EVALUATION OF ALFALFA LEAF PROTEIN CONCENTRATE (ALPC) FOR SWINE

by

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INTRODUCTION

Alfalfa

During the past 10 years, much consideration has been given to population growth in relation to the present and potential food supplied (Pimental et al., 1975). Grain is not only a food for humans but also for livestock. The shortage of protein food in various areas of the world has become an impending problem because of overpopulation and scarcity of arable land (Abbott, 1973). Realization of this problem has stimulated research on improving the yields and the quality of conventional protein rich foods and feeds and on development of novel, unconventional protein sources.

Leaves of the green plants which use the free energy of sunlight for photosynthesis are the primary source of almost all the amino acids of both plant and animal proteins. Cultivated forage crops are the most efficient leafy crops from the standpoint of nutrient production per acre per year. Alfalfa (Medicago sativa) is the best of the forage crops for large areas of the world because alfalfa produces more protein per acre than most other crops. Alfalfa is a potential protein source since it produces more than three times the amount of protein per acre than do soybeans (Stahmann, 1968) and since it also produces more essential amino acids per acre than do soybeans and other major crops (Akeson and Stahmann, 1966). In addition to its high protein yield, other advantages of alfalfa over oil seeds are that it does not require seeding and cultivation each year, it survives harvesting at frequent intervals and it can be grown under more diverse environmental conditions (Jorgenson, 1975; Kohler et al., 1973).

The alfalfa juice contains an amino acid composition similar to milk and over three times more xanthophyll and vitamins than the best dehydrated alfalfa (Hartman et al., 1967). Alfalfa has not yet become a major source of protein for nonruminants because of the high fiber, 26% on dry matter basis, and low digestible energy content (NRC, 1979). Nonruminants do not secrete enzymes capable of splitting β-linked glycosides of fibrous substances in alfalfa. The young pig can not utilize the energy of cellulose contaning fibers (De Goey and Ewan, 1975). The low digestibility of protein in alfalfa meal, the unpalatability of a high alfalfa level and the presence of inhibitors such as trypsin and saponins are also factors limiting the usage of alfalfa meal in the swine diets (Cheeke et al., 1977a; Cheeke et al., 1978; Leamaster and Cheeke, 1979).

Since plant proteins are located inside cellulosic supportive structures, the limited contact of protein with enzyme may influence the protein digestibility (Booher, 1948). The low digestibility of alfalfa protein may be caused by an increased binding of protein to cell wall components during the drying of alfalfa (Cheeke and Myer, 1975; Cheeke and Carlsson, 1978). During alfalfa dehydration, the retention of amino acid is correlated with meal moisture and dehydrator outlet temperature. Lysine and methionine are the most labile, undergoing maximum losses of 47 and 30%, respectively (Livingston et al., 1971). Trypsin inhibitor is resistant to trypsin hydrolysis in chicks and increases the requirement of sulfur-contain amino acids in rats (Kakade, 1974). Ishwaya and Birk (1965) showed saponins to have a nonspecific inhibitory effect on the digestion of proteins by various proteolytic enzymes. Saponins in alfalfa affect feed intake, digestion or absorption and reduce its feeding value for nonruminants (Cheeke 1976; Cheeke et al., 1977a and 1978). Alfalfa saponins decrease the lipid digestibility and increase the fecal lipids and fecal cholesterol in mice (Reshef et al., 1976). These problems are largely overcome if the protein is separated from the fiber and a protein concentrate prepared from low saponin varieties of alfalfa by using the Pro-Xan method (Kohler et al., 1973).

Production of Alfalfa Leaf Protein Concentrate (ALPC)

The alfalfa leaf protein concentrate made from the wet fractionation of fresh alfalfa by the "Pro-Xan Process" is a high protein, high xanthophyll and very low fiber product. The Pro-Xan process developed by the United States Department of Agriculture separates a portion of the proteins and carotenoid pigment from the freshly expressed juice of alfalfa (Lazar et al., 1971; Spencer et al., 1971; Knuckles et al., 1975; Kohler et al., 1978). The first commercial modification of this process was made by the Valley Dehydrating Company plant in Colorado in 1978 (Kohler and Edwards, 1980).

In the Pro-Xan process, the freshly harvested alfalfa is wet ground in a hammer mill, then pressed into two components - a press cake and a protein-rich green juice in a twin-screw type press. The pressed cake is dehydrated in a conventional rotary dehydrator equipped with a stack gas recycle system which recovers some heat and increases the water vapor concentration in the gases leaving the dehydrator.

The carotene, xanthophyll and green color in the green juice from the press is stabilized and preserved by an anti-foam agent and is treated with gaseous ammonia to get the pH of the juice to about 8.5. At this pH the lipoxygenases and proteases in the juice are not active. The green juice is then heated by continuous steam injection to about 85 C to coagulate the protein. Protein is removed from the heated juice in a decanter-type centrifuge. It is then granulated or extruded prior to drying in a tunnel dryer, a rotary dryer, a fluidized-bed dryer or freeze dryer. The product is the whole alfalfa leaf protein concentrate (Pro-Xan whole ALPC).

The products produced by the Pro-Xan process are alfalfa leaf protein concentrate, alfalfa solubles fraction and press cake. The solubles fraction can be used for single cell protein production. The press cake contains most of the fiber and is used as feed for ruminants. (Kohler *et al.*, 1979).

Utilization of Alfalfa Leaf Protein Concentrate

1) Human

Whole alfalfa leaf protein concentrate is a dark green product containing 40-60% protein, less than 3% fiber, 8-15% ether extract, 8-15% ash, about 660 mg carotene per kg and nearly 1300 mg xanthophyll per kg (Jorgenson, 1975). The freeze dried alfalfa leaf protein concentrate contains about 1.6 mg/g β-carotene so that two to three grams of a good leaf protein preparation eaten daily would supply enough beta-carotene to meet the human vitamin A requirement (Arkcoll, 1973). Studies on feeding whole green acid-washed leaf protein concentrate to children in Nigeria have shown that feeding 10 g/day cures Kwashiorkor (protein deficiency disease) in children consuming diets high in cassava (Oke, 1973).

Although whole alfalfa leaf protein concentrate is nutritious, it is green in color and has a grassy flavor that has been found unacceptable to most people. (Kohler and Knuckles, 1977). ALPC will probably be used as a potential foodstuff for poultry and swine.

2) In Vitro and in Vivo - Rat

The biological utilization of protein depends on such factors as protein content, protein quality and protein digestibility (Kakade, 1974). The *in vitro* methods of evaluating protein digestibility are used because of their rapidity and sensitivity.

The whole alfalfa leaf protein concentrate prepared commercially by the Pro-Xan process showed that protein digestibilities assayed by *in vitro*, pepsin-pancreatin and pepsin-trypsin methods, were in the range of 82.4 to 86.7% which showed a high degree of correlation with protein digestibility values in the range of 80.5 to 83% obtained in rat tests (Saunders et al., 1973). Bickoff et al. (1975) reported that the in vitro digestibility of Pro-Xan ALPC was 88%. Cheeke and Myer (1975) reported that the protein digestibility of ALPC was only 65.1% for the rat. Cheeke et al. (1977b) reported that the apparent protein digestibility of the Pro-Xan ALPC was 55%. These differences may be due to heat damage which may have occured during processing.

Amino acids deficiency or excess affects protein utilization by either limiting the amino acids for tissue protein synthesis or by creating an extra burden on the liver and kidney for degradation of the excessive amino acids (Kakade, 1974). Since protein utilization is a function of the amino acids present, the amino acid composition of protein plays an important role in determing the nutritive value of plant protein feedstuffs. When ALPC is used as the only protein supplement for rats, lysine and methionine are the limiting amino acids (Bickoff et al., 1975; Myer and Cheeke 1975; Cheeke et al., 1977b). Lysine availability for ALPC was found to be about 80% of that of casein in rats (Cheeke and Myer, 1975). The first and second limiting amino acids in ALPC are methionine and lysine, respectively (Bickoff, 1975). Myer and Cheeke (1975) reported that lysine was the first limiting amino acid in Pro-Xan ALPC when it was supplemented in a corn-based diet. Hove et al. (1974) reported that when methionine was added to Pro-Xan ALPC for rat, growth was improved. Cheeke et al. (1977b) reported that methionine was the first-limiting amino acid in freeze-dried ALPC and lysine was the first limiting amino acid in commercial Pro-Xan ALPC because of the heat damage in the process.

Reproductive performance was not affected by feeding ALPC. Organ Weights, liver histology and blood hemoglobin were normal in rats given the ALPC diet for 6 months. Total body lipid of male rats given ALPC was about half that of the control rats fed casein. Body protein was slightly increased and moisture content was higher in rats given ALPC (Hove et al., 1974)

3) Poultry

The alfalfa leaf protein concentrate (Pro-Xan ALPC) has been shown to be a good source of carotene and xanthophyll for the pigmentation of skin and yolk in broilers and laying hens. The biological xanthophyll availability of ALPC has been reported to be 1.6 to 2.2 times that of dehydrated alfalfa in the relative skin pigmentation potencies for the broiler and 1.9 to 2.3 times more efficient than xanthophyll in dehydrated alfalfa meal for the laying hen. It was also shown to have a xanthophyll availability of three times that of marigold meal (Kuzmicky et al., 1977).

The Pro-Xan ALPC which contains a high percentage of protein can be used as the protein source for the poultry.

Kuzmicky et al. (1972) reported that 54% of a commercially prepared Pro-Xan ALPC could be included in broiler rations with no loss in chick weight gain. Halloran (1972) also reported that a commercially prepared Pro-Xan could effectively replace soybean meal in broiler rations. Kuzmicky and Kohler (1977) indicated that for broilers the protein content and metabolizable energy (M.E.) of Pro-Xan, on a dry matter basis, were ranged from 51% to 68% and 2577 to 3182 kcal/kg, respectively. It was also indicated that there was no significant effect on chick weight gain or feed efficiency when 10% of Pro-Xan ALPC was used in the chick diets. When ALPC was washed by acid (pH 3.5), the M. E. appeared to be improved (Kuzmicky and Kohler, 1977). During storage with air present, the carotenoids were found to be lost faster from acid-washed leaf protein concentrate than from unwashed preparations. (Arkcoll, 1973).

4) Swine

Only limited investigations have been conducted to evaluate alfalfa leaf protein concentrate as a protein source for swine. Duckworth and Woodham (1961) reported that with about 7% of wheat leaf protein concentrate for swine, the rate of growth and feed efficiency were as good as that with diets containing 8% fish meal for newly-weaned pigs. Myer et al. (1975) reported no adverse effects on growth rate of growing-finishing pigs, 36 to 91 kg, when ALPC which contained 36% crude protein was used in a barley-based diet. With starter diets, the growth of pigs, 11 to 27 kg, fed ALPC was inferior to the controls receiving a soybean meal diet. The growth rate of the pigs, 17 to 27 kg, fed 20% ALPC was reduced as compared with the 7.5% ALPC diet. Cheeke et al.(1977b) indicated that the freeze-drying process could improve the pig's performance; the growth rate and feed efficiency were similar for growing pigs fed the freeze-dried ALPC diet and those fed a corn-soybean meal which were better than those of pigs fed a Pro-Xan ALPC diet. There was a trend toward decreased performance with increased temperature 77 to 91 C, in the processing of ALPC.

No significant effects of ALPC on carcass data were noted (Myer et al., 1975). There was a trend towards decreasing percentage lean cuts and lower market grades with increasing ALPC levels. Cheeke et al (1977b) gave supporting evidence that ALPC prepared with the avoidance of heat damage could give growth and feed efficiency comparable to that obtained with soybean meal for young pigs.

The data for the digestibilities of protein and energy of ALPC, the limiting order of amino acids in ALPC for swine and the effects of ALPC on the fat color of swine have not been investigated. A study is needed to determine the nutritive value of alfalfa leaf protein concentrate for swine in order to evaluate ALPC as a new feed ingredient for swine.

Objectives of Study

The purpose of this study was to evaluate the potential of alfalfa leaf protein concentrate (Pro-Xan ALPC) as a protein source for swine. ALPC was substituted for dehulled soybean meal in diets for starter, grower and finisher pigs to determine the digestibilities of protein and energy. The limiting order of amino acids in ALPC for starter pigs was also determined. The palatability of ALPC and the effects of ALPC on carcass characteristics and color of fat were also evaluated. An economic evaluation of ALPC as a new feed ingredient for growing pigs was also studied.

EXPERIMENTAL PROCEDURE

Preparation of Alfalfa Leaf Protein Concentrate (ALPC)

The protein concentrate (Pro-Xan) was prepared essentially as described by Kohler *et al.*, (1973) with modifications to increase yields (Kohler *et al.*, 1977) and to scale-up the process to commercial size (Edwards, *et al*, 1979). Briefly, field chopped harvested alfalfa (early bloom stage) was trucked to the processing plant where it was metered into grinders (Owen's Master Crusher) with about one half its weight of "brown juice" recycled from a later stage in the process. The ground alfalfa pulp was pressed through a screw press (Vincent single screw) to remove "green" juice containing much of the protein. The press cake was mixed with more of the recycled brown juice and repressed in a second single screw press to recover more green juice (and protein). The combined green juices were treated with ammonia to raise the pH to 8.5 and then heated to about 85 C by direct steam injection to coagulate the protein. The resulting protein curd was separated from the liquid using a continuous sludge discharge type centrifuge (Sharples). The protein curd was dried in a Heil triple pass rotary drum dehydrator with the exit gas temperature at 104 C to be the product, alfalfa leaf protein concentrate. A part of the brown deproteinized by-product juice from the centrifuge was used in the recycle system described above.

Chemical Analysis of Alfalfa Leaf Protein Concentrate

1) Proximate Analysis and Ammoniacal Nitrogen

Ammoniacal nitrogen and proximate analysis including moisture, crude protein, ether extract, ash and crude fiber contents of the ALPC were analyzed by the procedures described by the Association of Official Agricultural Chemistry for animal feed (AOAC, 1975).

2) Amino Acid Composition

Samples of ALPC were hydrolyzed at 100 C for 31 hr in 4 ml of 3N P-toluenesulfonic acid and 6.25 μM norleucine internal standard in evacuated sealed tubes (Liu and Chang, 1971). Estimation was carried out in a Dionex-microbore, high pressure and single column amino acid analyzer.

3) Elemental Analysis

The sample solution of ALPC was prepared by dry ashing (AOAC, 1975).

a) Phosphorus (P): A Gilford Model 240 Spectrophotometer was used for the colorimetric determination of phosphorus (Fiske and Subbarow, 1925).

b) Calcium (Ca), Iron (Fe), Magnesium (Mg), Zinc (Zn), Copper (Cu) and Manganese (Mn) were analyzed by atomic absorption spectrophotometry using an air-acetylene flame (AOAC, 1975). Sodium (Na) and Potassium (K) were analyzed by flame emission spectroscopy using air-hydrogen. A Jarrell-Ash Atomic Absorption/Flame Emission Spectrophotometer was used for the above mineral analysis.

c) Acid-insoluble ash: The HBr-insoluble materials, Silica etc., were analyzed (Goering and Van Soest, 1970).

4) Carotene and Pigment Content

Beta-carotene and pigment contained in ALPC were extracted and measured with an Erelyn Photoelectric Colorimeter using the methods of AOAC (1975).

5) Fatty Acid Composition

Five grams of ALPC was extracted and methylated (Kuntapanit, 1978). The methyl esters of the free fatty acids were then injected into a Hewlett-Packard Gas Liquid Chromatograph, Model 5730A, Column at 190 C with N_2 as the carrier gas. A flame ionization detector was used.

6) Gross Energy

The combustible (gross) energy was determined in an oxygen bomb calorimeter, a Parr Instrument.

Limiting Order of Amino Acids in ALPC for Starter Pigs

1) Feeding Trial - Experiment 1.

Seventy-two crossbred pigs averaging 10.7 kg initially were used to determine the limiting order of amino acids in ALPC for growing pigs. Pigs, 36 of each sex, were selected from 12 litters, 6 pigs from each litter, and were divided into two groups according to their initial weight. The 18 pigs in each group of each sex were assigned to 6 pens in which 3 pigs from different litters were housed. Pigs in each pen received one of the six dietary treatments assigned at random. Diets contained 20% ALPC as the amino acid source and dextrose as the energy source. The diets were: A) basal diet; B) basal +.3% DL-Methionine;C) basal + .35% L-Lysine HCl; D) C + .3%

DL-Methionine; E) D + .2% L-Isoleucine; and F) 17% protein corn-soybean meal positive control. The compositions of the diets are shown in Table 1.

Pigs were housed in an environmentally controlled nursery with concrete slotted floor pens, 5m X 11m. The pigs were offered feed and water ad libitum. Body weight and feed consumption were measured for calculating the daily gain, daily feed intake and feed efficiency at the end of the 28 - day trial.

2) Nitrogen Balance Trial - Experiment 2.

A nitrogen balance trial was conducted with 12 crossbred barrows, averaging 14.3 kg, selected from 3 litters (4 barrow from each). The randomized complete block design was used (Cochran and Cox, 1957). Pigs were housed individually in metabolism cages in the environmentally controlled house (Temp. 24 C, RH 76%). The four pigs in each litter were randomly assigned one of the four treatments: A) basal diet; B) basal + .3% DL-Methionine; D) basal + .3% DL-Methionine + .35% L-Lysine HCl; and E) D + .2% L-Isoleucine. The compositions of these four diets are the same as those in the feeding trial - Experiment 1.

Two collection periods were carried out for the nitrogen balance trial. Daily feed intake was constant and fed in two equal portions. Water was provided in a 2:1 ratio to feed at each feeding (morning and afternoon). A pre-test period of 6 days preceded each collection period. The marker-to-marker technique for collecting feces was used. A feed marker at approximately 2% of the diet was fed at a specific hour of the 1st and 5th day of each collection period. The feces collection was begun when the first marker appeared and was ended with the appearance of the second. Feces were collected daily and frozen. The entire fecal collection of each period was dried in a forced air oven at 57 C for 4 days. The dry feces of each pig were weighed and ground in a Wiley mill equipped with a 40-mesh screen. The samples of each diet and each pig's feces were analyzed for dry matter and nitrogen content by the methods of AOAC (1975).

Urine was collected in plastic containers to which 30 ml of HCl (2:1) had been used. Each daily collection was diluted to a constant volume of 1 liter and a 100 ml aliquot was taken. Accumulated aliquots of 5 days of urine collection were stored in a refrigerator until those could be analyzed for nitrogen by the method of AOAC (1975).

Apparent protein digestibility (APD) and nitrogen retention (NR) and biological value (BV) were calculated by the following formula (Maynard et al., 1979).

$$\text{Apparent protein digestibility (\%)} = \frac{\text{N intake} - \text{N in feces}}{\text{N intake}} \times 100$$

$$\text{Nitrogen retention (g/day)} = \text{N intake} - \text{N in feces} - \text{N in Urine}$$

$$\text{Biological value (\%)} = \frac{\text{Nitrogen retention}}{\text{Nitrogen intake} - \text{Nitrogen in feces}} \times 100$$

$$\text{Apparent biological value (\%)} = \frac{\text{Nitrogen retention}}{\text{Nitrogen intake}} \times 100$$

3) Digestibility of Amino Acids - Experiment 3.

TABLE 1. COMPOSITION OF DIETS FOR LIMITING ORDER OF AMINO ACIDS IN ALPC (EXPERIMENT 1, 2, 3)

Ingredients, %	A	B	C	D	E	F
Ground Corn (4-02-935) [a]	--	--	--	--	--	70.5
Soybean meal (5-04-604) [a]	--	--	--	--	--	25
ALPC	20	20	20	20	20	--
Dextrose	70.4	70.1	70.05	69.75	69.55	--
Tallow	5	5	5	5	5	--
Limestone, grnd, mn 33, (6-02-632) [a]	2.8	2.8	2.8	2.8	2.8	1.6
Calcium phosphate, dibasic, commercial (06-01-080) [a]	0.3	0.3	0.3	0.3	0.3	1.4
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Premix [b]	1.0	1.0	1.0	1.0	1.0	1.0
Amino acids						
DL-Methionine	--	0.3	--	0.3	0.3	--
L-Lysine-HCl [c]	--	--	0.35	0.35	0.35	--
L-Isoleucine	--	--	--	--	0.2	--
Calculated value, % [d]						
Crude protein	10.05	10.35	10.35	10.65	10.85	17.2
Met. + Cys.	0.34	0.64	0.34	0.64	0.64	0.63
Lysine	0.61	0.61	0.90	0.90	0.90	0.90
Isoleucine	0.44	0.44	0.44	0.44	0.64	0.88

a) International feed number.

b) Provided the following per kilogram of complete diet:
   (1) Vitamin: Vitamin A 4,410 IU; Vitamin D_3 330 IU; Vitamin E 22 IU; Riboflavin 5mg; d-pantothenic acid 13.2 mg; Niacin 27.5 mg; Vitamin B_{12} 24.3 μg and Choline Chloride 508 mg.
   (2) Antibiotic: Chlortetracycline 110 mg; sulfamethazine 110 mg and Penicillin 55 mg.
   (3) Trace mineral (mg): Mn 100; Fe 100; Zn 100; Cu 10; I 3 and Co 1.

c) L-lysine monohydrochloride (78% lysine).

d) Concentrations are as fed basis, 90% dry matter.

In experiment 3, 6 pigs averaging 14.4 kg were used to measure the digestibility of amino acids in ALPC for growing pigs. The pigs used were those fed treatment diet A (basal diet) and diet B (basal + .3% DL-Methionine) in the first collection period of Experiment 2. The diets and feces of each pig fed diet A or diet B in the first collection period of Experiment 2 were sampled and analyzed for amino acid composition by the method described in the section "Chemical Analysis of ALPC - Amino Acid Composition".

The apparent digestibility of individual amino acids in each pig were calculated.

Apparent amino acid (AA) digestibility =

$$\frac{\text{AA intake} - \text{AA in feces}}{\text{AA intake}} \times 100$$

Alfalfa Leaf Protein Concentrate As Feed Ingredient for Swine

1) Feeding Trial

Three feeding trials involving 96 starter, 48 grower and 48 finisher pigs were conducted to study ALPC as a feed to be substituted for dehulled soybean meal for swine. The four treatments were A) Corn-dehulled soybean meal (control); B) 33% of dehulled soybean meal replaced with ALPC; C) 66% of dehulled soybean meal replaced with ALPC; and D) Corn-ALPC (complete replacement of dehulled soybean meal with ALPC). ALPC was substituted for dehulled soybean meal on an equal weight basis. The diets were formulated to meet the requirements of pigs in each phase recommended by the NRC (1979) and KSU

(Allee, 1980 a, b).

The experimental design of those feeding trials was shown in Table 2.

a) Starter Pigs - Experiment 4.

A total of 96 crossbred pigs, averaging 7.5 kg and 50.6 days old, were used to study nutritive value of ALPC for starter pigs (Experiment 4). Forty-eight pigs of each sex were divided into two groups according to their initial weight. The 24 pigs in each group of each sex were randomly assigned to four pens. Treatments were randomly assigned to pens. Dietary treatments were a control diet and three ALPC diets which ALPC was substituted for dehulled soybean meal 33%, 66% and 100% on an equal weight basis. The control diet was a corn-dehull soybean meal diet containing 17.6% crude protein, .91% lysine, .92% calcium, and .70% phosphorus. The compositions of diets which ALPC was used as a feed ingredient for starter pig (Experiment 4) are shown in Table 3.

Six pigs per pen were housed in an environmentally controlled nursery with a concrete slatted floor pen, 5m X 11m. Feed and water were supplied ad libitum. Body weight and feed consumption were measured on the 1st, 14th and final day of the 35 days of the experimental period.

b) Grower Pigs - Experiment 5.

Forty-eight pigs, averaging 27.6 kg and 85.6 days old, were used to study ALPC as feed for grower swine (Experiment 5). At the end of the Experiment 4, the feeding trial for starter

TABLE 2 EXPERIMENTAL DESIGN OF ALPC AS FEED INGREDIENT FOR SWINE

Experiment	4	5	6
Phase	Starter	Grower	Finisher
Period, wk.	5	6	5
Weight, kg.	7.5 - 25.2	27.5 - 62	62 - 92
Total pigs, hd.	96	48	48
Pigs/sex	48	24	24
Pens/diet	4	4	4
Pigs/pen	6	3	3
Diet	4	4	4
Lysine, %[a]	0.90	0.75	0.60
Calcium, %[a]	0.9	0.7	0.7
Phosphorus, %[a]	0.7	0.6	0.6

[a]Concentrations are based upon amounts percentage of air-dry diet (90% dry matter). (Allee, 1980 a, b)

TABLE 3. COMPOSITION OF DIETS CONTAINING ALPC AS FEED INGREDIENT FOR STARTER PIGS (EXPERIMENT 4, 7 AND 8)

Diet ALPC substituted for SBM [a]	A --	B 33%	C 66%	D 100%
Ground corn (4-02-935) [b]	72.3	72.5	72.8	73.0
Soybean meal, dehulled (5-04-612) [b]	23.1	15.4	7.7	--
Alfalfa leaf protein concentrate	--	7.7	15.4	23.1
Calcium phosphate, dibasic (6-01-080) [b]	1.7	1.7	1.7	1.7
Limestone, grnd (6-02-632) [b]	1.4	1.2	.9	.7
Premix [c]	1.0	1.0	1.0	1.0
Salt	.5	.5	.5	.5
Calculated value, % [d]				
Crude protein	17.57	17.72	17.87	18.02
Calcium	0.92	0.93	0.93	0.93
Phosphorus	0.70	0.70	0.70	0.70
Lysine	0.91	0.90	0.89	0.89

a ALPC was substituted for dehulled soybean meal on an equal weight basis.

b International feed number.

c Provided the following contents per kilogram of diet:
(1) Vitamin: Vitamin A 4,410 IU; Vitamin D_3 330 IU; Vitamin E 22 IU; Riboflavin 5 mg; d-pantothenic acid 13.2 mg; Niacin 27.5 mg; Vitamin B_{12} 24.3 g and Choline Chloride 508 mg.
(2) Antibiotic (mg): Chlortetracycline 110; Sulfamethazine 110 and Penicillin 55.
(3) Trace mineral (mg): Mn 100; Zn 100; Cu 10 ; I 3 and Co 1. Fe 100

d As fed basis, 90% dry matter.

pigs, those pigs in group 1 (group of heavier initial weight) were used for the grower pigs trial. Pigs were moved from the nursery and housed three per pen (6m X 16m) in an open front building with a solid concrete floor.

Pigs were fed the same diet treatments, A) Control; and diets which ALPC was substituted for dehulled soybean meal B) 33%; C) 66% and D) 100%; on an equal weight basis, as they were fed in the starter phase. The compositions of the diets were changed to meet the requirements of growing pigs. The control diet was a corn-dehulled soybean meal diet containing 15.6% crude protein, .76% lysine .72% calcium and .60% phosphorus. The compositions of the diets containing ALPC for growing pigs (Experiment 5) are shown in Table 4.

Feed and water were supplied ad libitum. Body weight and feed consumption were measured on the 1st, 21st and 35th day of the 5-week feeding trial.

C) Finisher Pigs - Experiment 6.

Forty-eight pigs, averaging 62 kg and 127.6 days old, were used in evaluating ALPC as a feed ingredient for finisher pigs (Experiment 6). At the end of the Experiment 5, the feeding trial for grower pigs, pigs were weighed and switched to the finishing diets. The control finisher diet was also a corn-dehulled soybean meal diet containing 13.6% crude protein, .61% lysine, .72% calcium and .61% phosphorus. The compositions of the diets for finisher pigs (Experiment 6) are shown in Table 5.

TABLE 4 COMPOSITION OF ALPC DIETS FOR GROWER PIGS (EXPERIMENT 5)

Diet ALPC substituted for SBM, % [a]	A --	B 33%	C 66%	D 100%
Ground corn (4-02-935) [b]	78.1	78.3	78.5	78.7
Soybean meal, dehulled (5-04-612)[b]	18.0	12.0	6.0	--
Alfalfa leaf protein concentrate	--	6.0	12.0	18.0
Calcium phosphate, dibasic (6-01-080) [b]	1.3	1.3	1.3	1.3
Limestone, grnd (6-02-632) [b]	1.1	0.9	0.7	0.5
Premix [c]	1.0	1.0	1.0	1.0
Salt	0.5	0.5	0.5	0.5
Calculated value, % [d]				
Crude protein	15.60	15.72	15.84	15.96
Lysine	0.76	0.76	0.75	0.74
Calcium	0.72	0.72	0.72	0.71
Phosphorus	0.60	0.60	0.60	0.60

a, b, c, d as the footnotes described in Table 3.

TABLE 5 COMPOSITION OF ALPC DIETS FOR FINISHER PIGS (EXP. 6)

Diet ALPC substituted for SBM [a]	A --	B 33%	C 66%	D 100%
Ground corn (4-02-935) [b]	83.1	83.3	83.4	83.5
Soybean meal, dehulled (5-04-612) [b]	12.9	8.6	4.3	--
Alfalfa leaf protein concentrate	--	4.3	8.6	12.9
Calcium phosphate, dibasic (6-01-080) [b]	1.4	1.4	1.4	1.4
Limestone (6-02-632) [c]	1.1	0.9	0.8	0.7
Premix [c]	1.0	1.0	1.0	1.0
Salt	0.5	0.5	0.5	0.5
Calculated value, % [d]				
Crude protein	13.62	13.70	13.79	13.88
Lysine	0.61	0.61	0.60	0.60
Calcium	0.72	0.70	0.71	0.72
Phosphate	0.61	0.61	0.61	0.61

a, b, c, d Same as in Table 3 with the exception that the antibiotic was Aureomycin at 55 mg/kg of complete diet.

Feed and water were supplied *ad libitum*. The body weight and feed consumption were measured on the 1st, 19th and 35th day during this 5-week feeding trial.

2) Digestion and Nitrogen Balance Trial - Experiment 7.

Twelve crossbred barrows averaging 11.8 kg were used to determine the protein and energy digestibilities and nitrogen balance of starter diets where ALPC replaced 0, 66% or 100% of the dehulled soybean meal (Experiment 7). The compositions of three diets were the same as those used in Experiment 4 as shown in Table 3.

Pigs selected from 4 litters with 3 barrows of each litter were housed individually in metabolism cages. Split plot design with diet as an main plot effect, litter as an block effect and period as subplot effect were used in this trial. The methods and procedures were the same as those used in Experiment 2. The digestibility of protein and energy of ALPC were calculated by simultaneous equations.

Feed Preference Trial (Experiment 8)

Twenty crossbred pigs averaging 10.2 kg including 7 gilts and 13 boars were used to evaluate palatability of ALPC. Pigs were housed in an environmentally controlled nursery with a concrete slotted floor. Two self-feeders were put in a pen. The experimental diets were corn-dehulled soybean meal and a corn-ALPC diet in which ALPC was substituted completely for dehulled soybean meal. The compositions of these two diets were the same as diet A and diet D in Table 3.

The experimental diets and water were offered *ad libitum* to the pigs for 23 days. The feeder locations were rotated every day. Feed intake was measured and intake of each diet was expressed as a percentage of total intake.

Carcass Characteristics and Color of Muscle and Fat (Experiment 9)

Twenty-four barrows averaging 99 kg were used to determine the effects of ALPC on the carcass characteristics and color of muscle and fat. Six barrows from each treatment at the end of feeding finisher pig trial (Experiment 6) were slaughtered following an over night fast. The right side of each carcass was cut as recommended by the Pork Carcass Committee of the Reciprocal Meats Conference (National Livestock and Meat Board, 1952). Backfat thickness was calculated as the average of measurements taken at the first rib, last rib and last lumber verterbra. Length of the carcass was taken from the anterior tip of the aitch bone to the anterior edge of the first rib. Planimeter readings on the cross sectional area of the *longissimus* muscle were made from tracings taken at the tenth rib. The sample of loin eye at the tenth rib interface were evaluated the color of fat and muscle by visual measurement under a fluorescent day-light lamp, 100 ft candles (Kauffman *et al* 1969; National Pork Producers Council 1976). Color of backfat at first rib was measured with Hunterlab Reflectance Spectrophotometer, Model D 54 P-5. The percentage of light reflected in the region of 400 to 710 nm, Hunter L_L (lightness) a_L (for redness-greeness) b_L (for yellowness-greeness) and CIE (International Commission on Illumination) Y, x, y values using Illuminant C were read. The value of x (red) and y (green) represented the relative percentages of each of the primary colors present in the backfat. These were calculated from the CIE X, Y, Z values.

Statistical Analysis

All the data were analyzed statistically by means of analysis of variance (ANOVA) (Snedecor and Cochran, 1967) and Duncans Multiple Range Test (Steel and Torrie, 1969). The daily gain in feeding trial, Experiment 1, 4, 5 and 6, was adjusted for initial weight and the carcass characteristics as dressing percent, carcass length, backfat, etc. were adjusted for slaughter weight with analysis of covariance if the linear model was significant ($P < .10$). The computer program of Statistical Analysis System (SAS) was used to analysis all the data (Barr et al 1976).

An Economic Evaluation of ALPC As Feed Ingredient for Swine (Experiment 10)

Paramatric linear programming was used to estimate the potential value and usage level of ALPC as a new feed ingredient in the diet of growing pigs, 10 kg to 20 kg (Experiment 10). Information needed to make this evaluation were: 1) the nutritional specifications of the ration in which the ingredient was used; 2) the nutritional values of all ingredients that might be used to satisfy the nutritional specifications of the ration, including nutrient values for the new ingredient and

3) market prices of all feed ingredients that might go into a least cost ration. These three sets of specification were used by linear programming to determine the combination of ingredients that supplied all of the required nutrients in a ration at least cost.

The nutritional specifications of the ration used were those nutrient requirements of the growing pig, 10 to 20 kg (NRC, 1979). The nutritional value of the selected feed ingredients, such as corn (4-02-035), sorghum (4-04-444), dehulled soybean meal (5-04-612), soybean meal (5-04-604), dehulled sunflower meal (5-04-739), meat and bone meal (5-09-322), mono and dicalcium phosphate (Ca 18%, P 21%) and limestone were obtained from NRC (NRC, 1979). The composition of the 1% premix included .5% vitamin premix, .1% trace mineral premix, .25% antibiotic premix and .15% diluent - corn (4-02-935). The nutrient composition and biological availability of ALPC used were those values obtained from the above in vivo trials. The ingredient prices of the feed ingredient were those recorded in Kansas City (Feedstuff, May 12, 1980). The price of premix ingredient were the same as those for the Experiment 4. An IBM control program for parametric cost ranging of ALPC in the diet was used (IBM 1969). The results obtained from this program were expressed as the relationship of the cost of ALPC ($/kg) and the level of ALPC used (% of diet).

RESULTS AND DISCUSSION

Chemical Composition of ALPC

1) Data from proximate analysis, carotene, pigment and gross energy.

Results of the proximate analysis and analysis for ammonina nitrogen, carotene, pigment and gross energy of alfalfa leaf protein concentrate are shown in Table 6.

ALPC is a high protein and low fiber feed product. ALPC contained 55.81% crude protein, on a dry matter basis, which was higher than that found in dulled soybean meal (SBM) and dehydrated alfalfa meal, 19.02%. It included .07% urea and ammoniacal nitrogen in ALPC. ALPC only contained 2.59% crude fiber which was lower than that found in dehulled soybean meal 4.33% and dehydrated alfalfa meal, 26.20%. ALPC contained 10.41% ether extract which included not only fat but also 300 mg/kg carotene and 1184 mg/kg pigment. ALPC contained high ash (11.95%) in which 40.67% of the ash was acid-insoluble. These chemical compositions were similar to those observed by Jorgenson (1975) and Kuzmick and Kohler (1977). ALPC contained 5.37 kcal/g gross energy which was higher than that of dehulled soybean meal, 4.66 kcal/g.

2) Amino Acid Composition.

The amino acid composition of alfalfa leaf protein concentrate is presented in Table 7. Amino acid determinations showed resonable agreement with that found by Kuzmicky

TABLE 6 CHEMICAL COMPOSITION OF ALFALFA LEAF PROTEIN CONCENTRATE

Composition, % [a]	ALPC	Dehydrated alfalfa meal, 1-00-023	Dehulled soybean meal, 5-04-612[b]
Crude protein	55.81	19.02	53.33
Urea and ammoniacal nitrogen	0.07	ND	ND
Ether extract	10.41	2.72	1.11
Crude fiber	2.59	26.20	4.33
Nitrogen free extract	19.24	41.60	34.73
Ash	11.95	10.50	6.50
Calcium	1.64	1.57	0.30
Phosphorus	0.67	0.24	0.69
Carotene, mg/kg	300	120	ND
Pigment, mg/kg	1184	400-450	ND
Gross energy, kcal/g	5.37	4.11	4.66

[a]As dry matter basis.

[b]International feed number (NRC, 1979 and National Academy of Sciences, 1971).

[c]Not determined.

TABLE 7 AMINO ACID COMPOSITION OF ALFALFA LEAF PROTEIN CONCENTRATE

Amino acid	ALPC		
g/16g Nitrogen	Pro-Xan[a]	Pro-Xan#1[b]	Pro-Xan#2[b]
Essential amino acids			
Arginine	6.19	6.45	6.18
Histidine	4.13	2.32	2.40
Isoleucine	4.22	5.60	5.28
Leucine	8.96	9.29	9.18
Lysine	6.11	5.92	6.30
Methionine	1.82	2.30	2.16
Cystine	1.27	1.18	1.31
Phenylalanine	6.33	5.94	5.86
Tyrosine	4.77	4.75	4.43
Threonine	5.17	5.10	5.07
Tryptophan	2.99	ND[c]	ND[c]
Valine	5.29	6.33	6.54
Total E. A. A.	57.25	55.18	54.71
Nonessential amino acids			
Alanine	6.37	6.28	6.11
Aspartic acid	10.12	10.03	10.26
Glycine	5.52	5.52	5.30
Glutamic acid	11.21	11.35	11.39
Proline	4.94	4.86	4.68
Serine	4.59	4.33	4.40
Crude protein	55.81	62.81	51.37

[a]Present ALPC, rotary drum dried, exit gas temperature at 104 C.

[b]#1 hot air dried, #2 freeze-dried. Kuzmick and Kohler, 1977.

[c]ND = Not determined.

and Kohler (1977). Methionine and cystine are low in alfalfa leaf protein concentrate as is the case for many kinds of leaf protein. The total essential amino acids in ALPC was 57.25% of the protein.

The essential amino acid composition of ALPC compared closely with dehulled soybean meal, as shown in Table 8. Lysine content of ALPC was 3.41%, on dry matter basis, and was similar to that found in dehulled soybean meal (3.53%). ALPC contained 1.67% tryptophan which was twice the amount in dehulled soybean meal. The sulfur amino acids would appear to be the first limiting amino acid in ALPC and dehulled soybean meal. A chemical score and a requirement index were proposed as a chemical estimate of the nutrive value of proteins (Rama Rao *et al.*, 1964). The calculated chemical score, requirement index and the limiting amino acids of ALPC and dehulled soybean meal are shown in Table 9.

Chemical score of ALPC, expressed as percent of the most limiting amino acid in protein as compared with the requirement pattern of the growing pig, was 54.4% which was slightly higher than that of dehulled soybean meal at 50.9%. The second and third limiting amino acids in ALPC calculated as percent of requirement levels (NRC, 1979) were isoleucine 68.1% and lysine 69.4%. Lysine and isoleucine might be co-limiting amino acids. The second limiting amino acid would be lysine, 61.1%, if lysine requirement of starter pig was 1.00%, dry matter basis (Allee, 1980).

TABLE 8. ESSENTIAL AMINO ACID COMPOSITION OF ALFALFA LEAF PROTEIN CONCENTRATE COMPARED TO DEHULLED SOYBEAN MEAL

Essential amino acid	A L P C		Dehulled soybean meal 5-04-612[a]		Requirement of pig, 10-20kg[b]
	g/16gN	g/100g D.M.	g/16gN	g/100g D.M.	g/100g D.M.
Arginine	6.19	3.45	7.63	4.11	.25
Histidine	4.13	2.30	2.67	1.44	.22
Isoleucine	4.22	2.36	5.36	2.89	.62
Leucine	8.96	5.00	7.83	4.22	.75
Lysine	6.11	3.41	6.55	3.53	.88
Methionine	1.83	1.02	1.45	0.78	.57
Cystine	1.27	.71	1.45	0.78	
Phenylalanine	6.33	3.53	4.32	2.33	.88
Tyrosine	4.77	2.66	4.12	2.22	
Threonine	5.17	2.89	3.93	2.12	.57
Tryptophan	2.99	1.67	1.37	0.74	.14
Valine	5.29	2.95	5.57	3.00	.62
TOTAL E A A	57.25	31.95	52.25	28.16	5.50
Crude protein %		55.81		53.89	20

[a]International feed number.

[b]NRC, 1979.

TABLE 9 CHEMICAL SCORE AND ESSENTIAL AMINO ACID INDEX OF PROTEIN BASED ON THE REQUIREMENT PATTERN[a]

Essential	ALPC % [c]	Limiting order % [c]	Dehulled soybean meal 5-04-612[b]	Limiting order
Arginine	100		100	
Histidine	100		100	
Isoleucine	68.1	2 (3)[d]	86.5	4
Leucine	100		100	
Lysine	69.4(61.1)[d]	3 (2)[d]	74.4(65.5)[d]	3 (2)[d]
Met. + Cys.	54.4	1	50.9	1
Phe. + Tyr.	100		95.9	
Threonine	90.7	5	69.0	2 (3)[d]
Tryptophan	100		97.9	6
Valine	85.3	4	89.8	5
Chemical score, %	54.4	1	50.9	1
Requirement index % [e]	85.1		84.7	

[a]Amino acid requirement of pig, 10-20 kg live weight (NRC, 1979).

[b]International feed number (NRC, 1979).

[c]Percent of the limiting amino acid in protein as compared with the requirement pattern.

[d]Lysine requirement is 1.00%, dry matter basis (Allee, 1980a).

[e]Calculated according to Oser (1951) using amino acid requirements as standard instead of egg protein.

The requirement index of ALPC was calculated according to Oser (1951) using essential amino acid requirements of the growing pig (NRC, 1979) as standards instead of egg protein. The requirement index of ALPC was 85.1% which was similar to that found in dehulled soybean meal 84.7%. Rama Rao et al (1964) reported that a requirement index was highly significant in correlation with the biological value for the growing rat.

3) Element Composition.

Alfalfa leaf protein concentrate is high in mineral composition as shown in Table 10. Among those minerals, calcium was the higest, 1.64% and copper was the lowest, 11.89 ppm. Phosphorus content of ALPC was .67% and was similar to that of dehulled soybean meal. ALPC was rich in iron, .46% compared to that in dehydrated alfalfa meal .034% and dehulled soybean meal .013%.

4) Fatty Acid Composition.

The fatty acid composition in alfalfa leaf protein concentrate is presented in Table 11. ALPC contained 63.7% unsaturated fatty acids. This was higher than that of tallow 2.5% and butter 3.8%. The amount of linolenic acid (C18: 3) in ALPC was 51.9% which was similar to that found by Hove et al. (1974) and was higher than that found in soy 7.1%.

Limiting Order of Amino Acids in ALPC for Growing Pigs

1) Feeding Trial - Experiment 1.

The results obtained in this experiment are shown in

TABLE 10 ELEMENT COMPOSITION OF ALFALFA LEAF PROTEIN CONCENTRATE, DEHYDRATED ALFALFA AND DEHULLED SOYBEAN MEAL.

Element[a]	ALPC	Dehydrated alfalfa 1-00-023[b]	Dehulled soybean meal 5-04-612[b]
Calcium, Ca, %	1.64	1.57	.30
Phosphorus, P, %	.67	.24	.69
Iron, Fe, %	.46	.034	.013
Magnesium, Mg, %	.25	.28	.30
Potassium, K, %	.80	.26	2.24
Sodium, Na, %	.030	.087	.378
Zinc, Zn, ppm	23.88	18.48	50.00
Manganese, Mn, ppm	108.7	30.43	30.56
Copper, Cu, ppm	11.89	8.91	40.33
Crude Ash, %	11.95	10.05	6.50
HBr-insoluble ash, %	4.84	ND[c]	ND[c]

[a]As dry matter basis.

[b]International feed number (NRC, 1979).

[c]Not determined.

TABLE 11. FATTY ACID COMPOSITION OF ALFALFA LEAF PROTEIN CONCENTRATE (g/100g total fatty acids)

Item		A L P C	A L P C[a]	Soy[b]
Saturated acids				
Caproic	C 6:0	.14	ND[c]	ND
Caprylic	C 8:0	.19	ND	ND
Capric	C10:0	.13	ND	ND
Lauric	C12:0	2.38	ND	ND
Myristic	C14:0	2.95	.7	ND
Pentadecanoic	C15:0	ND	3.1	ND
Palmitic	C16:0	29.76	19.4	8.5
Heptadecanoic	C17:0	ND	1.0	ND
Stearic	C18:0	.71	3.1	3.5
TOTAL		36.26	27.3	12.0
Unsaturated acids				
Palmitoleic	C16:1	ND	2.5	
Oleic	C18:1	0.84	1.1	17.0
Linoleic	C18:2	11.00	11.4	54.0
Linolenic	C18:3	51.90	51.4	7.1
Total		63.74	66.4	78.1
Unknown[d]		--	6.3	

[a]Hove *et al* 1974.

[b]Goddard and Goodall, 1959 Agr. Res. Service, USDA.

[c]Not determined.

[d]Fatty acid not identified.

TABLE 12. PERFORMANCE OF GROWING PIGS FED ALPC DIETS SUPPLEMENTED WITH DL-METHIONINE, L-LYSINE AND L-ISOLEUCINE[a] (EXPERIMENT 1)

Diet	Daily gain, kg		Feed/Gain	
	Mean	S E[b]	Mean	S E[b]
A Basal diet, 20% ALPC	.23[e]	.02	3.43[cd]	.22
B Basal + .3% methionine	.30[cd]	.05	3.18[cd]	.26
C Basal + .35% lysine	.24[de]	.05	3.91[c]	.43
D As B + .35% lysine	.27[de]	.03	3.48[c]	.46
E As D + .20% isoleucine	.34[c]	.04	2.72[de]	.14
F Corn-soybean, 17% protein	.56[f]	.07	2.20[e]	.14

[A]Each value is the mean of four pens of three pigs each with an average initial weight 10.7kg for a 28 days feeding trial.

[b]Standard error.

[cdef]Means in a column with different superscripts differ significantly ($P < .05$).

Table 12. Supplemention of the basal diet with DL-methionine (.30%) resulted in improvement both in average daily gain and feed efficiency ($P<.05$). Supplementing L-lysine (.35%) in the basal diet did not significantly affect the performance of the growing pigs. Those results indicated that methionine was the first limiting amino acid in ALPC for the growing pig.

The addition of lysine in the presence of methionine did not significantly improve the daily gain or feed efficiency. It indicated that lysine was not the second limiting amino acid in ALPC, although lysine was calculated to be the second limiting amino acid. This may be due to under estimation about the biological availability of lysine or over estimation about the lysine requirement of pig at 1.0%, when the diet contained a low level of crude protein, 10%.

The addition of L-isoleucine (.2%) in the presence of methionine and lysine resulted in an improvement in daily gain and feed efficiency over that observed when the diet was supplemented with methionine and lysine ($P<.05$). These results indicated that isoleucine might be the second limiting amino acid with the possibility that isoleucine and lysine might be the co-limiting amino acids. Although the daily gain of pigs fed basal diet with 10% crude protein was less than that pigs for corn-SBM diet with 17% crude protein ($P<.05$), the feed efficiency was not significant difference between two diets.

2) Nitrogen Balance Trial - Experiment 2.

The results of the nitrogen balance trial are shown in

Table 13. The apparent protein digestibility of ALPC was 80.21%. The biological value expressed as nitrogen retained as percent of nitrogen digested was 68.57%.

Supplementation of basal diet with amino acids did not affect the protein digestibility but increased nitrogen retention. The addition of DL-methionine (.30%) to the basal diet increased nitrogen retention 0.88 g per day and biological value to 73.6% ($P<.05$). The addition of L-lysine (0.35%) in the presence of methionine decreased nitrogen retention per day below the value of methionine alone. This might be due to creating an amino acid imbalance. The addition of isoleucine (.20%) in the presence of methionine and lysine resulted in greater nitrogen retention by .32 g per day over that observed with methionine and lysine. However, those difference were not satistically significant. Those data confirmed the results of the growth trial indicating that methionine was the first limiting amino acid. In earlier experiments with rats, it was observed that methionine was the first limiting amino acid (Hove et al 1974, Bickoff, 1975). Nanda et al (1977) reported that methionine, cystine and isoleucine in the steam coagulated plant protein concentrate (PPC) were less than those in the acid coagulated PPC.

3) Digestibility of Amino Acids in ALPC.

The apparent digestibility of amino acids in ALPC is shown in Table 14. The digestibilities of methionine, cystine, lysine and isoleucine were 81.84%, 84.44%, 84.37% and 77.92%, respectively. The digestibility of total amino acids was 81.33%.

TABLE 13 APPARENT PROTEIN DIGESTIBILITY AND NITROGEN RETENTION OF PIGS FED ALPC DIETS SUPPLEMENTED WITH DL-METHIONINE, L-LYSINE AND L-ISOLEUCINE (EXPERIMENT 2)[a]

Diet	Apparent protein digestibility, %		Nitrogen retention			
			G/day		BV[b], %	
	Mean	SE[c]	Mean	SE[c]	Mean	SE[c]
A basal diet	80.2[d]	1.70	6.10[e]	.58	68.6[e]	3.40
B as A + .3% methionine	82.2[d]	.90	6.79[d]	.25	73.6[d]	1.00
D as B + .35% lysine	81.1[d]	1.43	6.55[de]	.40	70.4[de]	1.85
E as D + .2% isoleucine	80.5[d]	1.07	6.87[d]	.33	73.3[d]	1.44

[a]Each value is the mean of two periods of three pigs each averaging 14.3 kg initially.

[b]Biological value, nitrogen retained as percent of nitrogen digested.

[c]Standard error.

[de]Values with different superscripts are different ($P < .05$).

TABLE 14 APPARENT DIGESTIBILITY OF AMINO ACIDS IN ALPC (EXP. 3)

ITEM	ALPC		ALPC + .3% DL-methionine		Average
	Mean	S E	Mean	S E	
Indispensable amino acid					
Arginine	79.1	1.15	83.4	.26	81.3
Cystine	84.4	1.37	88.0	.09	86.2
Histidine	83.4	1.28	80.2	.33	81.8
Isoleucine	77.9	1.82	79.8	.21	78.9
Leucine	82.1	1.57	82.1	.28	82.1
Lysine	84.4	1.26	84.6	.53	84.5
Methionine	81.8	1.18	92.2	.23	87.0
Phenylalanine	76.3	3.03	81.5	.20	78.9
Tyrosine	80.5	2.03	83.8	.62	82.1
Threonine	81.8	1.45	81.5	.14	81.7
Valine	82.0	1.07	81.9	.56	81.9
Dispensable amino acid					
Alanine	81.8	.68	81.0	.64	81.4
Aspartic acid	82.6	1.44	82.7	.25	82.6
Glutamic acid	82.0	1.59	82.6	.48	82.3
Glycine	80.6	1.55	79.9	.38	80.3
Proline	78.1	1.86	82.1	.40	80.1
Serine	79.5	1.42	79.1	.19	79.3
Total amino acids	81.3	1.55	82.3	.28	81.8
Crude protein	80.3	1.60	81.1	.59	80.7
DL-methionine			100.0	.00	100.0

[a]Each value is the mean of three pigs averaging 13.2 kg initially.

[b]Standard error.

when DL-methionine (.3%) was added to the ALPC diet, the digestibility of methionine was increased to 92.2% which was due to high digestibility of the added DL-methionine (DL-methionine digestibility = 100%). The digestible methionine, cystine, lysine and isoleucine in ALPC were .83%, .6%, 2.88% and 1.84%, dry matter basis, respectively.

Kuiken and Lyman (1948) developed the fecal analysis method to determine the availability of the indispensable amino acids in several proteins. Amino acid availability determined by the fecal analysis method were derived from their apparent digestibility by correcting the latter estimates for those amino acids of metabolic origin in the feces. The metabolic fecal amino acid excretion is usually determined from feces of animals fed protein-free diets. The value of amino acid availability of ALPC will be larger than the apparent digestibility of amino acids measured in this study. The discussion of fecal analysis method for the estimation of amino acid availability can be found in the literature (Eggum 1973; Meade, 1972).

Alfalfa Leaf Protein Concentrate As Feed Ingredient for Swine

1) Feeding Trial

The performance of pigs fed different level of alfalfa leaf protein concentrate diets during the starter (Exp. 4), grower (Exp. 5) and finisher (Exp. 6) phases are shown in Table 15. ALPC substituted for dehulled soybean meal 33%, 66% or 100% in the diet did not significantly affect feed intake or feed efficiency during the starter, grower or finisher phases.

TABLE 15 PERFORMANCE OF PIGS FED VARIOUS LEVELS OF ALFALFA LEAF PROTEIN CONCENTRATE DIET (EXPERIMENT 4, 5 AND 6)[a]

Diet	A		B		C		D	
ALPC replaced for SBM, %	0%		33%		66%		100%	
	Mean	S E[b]	Mean	S E[b]	Mean	S E[b]	Mean	S E[b]
Starter phase (7.5-25.2 kg, Exp. 4)								
Daily gain, kg	$.52^{c}$	.03	$.51^{c}$	.03	$.52^{c}$	.03	$.47^{c}$	.02
Daily feed intake, kg	1.03^{c}	.07	0.98^{c}	.07	1.06^{c}	.07	$.99^{c}$	.06
Feed/gain	1.96^{c}	.08	1.92^{c}	.06	2.03^{c}	.06	2.09^{c}	.03
Grower phase (27.6-62 kg, Exp. 5)								
Daily gain, kg	$.83^{cd}$	.03	$.79^{d}$	.03	$.84^{c}$	.05	$.82^{cd}$	.03
Daily feed intake, kg	2.25^{c}	.10	2.18^{c}	.03	2.37^{c}	.15	2.22^{c}	.11
Feed/gain	2.73^{c}	.04	2.77^{c}	.06	2.82^{c}	.04	2.72^{c}	.08
Finisher phase (62-91.6 kg, Exp. 6)								
Daily gain	$.84^{e}$	.03	$.83^{e}$	.05	$.93^{c}$	.05	$.90^{d}$	.04
Daily feed intake	2.99^{c}	.17	3.02^{c}	.18	3.23^{c}	.19	3.00^{c}	.15
Feed/gain	3.58^{c}	.14	3.67^{c}	.17	3.50^{c}	.16	3.35^{c}	.12
Entire trial (8.7-91.6 kg)								
Daily gain, kg	$.74^{d}$	.05	$.73^{d}$	.03	$.78^{c}$	.03	$.74^{d}$	.02
Daily feed intake, kg	2.12^{c}	.09	2.09^{c}	.08	2.25^{c}	.12	2.10^{c}	.10
Feed/gain	2.91^{c}	.07	2.88^{c}	.05	2.90^{c}	.04	2.83^{c}	.06
Days to 100 kg wt., day	173^{c}	2.4	174^{c}	3.0	168^{c}	4.1	170^{c}	4.4

[a]Each value is the mean of four pens of three pigs each with the exception of six pigs per pen during the starter phase.

[b]Standard error.

[c, d, e]Means in a row different superscripts differ significantly ($P<.05$).

level of ALPC did not affect the daily gain during the starter (7.5 to 25 kg) or grower (28 to 62 kg) phase. During the finisher period (62 to 92 kg), the average daily gain for pigs fed ALPC diets, in which ALPC was substituted for dehulled soybean meal at 66% or 100%, was greater than that for pigs fed control diet ($P<.05$).

For the entire trial, level of ALPC did not affect feed efficiency but the average daily gain was improved when 66% of the dehulled soybean meal was replaced with ALPC ($P<.05$). The pigs fed the corn-ALPC diet performed similarly to the pigs fed the corn-SBM diet. Level of ALPC did not significantly affect the feed intake, feed efficiency or the number of days to 100 kg body weight (Table 15).

These results suggest that ALPC can be used to replace dehulled soybean meal in a corn diet for pigs from 8.7 kg to 95 kg without any adverse effect on feed efficiency or average daily gain.

2) Digestion and Nitrogen Balance Trial

The results of the digestion and nitrogen balance trial are shown in Table 16. Apparent digestibility of energy and protein were decreased as the level of ALPC increased in the diet for starter pigs ($P<.05$). However, level of ALPC did not significantly affect the nitrogen retention ($P>.05$). As shown in Table 17, it was assumed that the digestibility of protein and energy of dehulled soybean meal was 90% and 94.2%, respectively (NAS, 1971), therefore allowing calculation by the use of

TABLE 16 APPARENT DIGESTIBILITY AND NITROGEN RETENTION OF PIGS FED VARIOUS LEVELS OF ALFALFA LEAF PROTEIN CONCENTRATE (EXPERIMENT 7)[a]

Diet	A		C		D	
ALPC replaced for SBM	0%		66%		100%	
	Mean	S E[b]	Mean	S E[b]	Mean	S E[b]
Energy digestibility,%	85.8[e]	.52	82.9[f]	.59	81.8[f]	.51
Digestible energy, kcal/g	3.70[e]	.02	3.69[e]	.03	3.69[e]	.23
Protein digestibility, %	83.8[e]	.89	80.9[ef]	.80	79.9[f]	.94
Nitrogen retention, g/day	12.3[e]	.44	12.1[e]	.31	12.0[e]	.48
ABV[c]	59.5[e]	.75	58.6[e]	1.07	56.5[e]	1.29
BV[d]	71.0[e]	.98	72.4[e]	1.28	70.6[e]	1.21

[a]Dry matter basis; Each value is the mean of two periods of four pigs each averaging 11.8 kg initially.

[b]Standard error.

[c]Apparent biological value is expressed by nitrogen retained as percent of nitrogen intake.

[d]Biological value is expressed by nitrogen retained as percent of nitrogen digested.

[ef]Means in a row different superscripts differ significantly ($P<.05$).

TABLE 17 APPARENT DIGESTIBILITY OF PROTEIN AND ENERGY AND DIGESTIBLE ENERGY OF ALFALFA LEAF PROTEIN CONCENTRATE[a] COMPARED TO DEHULLED SOYBEAN MEAL

Item	ALPC			Dehulled soybean meal 5-04-612[c]
	Diet C[b]	Diet D[b]	Average	
Protein digestibility, %	83.15	83.89	83.52	90.0
Energy digestibility, %	77.03	78.39	77.71	94.2
Digestible energy, kcal/g	4.137	4.210	4.173	4.39

[a]Value calculated from the result of Exp. 7.

[b]ALPC substituted for dehulled soybean meal in diet C and diet D are at 66% and 100%, respectively.

[c]International feed number, NAS (1971).

simulataneous equations of the digestible energy and protein in ALPC. The digestibility of protein in ALPC calculated from diet C was 83.15% which was similar to that calculated from diet D, 83.89%. The energy digestibility of ALPC calculated from diet C and diet D were 77.03% and 78.39%, respectively. Since the calculated values of diets C and D were similar, the average values were used to estimate the protein and energy digestibilities of ALPC for the young pigs. The digestibility of ALPC portion of the diet was 83.5 and 77.7% for protein and energy, respectively. Apparent protein digestibility of ALPC was higher than previously determined in Experiment 2, 80.21% in which a purified diet with 20% ALPC was the protein source. This may be due to over estimate of the protein digestibility of dehulled soybean meal, which was assumed to be 90% digestible for the young pig, or due to differences between experiments.

Feed Preference

The results of feed preference trial (Experiment 9) are shown in Table 18. Pigs consumed 87% of the corn-SBM diet and 13% of the corn-ALPC diet, indicating a marked preference for the corn-SBM diet when given a choice. Leamaster and Cheeke (1979) reported that alfalfa meal had low palability to swine. They reported that diets supplemented with as little as 1% alfalfa in the diet, pigs exhibited a preference for a diet deviod of alfalfa. Myer et al. (1975) reported that 20% of ALPC, which contained 36% crude protein, in the diet for

TABLE 18 EFFECT OF ALFALFA LEAF PROTEIN CONCENTRATE ON FEED PREFERENCE OF SWINE[a] (EXPERIMENT 8)

Avg. initial weight, kg	10.2 ± 0.51[b]
Avg. final weight, kg	22.0 ± 0.92[b]
Avg. daily gain, kg	0.51 ± 0.02[b]
Avg daily feed intake, kg	1.144
Diet A (Corn-SBM diet), kg	1.000 (87.4%)[c]
Diet D (Corn-ALPC diet) kg	0.144 (12.6%)[c]
Diet A/Diet D	6.94

[a]Each value is the mean of twenty pigs (7 gilts and 13 barrows).

[b]Standard error.

[c]Percent of feed intake.

starter pig decreased the growth rate. They suggested that the decrease may be due to higher lysine requirement of growing pigs, poor digestibility or the unpalatability of ALPC to young pig. However, level of ALPC substituted for the dehulled soybean meal did not affect feed intake or feed efficiency during the starter, grower or finisher phases as shown in Experiment 4, 5 and 6. This indicated that when ALPC was added to the diet, regardless of the level, the pigs consumed the same amount of feed as the control group.

Carcass Characteristics and Fat Color

1) Carcass characteristics

The effect of the addition of ALPC on the carcass characteristics is shown in Table 19. ALPC substituted for the dehulled soybean meal 66% or 100% did not affect the percentage of the carcass in the four lean cuts, carcass length, backfat thickness or loin eye area compared to pigs fed the control diet. ALPC substituted for the dehulled SBM 66% for pigs increased the dressing percent ($P<.05$). Pigs fed diet B were shorter and had lower dressing percentages than pigs fed the other diets. This may be due to the lighter slaughter weight of pigs fed diet B. There was a trend toward decreased loin eye area as ALPC used in the diet.

Myer et al. (1975) reported that there was a trend toward decreased percent of lean cuts and lower market grade with increased ALPC levels. Brown et al (1973 a and 1973 b) reported an estimate lysine requirement of .48% for maximum daily gain,

TABLE 19 EFFECT OF ALPC ON CARCASS CHARACTERISTICS OF BARROWS[a] (EXPERIMENT 9)

Diet ALPC substitute for SBM, %	A 0%		B 33%		C 66%		D 100%	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Slaughter weight, kg	101.5^{c}	1.93	93.7^{d}	2.33	102.5^{c}	0.91	98.4^{cd}	2.04
Dressing percent, %[b]	74.9^{d}	.48	73.3^{e}	.10	75.9^{c}	1.01	74.7^{d}	.42
Carcass length[b], cm	80.5^{c}	1.34	78.2^{d}	.76	80.0^{c}	.89	79.0^{cd}	1.09
Backfat thickness, cm	3.43^{c}	.04	3.00^{e}	.14	3.50^{c}	.22	3.10^{c}	.16
Loin eye area, sq. cm	30.1^{c}	1.23	27.4^{c}	1.18	27.9^{c}	1.42	27.0^{c}	.74
Four lean cuts[b], %	54.7^{cd}	0.77	55.3^{cd}	2.14	54.2^{d}	1.56	56.3^{c}	1.05

[a]Each value, mean ± standard error, is the mean of six pigs with the exception of five pigs in diet A.

[b]Covariance adjustment was made to a constant slaughter weight.

[cde]Means in a row different superscript differ significantly ($P < .05$).

.50% for maximum four lean cuts, .60% for maximum loin eye area and .62% for maximum gain/feed. Calculated lysine levels of the control diet and ALPC diets were 0.61 and 0.60% respectively. The ALPC diet may have met the lysine requirement for maximum growth rate and four lean cuts but it may be marginal for loin eye area and gain/feed.

Unsaturated fat can be produced in pork by feeding unsaturated fats in the diet. Brooks et al. (1971) and Laudert (1974) reported that the unsaturated fatty acids of backfat and *longissimus* muscle lipid were increased as unsaturated fatty acids increased in the diet. From the data of fatty acid composition of ALPC (Table 11), more linolenic acid in lipid tissue and pork of pigs fed ALPC diet than pigs fed SBM diet would be expected.

2) Color of Muscle and Fat

No significant differences in the visual scores of muscle or fat color were found with the varying levels of ALPC (Table 20). The effect of ALPC on the backfat color as measured by the Reflectance Spectrophotometer is shown in Table 22 and Figure 1. The plotted data indicate a peak in the area of 490 to 510 nm and another from 650 to 700 nm on the spectral reflectance curve (Figure 1). Level of ALPC did not affect the percent reflectance at either 500 or 650 nm when these data were analyzed statistically. Backfat from pigs fed diets C or D was mor yellow (higher b^+ values) than backfat from pigs fed the control

TABLE 20 EFFECT OF ALPC AS FEED INGREDIENT ON COLOR[a] OF MUSCLE AND FAT (EXPERIMENT 9)

Diet	A	B	C	D
ALPC substituted for SBM, %	-	33	66	100
Muscle Color Score[b]				
Mean	3.2[d]	2.8[d]	2.9[d]	2.9[d]
S E	.22	.16	.24	.08
Fat Score[b]				
Mean	2.4[d]	2.2[d]	2.5[d]	2.0[d]
S E	.40	.33	.33	.24

[a]Visual measurement; samples taken at 10th rib interface; each value is the mean ± standard error of mean of 6 pigs with the exception of 5 pigs in diet A.

[b]Loin eye muscle at tenth rib interface; color score: 1 = pale, 2 = slightly pink, 3 = grayish pink or normal, 4 = slightly dark and 5 = dark.

[c]Out layer of loin eye area at tenth rib interface; color score: 1 = white, 2 = very slight yellow, 3 = slight yellow.

[d]There is no significant among the diets either on muscle color score or fat color.

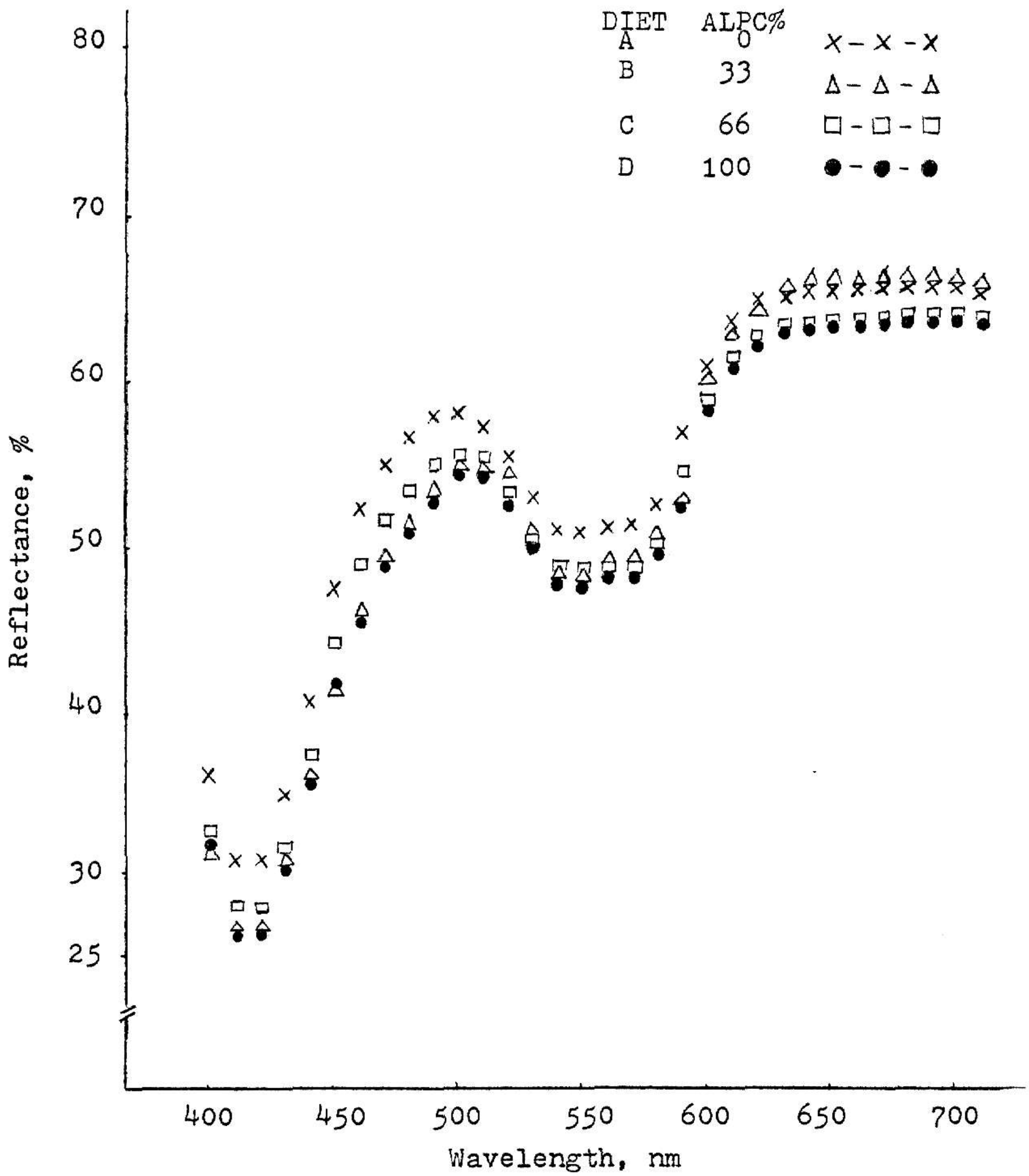

Figure 1. Spectral reflectance curve of backfat from swine fed different levels of alfalfa leaf protein concentrate.

TABLE 21 EFFECT OF ALFALFA LEAF PROTEIN CONCENTRATE ON BACKFAT COLOR[a] (EXPERIMENT 9)

Diet	A	B	C	D
ALPC substituted for SBM	0%	33%	66%	100%
Reflectance, %				
at 500 nm	58.12[c]	55.48[c]	55.23[c]	54.24[c]
at 650 nm	65.82[c]	63.88[c]	65.81[c]	63.63[c]
Illuminant C[b], %				
x	33.24[c]	33.32[c]	33.86[d]	33.67[d]
y	33.33[e]	33.62[d]	34.11[c]	34.00[c]
Illuminant C, %				
L, lightness	74.25[c]	72.67[c]	72.93[c]	72.17[c]
a, redness	1.40[c]	1.36[c]	1.60[c]	1.28[c]
b, yellowness	7.57[d]	8.53[d]	10.46[c]	9.84[c]
b/a	9.62[c]	7.92[c]	8.62[c]	8.35[c]

[a]Backfat taken at the first rib; each value is the mean of 6 pigs with the exception of 5 pigs in the diet A.

[b]Value of x (red) and y (green) represented the relative percentage of the primary colors present in the backfat.

[cde]Means in a row different superscript differ significant ($P<.05$).

diet or diet B ($P < .05$). ALPC did not affect the lightness redness or the ratio of yellowness to redness (Table 21). The chromaticity coordinates, when plotted on a CIE chromaticity diagram, indicate a trend toward slightly more yellow backfat with 66 and 100% ALPC than with 0 and 33% ALPC. Although this trend toward increasing yellowness of backfat as ALPC is increased that is shown by the b^+ and the x, y values, the color change is of little practical importance since it can not be distinguished by the human eye.

Cost and Usage of ALPC in Diets for Starter Pigs

The results of the paramatric linear programming showed that the initial least cost formulation contained no ALPC because it was arbitrarily priced to be economically unacceptable for the ration. The computer than recalculated the ration composition at sucessively lower prices for ALPC until the price of the new ingredient, ALPC, was low enough (lower than 0.183 $/kg) for it to replace some of the other ingredients such as soybean meal and dehulled soybean meal that supplied the same nutrients. This procedure results in a series of prices at which use of ALPC would be feasible in successively larger quantities (Table 22). When ALPC was priced at .18$/kg, 2.98% ALPC was used with corn as the energy source. The usage level of ALPC was 21.87% when it was priced at 0.16$/kg with milo as the energy source. The highest level used in milo-corn diet and corn diet were 23.52% and 23.65% at ALPC costs of .084/kg and .106$/kg, respectively.

TABLE 22 PRICE AND USAGE OF ALPC IN FEED FORMULATION FOR STARTER PIGS[a] (EXPERIMENT 10)

Price of ALPC $/kg	Ingredient, %						
	ALPC	Corn 4-02-935[b]	Milo 4-04-383[b]	H.P.SBM[c] 5-04-612[b]	SBM 5-04-604[b]	Di-Ca-p	Lime-stone
.183	-	-	72.17	22.69	.65	1.61	1.38
.160	21.87	-	72.14	2.0	.20	1.61	.68
.144	22.76	4.15	67.93	-	1.40	1.61	.65
.084	23.52	8.56	63.31	-	.60	1.62	.89
.000	24.05	14.76	57.19	-	-	1.63	.87
.183	-	71.08	-	2.81	21.61	1.62	1.38
.180	2.98	71.08	-	-	21.54	1.62	1.28
.173	5.08	70.94	-	-	19.37	1.63	1.48
.106	23.65	72.29	-	-	-	1.69	.87
.000	24.20	71.77	-	-	-	1.68	.85

[a]Prices of ingredient were according to that in Kansas City (Feedstuff May 12, 1980).; Premix 1.5% in each diet contained salt .5%, vitamine premix .5%, mineral premix .10% antibiotic premix .25% and diluent-corn .15%.

[b]International feed number (NRC, 1979).

[c]Dehulled soybean meal.

CONCLUSION

Alfalfa Leaf Protein Concentrate (ALPC) is a high protein (55.81%) and low fiber (2.59%) feed product. Methionine was determined to be the most limiting amino acid with isoleucine appearing to be the second limiting amino acid. It is possible that isoleucine and lysine could be second co-limiting amino acids in ALPC for growing pigs. Level of ALPC did not affect the feed intake or feed efficiency during the starter, grower, finisher phases, or the number of days to 100 kilograms. Level of ALPC did not affect the daily gain during the starter and grower phases but ALPC substituted 66% or 100% of dehulled soybean meal (SBM) improved the daily gain during the finisher period ($P < .05$). For the entire period, pigs fed diet D (total replacement of soybean meal with ALPC) had the same performance as pigs fed control diet but they gained more slowly than pigs fed diet C (66% replacement of SBM with ALPC) ($P < .05$). Although the digestibilities of protein and energy of ALPC were lower than that of dehulled SBM, the nitrogen retention and digestible energy of the corn-ALPC diet were not significantly decreased by any level of ALPC in the diet for growing pigs. Level of ALPC did not significantly affect carcass characteristics or color of muscle and fat. These results indicated that ALPC could be used to replace dehulled SBM in a corn diet for pigs from 8.7 kg to 95 kg without any adverse effect on feed efficiency, rate of gain or carcass quality. These results suggest that ALPC can be used as a partial or total replacement for soybean meal in swine diets.

SUMMARY

A commercially prepared alfalfa leaf protein concentrate (ALPC) containing 55.8% crude protein was evaluated as a protein source for swine. Seventy-two crossbred pigs averaging 10.7 kg initially and 12 crossbred barrows averaging 14.3 kg initially were used to determine the limiting order of amino acids in ALPC for growing pigs by a feeding trial and nitrogen balance trial. Methionine was determined to be the most limiting amino acid. The results suggest that isoleucine may be the second limiting amino acid with the possibility that isoleucine and lysine may be second co-limiting amino acids. Three feeding trials involving 96 starter pigs, 48 grower pigs and 48 finisher pigs were used to determine the feeding value of ALPC for swine. No adverse effects on growth rate or feed efficiency were observed with any level of ALPC at 33%, 66% or 100% substitution for the dehulled soybean meal. During the finisher phase, ALPC substituted for 66% or 100% dehulled soybean meal improved the daily gain ($P<.05$). For the entire trial, pigs fed ALPC substituted for 66% dehulled SBM gained faster than pigs fed the control diet ($P<.05$). Twelve crossbred barrows averaging 11.8 kg were used to determine the protein and energy digestibilities and nitrogen balance. The apparent digestibility of protein and energy were decreased as level of ALPC increased ($P<.05$) but no significant effect on nitrogen retention was observed. As the

digestibilities of protein and energy of dehulled SBM were 90% and 94.2%, respectively, the digestibilities of protein and energy of ALPC were 83.5% and 77.7%, respectively. The digestible energy of ALPC was 4.17 kcal/g and was similar to that of dehulled SBM 4.39 kcal/g. Carcass measurements were similar for pigs fed the control diet and those fed various levels of ALPC. These results suggest that ALPC can be used as a partial or total replacement for dehulled soybean meal in swine diets.

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EVALUATION OF ALFALFA LEAF PROTEIN CONCENTRATE (ALPC) FOR SWINE

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ABSTRACT

Alfalfa Leaf Protein Concentrate (ALPC) is a high protein feed product made from the wet fractionation of fresh alfalfa by the Pro-Xan process. The commercially produced ALPC used in these studies contained 55.8% crude protein and 2.59% crude fiber on a dry matter basis. The purpose of this study was to evaluate the potential of ALPC as a protein source for swine. This was accomplished by determing the limiting amino acids in ALPC for growing pig, by determining the nutritive value of ALPC substituted for dehulled soybean meal (SBM) for starter, grower and finisher pigs and by determining the digestibility and nitrogen balance. The palatability of ALPC and the effects of ALPC on the carcass quality were determined. An economic feasibility of ALPC as a new feed ingredient for growing pig was also evaluated.

The lysine content of ALPC is similar to that found in dehulled SBM (3.41 <u>vs</u> 3.20%). ALPC contains 1.67% tryptophan which is twice the amount in dehulled SBM. The sulfur amino acids appear to be the first limiting amino acid in ALPC and dehulled SBM. Seventy-two crossbred pigs averaging 10.7 kg initially were used to determine the limiting order of amino acids in ALPC for growing pigs. Pigs were allotted to treatments based on initial weight and sex to 24 pens with four replications of the six dietary treatments. The diet contained 20% ALPC as the amino acids source and dextroxe as the energy

source. The diets were: A) basal diet, B) basal + .3% DL-methionine, C) basal + .35% L-lysine HCL, D) C + .3% DL-methionine, E) D + .2% L-isoleucine and F) corn-soybean meal positive control (17% crude protein). Pigs fed the basal diet supplemented with methionine gained faster and more efficiency than pigs for the basal diet ($P < .05$), indicating that methionine was the first limiting amino acid in ALPC for grwoing pigs. The addition of lysine to the basal diet with or without methionine did not significantly improve performance. The addition of L-isoleucine (.2%) in the presence of methionine and lysine resulted in an improvement in daily gain and feed efficiency when compared to pigs fed the diet supplemented methionine and lysine ($P < .05$). These results suggest that isoleucine may be the second limiting amino acid with the possibility that isoleucine and lysine be second co-limiting amino acids.

A nitrogen balance trial was conducted with 12 crossbred barrows averaging 14.3 kg in a randomized complete block design with four treatments. The diets were as the same as that of feeding trial A), B), D) and E) in which the basal diet was supplemented with none, methionine, methionine + lysine, or methionine + lysine + isoleucine, respectively. The addition of DL-methionine (.3%) to the basal diet increased nitrogen retention .88 g/day and the biological value ($P < .05$). The addition of L-isoleucine (.2%) in the basal diet in combination with methionine and lysine tended to increase the nitrogen retention but it was not significant. These nitrogen balance data confirmed the results of the growth trial indicating that methionine is the first limiting amino acid in ALPC for growing pigs. The apparent protein digestibility and biological value expressed by nitrogen retained as percent of nitrogen digested of ALPC were 80.21% and 68.57%, respectively.

Three feeding trials involving 96 starter pigs averaging 7.5 kg, 48 grower pigs averaging 27.6 kg and 48 finisher pigs averaging 62 kg were allotted based on sex to four dietary treatments with four replications. The treatments were A) corn-dehulled SBM (control diet), B) 1/3 of dehulled SBM replaced with ALPC, C) 2/3 of dehulled SBM replaced with ALPC and D) corn-ALPC (complete replacement of dehulled SBM with ALPC). ALPC was substituted for dehulled SBM on an equal weight basis. Pigs were housed six per pen during the starter phase and three pigs per pen during the grower and finisher phases. Level of ALPC did not affect the feed intake or feed efficiency during the starter, grower or finisher phases and the number of days to 100 kg body weight. Level of ALPC did not affect the daily gain during the starter and grower phases but ALPC substituted for 66% or 100% of dehulled SBM improved daily gain during the finisher period ($P<.05$). For the entire feeding trial pigs fed diet D had the same performance as pigs fed control diet but they gained slowly than pigs fed diet C ($P<.05$).

Twelve crossbred barrows averaging 11.8 kg were used to determine the protein and energy digestibilities and nitrogen balance of the starter diets which ALPC replaced 0, 66% or 100% of the dehulled SBM. The apparent digestibilities of protein and energy were decreased as level of ALPC increased ($P<.05$). The level of ALPC did not affect the nitrogen retention. As the digestibility of protein and energy of dehulled SBM were 90% and 94.2%, respectively, the digestibilities of protein and energy of ALPC were 83.52% and 77.71%, respectively. The digestible energy of ALPC were 4.17 kcal/g which was similar to that of dehull SBM 4.39 kcal/g.

Twenty-four barrows, from the finisher trial, averaging 99 kg were used to evaluate the carcass quality. Dressing percent was increased as ALPC replaced 66% of dehulled SBM ($P<.05$). Level of ALPC did not significantly affect carcass length, the backfat thickness, the percent of four lean cuts and loin eye area but it was a trend towards decreasing the loin eye area in ALPC diets. Although there is a trend towards increasing the yellowness of backfat as level of ALPC increased in the diet, the color change is of little practical importance since it can not distinguished visually.

Twenty pigs averaging 10.2 kg were used for feed preference trial. Through 23 days, pigs consumed 87% of the corn-SBM diet and 13% of the corn-ALPC diet. It indicated that pigs prefered the corn-SBM diet when given a choice. However, when ALPC was used in the diet, regardless of the level, the pigs consumed the same amount of feed as the control group when pigs were not allowed a preference.

These results suggest that ALPC can be used to replace dehulled SBM in a corn diet for pigs from 8.7 kg to 99 kg without any adverse effect on feed efficiency, rate of gain, carcass characteristics or color of fat and muscle. The usage level of ALPC will be based on price.