeast. An important factor in our war economy. From the February, 1942 issue of Brewers Digest.

Fischer, A.M., 1944. Dried brewers yeast. A valuable poultry feed supplement. From the June, 1944 issue of Brewers Digest.

Griffiths, T.W., 1971. Nutritive value of dried brewers grains for dairy cattle. Ir. J. Agric. Res. 10:129-138.

Groot, A.P. de, H.P. Til and V.J. Feron, 1970. Safety evaluation of yeast grown on hydrocarbons. I. One-year feeding study in rats with yeast grown on gas oil. Fd. Cosmet. Toxicol. 8:267-276.

Groot, A.P. de, H.P. Til and V.J. Feron, 1970. Safety evaluation of yeast grown on hydrocarbons. II. One-year feeding study in rats with yeast grown on pure n-paraffins. Fd. Cosmet. Toxicol. 8:499-507.

Groot, A.P. de, H.P. Til and V.J. Feron, 1971. Safety evaluation of yeast grown on hydrocarbons. III. Two-year feeding and multi-generation study in rats with yeast grown on gas-oil. Fd. Cosmet. Toxicol. 9:787-800.

Harmon, B.G., S.G. Cornelius, D.H. Baker and A.H. Jensen, 1975. Brewers dried grains as an amino acid supplement in gestation diets. J. Anim. Sci. 41:315. (abstract).

Hatch, C.F., T.W. Perry, M.T. Mohler and W.M. Beeson, 1972. Effect of corn distillers solubles and brewers dried grains with yeast in urea-containing rations on steer performance. J. Anim. Sci. 34 (2):326-331.

Kirchgessner, M. and F.X. Roth, 1973. Use of yeast grown on n-paraffin in fattening calves. Zuchtungskunde. 45 (3/4) pp. 208-214.

Kneale, W.A., 1972. Yeast grown on hydrocarbons as a protein supplement in rations for bacon pigs. Experimental Husbandry, 22:55-60.

Kulasek, G. 1972. A micromethod for determination of urea in plasma, whole blood and blood cells using urease and phenol reagent. (Polish, English and Russian summary). Pol. Arch. Wet. 15:801.

Legendre, J.R., R. Totusek and W.D. Gallup, 1957. Effect of live-cell yeast on nitrogen retention and digestibility of rations by beef cattle. J. Anim. Sci. 16:671-674.

Loosli, J.K. and R.G. Warner, 1958. Distillers grains, brewers grains, and urea as protein supplements for dairy rations. J. Dairy Sci. 41:1446-1450.

Maclean, C.W. 1969. A survey of the nutritive value of brewery and distillery by-products. The Veterinary Record. 84:572-575.

Mimura, K., T. Yoshimoto and K. Mitani, 1973. Hydrocarbon grown yeast as the protein source of diet for dairy beef production. J. Fac. Fish. Anim. Husb. 12:101-116.

Morrinson, F.B., 1957. Feed and Feeding. 22th edition, New York.

Okuda, H., S. Fujii and Y. Kawashima, 1965. A direct calorimetric determination of blood ammonia. Tokushima J. Exp. Med. 12:11.

Oleas, T.B., 1977. Storage trials with wet brewers' grains. Thesis for the Degree of M.S., Michigan State University.

Omole, T.A. and T.A. Ajayi, 1976. Evaluation of brewers dried grains in the diets of growing rabbits. Nutr. Rep. International. 13 (4):383-387.

Paliev, H., J. Peyrellade, 1972. Estudios de diferentes fuentes de energia (ázucar crudo y maiz amarillo) y de proteina (levadura Torula, harina de pescado y levadura Torula suplementada con grasas y metionina) en las raciones para pollos de asar (broilers). Torreia. 24:3-22.

Paruelle, J.L., R. Toullee, J.F. Frantzen and C.M. Mathieu, 1972. Utilisation des proteines par the veau preruminant a l' engrais. I. Utilisation digestive des proteines de soja et des levures d' alcanes incorporees dans les aliments d' allaitement. Ann. Zootech. 21 (3):319-331.

Preston, R.L., R.D. Vance and V.R. Cahill, 1973. Energy evaluation of brewers grains for growing and finishing cattle. J. Anim. Sci. 37 (1):174-178.

Richardson, D., F.H. Baker, J.O. Harris, E.F. Smith, R.F. Cox, and O.M. Bowman, 1956. The use of live-yeast suspensions in beef cattle rations. Kan. Agri. Exp. Sta. Circ. p. 54-57.

Ruf, E.W., W.H. Hale and W. Burroughs, 1953. Observations upon an unidentified factor in feedstuffs stimulatory to cellulose digestion in the rumen and improved liveweight gains in lambs. J. Anim. Sci. 12:731-739.

Shacklady, C.A., 1972. Yeast grown on hydrocarbons as new sources of protein. World Review of Nutrition and Dietetics. (14):154-179.

Shannon, D.W.F., and J.M. McNab, 1972. The effect of different dietary levels of a n-paraffin-grown yeast on the growth and food intake of broiler chicks. Br. Poult. Sci., 13:267-272.

Thompson, W. and J. Tosic, 1949. "Fodder Yeast" as a dietary supplement for sheep maintained on poor quality hay. Jour. Agr. Sci. 39:283-286.

Tiews, V.J., J. Gropp, V. Schulz, H. Erbersdobler and H. Beck, 1974. Alkanhefen in der Geflugelernahrung. 3. Kukenmastversuche mit alkanhefen in praxisnahen und halbsynthetischen rationen. Z. Tierphysiol. Tierernahrg. u. Futtermittelkde. 34 (2):86-113.

Van Weerden, E.J., C.A. Shacklady and P. Van Der Wal, 1970. Hydrocarbon grown yeast in rations for chicks. Br. Poult. Sci. 11:189-195.

Veum T.L. and G.L. Bowman, 1973. Saccharomyces cervisiae yeast culture in diets for mechanically-fed neonatal piglets and early growing self-fed pigs. J. Anim. Sci. 37 (1):67-71.

Wahlstrom, R.C. and G.W. Libal, 1977. Brewers dried grains as a nutrient source in diets for pregnant sows. J. Anim. Sci. 42 (4):871-875.

Waldroup, P.W., C.M. Hillard and R.J. Mitchell, 1971. The nutritive value of yeast grown on hydrocarbon fractions for broiler chicks. Poult. Sci. 50:1022-1029.

Waldroup, P.W., and N.W. Flynn, 1975 a. Comparison of the nutritive value of yeasts grown on hydrocarbon feedstocks under varying processing conditions. Poult. Sci. 54:1129-1133.

Waldroup, P.W., and K.R. Hazen, 1975 b. Yeast grown on hydrocarbon fractions as a protein source in the diet of laying hens. Poult. Sci. 54:635-637.

Yoshida, M., M. Tada, H. Bansho, M. Matsushima, K. Ogata, M. Iino, and I. Umeda, 1972 a. Effect of hydrocarbon yeast as dietary protein source on reproducibility of breeding hens. I. Performance of the first generation. Japan. Poult. Sci. 9:173-181.

Yoshida, M., and H. Hoshii, 1974 b. Effect of dietary calcium and phosphorus levels on growth of chicks fed yeast grown on methanol. Japan. Poult. Sci. 11 (6):225-228.

Yoshida, M., M. Tada, H. Bansho, M. Matsushima, K. Koba, M. Iino, and I. Umeda, 1974 c. Effect of hydrocarbon yeast as dietary protein source on reproducibility of breeding hens. III. Performance of the fourth, fifth and sixth generations. Japan. Poult. Sci., 11 (5):163-178.

Yoshida, M., M. Tada, H. Bansho, M. Matsushima, K. Koba, M. Iino, and I. Umeda, 1974 d. Effect of hydrocarbon yeast as dietary protein source on reproducibility of breeding hens. IV. Performance of the third generation from 36 to 108 weeks of age. Japan. Poult. Sci., 11 (5):179-189.

Yoshida, M., M. Tada, H. Bansho, M. Matsushima, K. Koba, M. Iino and I. Umeda, 1975 e. Effect of hydrocarbon yeast as dietary protein source on reproducibility of breeding hens. V. Combined analyses of multi-generation feeding experiment. Japan. Poult. Sci., 12 (2):83-91.

Yoshida, M., 1974. Note on the flavor of the egg and meat of the hens fed yeast grown on n-paraffin. Japan. Poult. Sci., 11 (5):194-196.

Young, L.G., and R.H. Ingram, 1968. Dried brewers' grains in rations for market hogs. Can. J. Anim. Sci. 48:83-88.