Protein Content and Nutritional Value of Grains Grown in Interior Alaska

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Introduction

Inadequate dietary protein, resulting in slow growth, inefficient feed utilization, and general unthriftiness, is probably the most frequent nutrient deficiency encountered in swine (Pond and Maner 1974). Proteins are composed of amino acids. Although over one hundred amino acids have been identified in nature, twenty are considered of primary biological importance in the formation of plant and animal tissue protein. Of these twenty amino acids, ten have been reported to be indispensable or essential dietary components for swine and other nonruminant animals. The remaining amino acids are considered dispensable, or nonessential, dietary components. Rose and Rice (1939) defined an essential amino acid as one that cannot be synthesized by the body from materials ordinarily available at a rate sufficiently rapid to promote normal growth and a nonessential amino acid as one that can be synthesized in the body in sufficient quantities from materials available to the animal. Therefore, essential amino acids must be provided by the diet.

During protein synthesis, such as that which occurs in the growth of muscle tissue, the amino acids are linked together in long chains similar to a string of beads. The order of the twenty amino acids can vary greatly depending on the particular tissue protein that is being synthesized. However, the order of amino acids is a characteristic of each specific protein. When one of the ten essential amino acids is not present, protein synthesis (muscle growth) ceases at the point at which that amino acid was required in the protein chain. The first amino acid that becomes deficient is referred to as the first limiting amino acid for protein synthesis. If that amino acid is supplied in sufficient quantities by a dietary supplement, then another amino acid may become deficient and is referred to as the second limiting amino acid. This process will be repeated until the correct amount or proportion of amino acids has been supplied to the body.

A dietary protein with high biological value or high protein quality supplies the exact amount and proper proportion of amino acids required by the body with no limiting or excess amino acids.

Cereal grains are the primary dietary energy source in nonruminant diets. Sorghum and corn can supply 40-50 per cent of the protein, and wheat and barley can supply up to 65 per cent of the protein in growing-finishing swine diets. However, cereal grain protein quality is low in reference to the amino acid requirements for efficient swine growth (N.R.C. 1973). The order of limiting amino acids in sorghums are lysine, threonine, tryptophan, and isoleucine (Eckert and Alle 1974, Copelin et al. 1978). Tryptophan and lysine have been determined to be the first and second limiting amino acids in corn (Gallo and Pond 1968, Baker et al. 1969). Oats, barley, wheat, and triticale all have lysine and threonine as their first and second limiting amino acids (Robbins et al. 197 1, Chung and Beanies 1974, Murata et al. 1973, Luce et al. 1972, Shimada and Cline 1974). The nutritional value of cereal grain is one of high available energy and low protein quality.

The success or failure of any cereal crop is usually measured by the total yield per unit area of land. The view that any increase in protein content was accompanied by a decrease in grain yield (Frey 1973) and that the percentage of limiting amino acids, specifically lysine, in the protein decreases (Whitehouse 1970, Kolderup 1975, Lawrence et al. 1958, Munck et al. 1969) has been accepted widely. However, Waggle et al. (1967) have reported that the amino acid percentage remained the same in sorghums as the protein content increased from 8.3 to 12.1 per cent, and Robbins et al. (1971) have suggested that increased protein in oats was not accompanied by a decreased lysine concentration in the protein. Data on the percentage of lysine in the protein of grains grown under different conditions and affected by different cultural practices is limited (Pomeranz 1975).

The quantity and quality of protein in cereals can be altered by genetic selection, climatic conditions, and cultural techniques. There has been much interest in the protein quality of cereal grains since Mertz et al. (1964) showed that the opaque-2 mutant gene in corn increased the lysine and tryptophan content and Munck et al. (1969) identified the high protein and lysine content of 'Hiproly' barley (C13947) of Ethiopian origin. Oat varieties 'Dal' and 'Spear,' selected for higher protein and lysine contents have been reported to have greater nutritional value for growing pigs (Wahlstrom and Libal 1975, Wahlstrom et al. 1977). An increase in temperature and photoperiod results in an increase of protein content in wheat and barley, but the nutritional value of the protein is not consistently improved for either cereal (Kolderup 1975, Gohl and Thomke 1976, Berdahl and Bhatty 1977, Sosulski et al. 1963). Nitrogen fertilization and irrigation results in wheat varieties with increased protein and lysine contents that need be supplemented only with low levels of lysine and no soybean oil meal in order to maintain high egg production and egg weights in White Leghorn laying hens (Gardiner and Dubetz 1977).

The protein content of selected cereal grain varieties grown at Fairbanks, Alaska, has been reported to be significantly higher than the protein content of the introduced seed used for planting that grain. The greatest differences were detected in barleys. Barley varieties grown in Fairbanks averaged 17.3 per cent protein compared to 12.6 per cent for the introduced seed for those varieties. Wheat varieties exhibited the least response—the average protein for Alaska-grown varieties was 16.2 per cent, while that for the introduced seed was 15.4 per cent. The protein content of Alaska-grown varieties of both barley and wheat were considerably higher than the U.S. average of 12 per cent protein for both crops (Wooding and Knight 1972). Protein levels of barley and wheat varieties have remained high in successive years when grown on summer-fallowed soil. Protein content of Alaska-grown wheat, barley, and oats is higher than for those grown in middle latitudes (Wooding 1977, 1978). Swedish workers have reported that barley protein content increased in the same variety when cultivated at increased latitudes (Gohl and Thomke 1976). Kolderup (1975) has reported that the protein content of wheat increased with longer photoperiods.

A limited amino acid analysis of barley and wheat varieties grown in Alaska indicated that protein quality increased with the increased protein content (unpublished data, Tomlin and Wooding). The amino acid content of Alaska-grown barley varieties was approximately 50 per cent higher than that of the introduced seed. The amino acid content of the Alaska-grown wheat varieties was not higher than the introduced seed with the exception of a 40 per cent increase over wheat from the Pacific Northwest. Protein quantity and quality of the Alaskagrown barleys compared favorably to values for high-protein naked barleys selected for improved nutritional value in plant-breeding programs at other experiment stations (Munck et al. 1969, Berdahl and Bhatty 1977, Newman et al. 1974, Newman et al. 1977). The potential nutritional value of higher-protein (17 per cent), Alaska-grown barleys was estimated by comparing the amino acid content to the requirement for a young, growing pig. The only limiting amino acid was lysine. Although the chemical analyses of Alaska-grown cereal grains indicated a high nutritional value, there has been no biological testing with animals. Therefore, it was important to examine the agronomic cultural practices that influence the protein content of cereal grains and to determine the nutritional value and protein quality of selected grain varieties for production in interior Alaska.

This report is presented in three sections: (1) agronomic factors influencing protein content of grains, (2) influence of cultural technique on protein quality and nutritional value of 'Finnaska' barley for growing pigs, and (3) summary and conclusions.

Section I addresses the following: effect of summer-fallowing crop land on yield and protein content of grains; high-protein barley varieties; long-term average and range of yields and protein contents for barley standard varieties grown at Fairbanks and Delta Junction from 1971-1979; and relationships between yield, nitrogen content, and crude- protein content of barley.

Barley grown in Alaska is utilized primarily as a livestock feed, and Section II reports the effect of summer- fallow and continuouscropping cultural practices on a selected barley variety (Rovaniemi Selection 70-B, Hordeum vulgare 'Finnaska') for protein quality and nutritional value to growing pigs.

Section III contains a summary and conclusions for the first two sections that should be considered by Alaskan farmers, grain handlers, feed mill operators, and various Alaska state agencies concerned with barley production and marketing.

Section I
Agronomic Factors Influencing Protein Content of Grain

Effect of Summer Fallowing on Yield and Protein Content

Summer-fallowing is the practice of leaving the soil uncropped from one harvest through the next year's growing season. One of the purposes of this practice is to retain the moisture which falls during this period in the soil. Weed control is another important aspect of fallowing. In dryland farming areas, a crop-fallow rotation, compared with continuous annual cropping, has shown higher total production, greater production stability, lower unit production costs, and greater moisture efficiency. The practice of summer-fallowing in the semiarid regions of the United States is based primarily on the benefit of moisture storage (Chapman and Carter 1976, Martinet al. 1976). In more northern regions, fallowing the land also results in decomposition of crop residues and accumulation of nitrogen and other nutrients.

Microbial activity and mineral weathering is negligible in frozen soils. Release of available nutrients from these processes occurs for only a few months of the year under interior Alaska conditions. This results in lower natural fertility and higher fertilizer requirements, particularly for a continuous-cropping system. During the fallow period, the soil accumulates or stores nutrients. This makes it possible for the soil to contribute more of its natural fertility to the production of a crop. Fertilizer requirements, particularly for nitrogen, are noticeably decreased by fallowing the land (Wooding and Knight 1973, Chapman and Carter 1976, Lewis and Wooding 1978).

Crop residues left on or above the soil surface undergo virtually no decomposition during the 7 months of winter. If these residues are incorporated into the soil in the spring just prior to seeding the new crop, the microorganisms which feed on them will compete with the grain crop for available nutrients during the first 7 to 8 weeks of the growing season. This phenomenon is referred to as nutrient immobilization. Immobilization of nutrients can be alleviated to some extent by incorporating the crop residues into the soil during the fall of the year and by increased nitrogen fertilization (Lewis and Wooding 1978).

Table 1. Yield and protein content of Edda barley grown on summer fallowed and stubble land at Fairbanks. (air-dry basis)

Treatment	Grain Yield (bu/acre)	Grain Protein (%)
Summer Fallow	88.3	15.3
Stubble	21.3	12.4

The data presented in Table I show a comparison between barley grown on summer-fallowed land and barley grown on stubble land. Nitrogen fertilizer was supplied at the rate of 25 lb N/acre for both crop rotations. Grain yield on the fallowed land was four times greater than for the stubble land, while grain protein contents for the two treatments were 15.3 per cent and 12.4 per cent, respectively. This represented extreme yield differences for a crop-fallow system and a continuous cropping system. Yields are almost always higher for crops grown on fallow land but the differences are often not great.

In the case of the stubble treatment, large amounts of straw from the previous year's crop were tilled into the soil in the spring which resulted in immobilization of available soil nitrogen. The stubble treatment would probably have yielded considerably more if it had received a higher rate of nitrogen fertilizer and fall tillage.

Table 2 lists protein contents of six varieties each of wheat, barley, and oats grown on summer-mowed land at Fairbanks during a four year period. These are varieties that were selected in a testing program for their overall adaption to interior Alaska. They were selected primarily for yield and ability to mature. They were not selected on the basis of protein content.

Crude protein content of the wheat consistently exceeded that for barley and oats. For the four-year period, wheat averaged 17.3 per cent protein compared to 14.8 per cent for barley and 14.7 per cent for oats. The highest average protein content for individual varieties of each grain crop was 19.5 per cent for 'Gasser' wheat, 15.7 per cent for 'Lidal' barley, and 16.0 per cent for 'Ceal' oats. In general, protein contents of Alaska-grown grains were noticeably higher than those obtained in middle latitudes. The United States average protein content for wheat is about 12 per cent, while barley and oats range from 10 to 12 per cent.

High-Protein Barley Varieties

Since 1971, a large number of barley varieties and experimental lines have been tested at Fairbanks. The most adapted of these varieties, with regard to yield and early maturity, have been tested in other areas of Alaska. Table 3 provides a list of barleys that have produced protein contents of 17 per cent and greater. Included in the list are five barleys which exceeded 20 per cent protein. Nevertheless, these barleys are considered to be poorly adapted because of extremely low grain yields produced.

Hyproly and 'Hyproly Normal' are varieties which were selected and developed in Sweden specifically for their high protein content. For these varieties, the protein content remains fairly constant over a wide range of growing conditions. If available soil nitrogen becomes limiting, grain yield is reduced while nitrogen in the vegetative portion of the

Table 2. Protein content of spring-sown wheat, barley, and oats for a 4-year period grown on summer-fallowed land at Fairbanks. (air-dry basis)

Crop Variety	Crude Protein (%)				
	1972	1973	1974	1975	Average
Wheat					
Gasser	18.8	18.0	21.4	19.8	19.5
Park	17.2	16.3	19.4	18.8	17.9
Thatcher	16.7	15.6	19.3	17.3	17.2
Saunders	15.9	15.4	19.7	18.0	17.3
Canthatch	16.9	15.0	18.5	17.0	16.9
Rovaniemi Sel. 70-W	14.3	13.3	16.1	15.8	14.9
Average	16.6	15.6	19.1	17.8	17.3
Barley					
Edda	14.4	13.8	16.8	16.6	15.4
Olli	12.4	13.0	16.5	16.1	14.5
Gait	14.0	10.8	15.5	15.1	13.9
Lidal	14.5	15.2	16.9	16.3	15.7
Weal	14.1	11.3	14.3	16.9	14.2
Rovaniemi Sel. 70-B	15.0	12.8	15.3	17.3	15.1
Average	14.1	12.8	15.9	16.4	14.8
Oats					
Nip	16.3	12.0	16.4	16.0	15.2
Toral	16.1	12.3	15.8	17.0	15.3
Cayuse	13.0	11.3	13.1	13.8	12.8
Rodney	14.2	11.5	14.6	14.4	13.7
Pendek	14.2	12.4	16.6	16.2	14.9
Ceal	16.0	13.6	16.8	17.5	16.0
Average	15.0	12.2	15.6	15.8	14.7

Table 3. High protein barley varieties and experimental lines tested at Fairbanks. (air-dry basis)

Variety or Experimental Line	Grain Protein (%)	Grain Yield (bu/acre)	Year of Testing
Hyproly	22.1	13.3	1976
Br 6505-21*	21.1	25.8	1971
Br 6505-31-1*	20.9	22.1	1971
Br 6505-5*	20.8	37.5	1971
Hyproly Normal	20.8	19.2	1976
Conquest	19.1	25.4	1971
Gateway 63	18.7	56.3	1971
Parkland	18.5	22.5	1971
Tibet Hulless	18.2	61.5	1976
Lidal	18.1	55.8	1971
0lli	17.7	64.2	1971
Frontier	17.6	43.8	1971
Jubilee	17.3	64.6	1971
Edda	17.3	67.9	1971

*Selections developed by the Canada Department of Agriculture, Research Station, Brandon, Manitoba.

Table 4. Long-term average and range of yields for barley standard varieties grown at Fairbanks and Delta Junction, 1971-79.

	Grain Yield (bu/acre)			
Location	Galt	Otra	Lidal	Weal
Fairbanks	— — — — — — — — — (bu/acre) — — — — — — — — — — —			
Average Yield	87	71	64	70
Range of Yields	59-117	50-99	46-91	43-101
Delta Junction				
Average Yield	68	80	59	59
Range of Yields	30-101	48-123	27-92	31-81
Fairbanks & Delta Junction				
Average Yield	78	77	62	64
Range of Yields	30-117	48-123	27-92	31-101

plant is diverted for protein synthesis in the developing grain. ‘Tibet Hulless’ has shown a similar relationship between yield and protein content, but not to the extent of Hyproly and Hyproly Normal. For the other varieties included in the list, protein contents tend to fluctuate much more widely. When available soil nitrogen becomes limiting, yield is maintained, but at the expense of protein.

Five of the varieties (‘Lidal’, ‘Olli’, ‘Gateway 63’, ‘Edda,’ and ‘Tibet Hulless’) have shown a fairly high degree of adaptation to growing conditions in interior Alaska. Lidal is currently a recommended variety for the Tanana Valley. Edda and Olli were formerly on the recommended variety list for the Tanana Valley, but in recent years they have been replaced by improved varieties.

Performance of Barley Standard Varieties in the Interior

Standard varieties, as defined for this report, are varieties that have performed consistently well in tests conducted in at least two Tanana Valley locations for several years. Standard varieties are used as a means for evaluating new entries in the variety-testing program each year. Comparisons are made with regard to yield, maturity, quality, and growth characteristics. Galt, Otra, Lidal and Weal are, or have been, standard barley varieties for the Tanana Valley. Yield and protein data for Galt, Lidal, and Weal have been collected at Fairbanks since 1971 and at Delta Junction since 1972. Otra was included in the testing programs at both locations beginning in 1973. Long-term average yields and ranges in yields for each of the standards are given in Table 4. The corresponding protein values for these barleys are given in Table 5.

In general, the protein contents for barley grown at Fairbanks were higher than for barley grown at Delta Junction. The difference between the two locations could, in part, be due to soil pH. At Fairbanks, the soil pH ranges between neutral and calcareous (pH 7.0 to 7.4). At Delta Junction the soil pH is in the acid range, between 5.2 and 5.8. Uptake of soil nitrogen by plants can be greatly reduced on acid soils. Liming the soil at Delta Junction could increase the protein contents of barley noticeably.

For both locations, Lidal consistently contained the highest protein levels. Galt and Otra were the highest-yielding varieties, but they produced the lowest protein contents.

Relationship Between Yield, Nitrogen Content, and Crude Protein Content

Years ago, biochemists established that protein was

Table 5. Long-term average and range of protein contents for barley standard varieties grown at Fairbanks and Delta Junction, 1971-79. (air dry basis)

	Grain Protein			
Location	Galt	Otra	Lidal	Weal
Fairbanks	(%)			
Average	14.5	15.1	16.6	14.9
Range	10.8-16.1	12.8-16.4	14.5-18.1	10.3-16.9
Delta Junction				
Average	13.2	13.2	14.8	13.3
Range	10.9-16.1	11.5-13.8	12.2-17.3	12.0-14.6
Fairbanks & Delta Junction				
Average	14.0	14.2	16.0	14.4
Range	10.8-16.1	11.5-16.4	12.2-18.1	10.3-16.9

about 16 per cent nitrogen, therefore a factor of 6.25 multiplied by the per cent nitrogen is equal to per cent crude protein. Conversely, per cent crude protein divided by 6.25 equals per cent nitrogen. If a farmer produces a crop of barley yielding 60 bushels per acre, weighing 48 pounds per bushel, and containing 12 per cent protein (air-dry basis), the following calculations can be made:

60 bu/acre x 48 lbs/bu = 2880 lbs/acre

12% crude protein ÷ 6.25 = 1.92% nitrogen

1.92% 100 = 0.0192

2880 lbs x 0.0192 = 55.3 lbs nitrogen per acre in the grain.

Suppose the farmer wanted to raise 60 bushels of barley per acre that contained 15 per cent crude protein. The nitrogen requirement for the higher-protein barley would then be:

15% crude protein 6.25 = 2.4% nitrogen

2.4% ÷ 100 = 0.024

2880 lbs x 0.024 = 69.1 lbs nitrogen in the grain

To grow the higher-protein barley and still maintain the same yield per acre, an additional 13.8 pounds of nitrogen would have to be taken up by the plants from the soil and assimilated into the grain as protein. The protein content of the crop could theoretically be increased from 12 to 15 per cent by applying 13.8 pounds more nitrogen per acre as fertilizer. Unfortunately, this seldom occurs under field conditions. If climatic conditions are favorable for plant growth, part of the added nitrogen may be used for the production of increased grain yield and vegetative growth. Due to the increased vegetative growth, any increased yield over the 60 bushels per acre has a dilution effect on the nitrogen required for protein synthesis in the grain. Further, not all of the added nitrogen will be recovered by the crop under field conditions. There are usually some losses of nitrogen from the soil system due to leaching and volatilization.

The data presented in Table 6 show some relationships between nitrogen fertilizer rate, grain yield, and grain- protein content of barley grown in Delta-Clearwater area. For this study, two chemical forms of nitrogen fertilizer (urea and ammonium nitrate) were used, and the materials were applied at three different times (preplant, early topdressing, and late topdressing). The preplant applications were incorporated into the soil during seedbed preparation. The two topdressings were broadcast onto the soil surface 2 weeks and 4 weeks after seedling emergence.

The results show grain-protein content increasing with each additional increment of nitrogen fertilizer. Grain yield followed a similar trend with the exception of the 100-pound nitrogen rate applied as urea or as ammonium nitrate as a late topdressing. In response to the late topdessing, grain yield peaked at the 66-pound nitrogen rate, but protein content continued to increase with added nitrogen. The highest protein content, for both fertilizer materials, was achieved at the 100-pound nitrogen rate applied as a late topdressing. In general, topdressing applications of nitrogen fertilizer produced higher-protein barley than preplant applications. Overall, there was little difference between urea and ammonium nitrate as sources of nitrogen.

Section II Effect of Cultural Techniques on Feeding Value of Finnaska Barley for Growing Pigs

Experimental Procedure

A single barley variety, Rovaniemi Selection 70-B *(Hordeum vulgare* Finnaska), was selected for production in two consecutive years on 8.5 acres of Tanana Silt Loam soil at the Fairbanks Agricultural Experiment Station farm. The seeding rate was adjusted within each year to provide 1.5 bushels of seed at 100 per cent germination per acre. The first year of seeding was on acreage that had been summer-fallowed for a minimum of one previous year, and the resultant crop represented a summer-fallow cultural practice. The second year's crop was seeded on the same 8.5 acres as in the first year and was considered representative of a continuous-cropping cultural practice. Prior to seeding each year, the area was fertilized with 300 pounds of 20-10-10 (N-P-K) disked and harrowed.

Both barley crops were analyzed for proximate composition (A.O.A.C. 1975) with the exception of crude fiber (which was determined as acid detergent fiber [Van Soest and Wine 19681), calcium (atomic absorption), and phosphorus (auto analyzer) (table 7). Amino acid composition of 24-hr acid hydrolysates of the barleys and soybean meal was determined on a Durrum Model D-500 automatic amino acid analyzer. With the exception of cysteine (Hirs 1967) and tryptophan (Hugh and Moore 1972), the amino acids were determined by the methods of Spackman et al. (1958) and Moore (1963) and are compared to the National Research Council (N.R.C.) (1973) amino acid requirements of a 44-pound growing pig (table 8).

In the growth trials, pigs were allotted for group feeding in partially slotted pens of 3 x 9 feet located in a building in which the temperature was maintained at 65ºF. Feed and water were supplied ad libitum. Initial and final weights were recorded, and daily gain and feed efficiency were determined at the conclusion of the trials. Growth trials were initiated when pigs had attained a minimum average of 44 pounds bodyweight, and the pigs were weighed off the trial when approximately 125 pounds bodyweight had been attained. A completely randomized design was used for all trials, and the data were analyzed by analysis of variance and Duncan's multiple range test (Steel and Torrie 1960).

Basal barley diets (air-dry basis) were fortified with vitamins, minerals, and various levels of amino acids and were formulated from summerfallow and continuous-crop Finnaska barley in Trials I and II (table 9) and Trials III and IV (table 10), respectively (see pages 18 and 19). Positive-control diets for each trial were formulated from fortified mixtures of each barley plus 44 per cent soybean meal to contain 16 per cent crude protein as required for growing pigs (N.R.C. 1973). Barleys were coarse ground in a hammer

Table 6. Evaluation of urea and ammonium nitrate as sources of nitrogen for Otra barley grown on fall-tilled barley-stubble land in the Delta-Clearwater area. (air-dry basis)

Nitrogen[a] Content Fertilizer Rate (lbs N/acre)	Nitrogen Fertilizer Carrier	Time of Nitrogen Application[b]	Grain Yield (bu/acre)	Grain Yield (lbs/acre)	Grain Protein (%)	Protein Yield (lbs/acre)	Nitrogen of Grain (lbs/acre)
0			26	1248	11.0	137	21.9
33	Urea	Preplant	44	2112	13.6	287	45.9
66	Urea	Preplant	61	2928	14.5	425	68.0
100	Urea	Preplant	80	3840	14.9	572	91.5
33	Ammonium Nitrate	Preplant	40	1920	13.2	253	40.5
66	Ammonium Nitrate	Preplant	51	2448	14.8	362	57.9
100	Ammonium Nitrate	Preplant	75	3600	15.9	572	91.5
33	Urea	Early topdressing	43	2064	14.0	289	46.2
66	Urea	Early topdressing	53	2544	16.0	407	65.1
100	Urea	Early topdressing	69	3312	16.1	533	85.3
33	Ammonium Nitrate	Early topdressing	43	2064	135	279	44.6
66	Ammonium Nitrate	Early topdressing	69	3312	14.5	480	76.8
100	Ammonium Nitrate	Early topdressing	78	3744	16.0	599	95.8
33	Urea	Late topdressing	67	3216	12.7	408	65.3
66	Urea	Late topdressing	74	3552	15.9	565	90.4
100	Urea	Late topdressing	73	3504	17.5	613	98.1
33	Ammonium Nitrate	Late topdressing	59	2832	12.8	362	57.9
66	Ammonium Nitrate	Late topdressing	71	3408	16.2	552	88.3
100	Ammonium Nitrate	Late topdressing	69	3312	16.7	553	88.5

[a]In addition to nitrogen, all treatments received 40 lb. P_2O_5/acre as triple superphosphate (0-45-0) and 40 lb. K_2O/acre as K_2SO_4 (0-0-50).

[b]Triple superphosphate, K_2SO_4, and preplant applications of urea and NH_4NO_3 were applied broadcast and disked in prior to planting. Early and late topdressing applications of urea and NH_4NO_3 were applied broadcast 2 weeks and 4 weeks after seedling emergence.

mill, and complete diets were fed in a loose, ground form. In Trials I and 111, lysine, isoleucine, and methionine were added to the basal barley diet to meet N.R.C. requirements (1973). Threonine was not required to meet N.R.C. requirements for summer-fallow barley but was supplemented at 0.1 per cent above the requirement to determine the effect on growth response. However, threonine was required in continuous-crop barley and was supplemented to meet the N.R.C. requirements for Trial III. In Trials Il and IV, lysine, threonine, isoleucine, and methionine were included in the basal barley diets to equal the level of these amino acids present in the respective 16 per cent positive-control barley-soybean diets. Equimolar additions of glycine and glutamic acid were made to give a 16 per cent crude protein diet in the presence of the basal barley diet plus lysine, threonine, isoleucine, and methionine in Trials III and IV. Only the L-isomers of amino acids were added to all diets with the exception of DL-methionine. Lysine was added as L-lysine HCL and contained 78 per cent L-lysine.

Trial I-Seventy-two Duroc pigs weighing an average of 43.9 pounds were allotted on the basis of weight and sex to two replicates with six pigs per pen for group feeding of six diet treatments: (1) basal summer-fallow Finnaska barley diet, (2) a 16 per cent crude protein Finnaska-soybean meal positive control, (3) diet 1 plus 046 per cent lysine, (4) diet 3 plus 0. 10 per cent threonine, (5) diet 4 plus 0.07 per cent isoleucine, and (6) diet 5 plus 0.04 per cent DL-methionine. Composition and calculated analyses of diets I through 6 are presented in Table 9.

Trial II-Sixty Duroc pigs weighing an average of 56.2 pounds were allotted on the basis of weight and sex to two replicates of five pigs per pen for group feeding of six diet treatments: (A) basal summer-fallow Finnaska barley diet, (B) a 16 per cent crude protein Finnaska-soybean meal positive control, (C) diet A plus 0.11 per cent lysine, (D) diet C plus 0.05 per cent threonine, (E) diet D plus 0.06 per cent isoleucine, and (F) diet E plus 0.06 per cent DL-methionine. Composition and calculated analyses of diets A through F

Table 7. Composition of Finnaska barleys and soybean meal. (air-dry basis)

Component	Summer-Fallow	Continuous-Crop	Soybean Meal
	(%)		
Moisture	10.1	9.8	10.3
Crude protein[a]	15.4	13.5	44.0
Ether extract	1.7	1.7	1.3
Acid detergent fiber	7.8	8.0	9.8
Ash	2.2	2.3	5.8
Calcium	0.03	0.04	0.29
Phosphorus	0.42	0.46	0.66

[a]Nitrogen x 6.25.

Table 8. Amino acid composition of Finnaska barleys and soybean meal and requirement of growing swine. (air-dry basis)

Amino Acid	Summer-Fallow	Continuous-Crop	Soybean Meal	N.R.C. Requirement[a]
Essential		(%)		
Lysine	0.355	0.403	2.67	0.70
Threonine	0.469	0.426	1.78	0.45
Isoleucine	0.443	0.403	1.99	0.50
Methionine[b]	0.195	0.184	0.60	0.50
Cystine/2	0.307	0.359	0.67	-
Tryptophan	0.255	0.257	0.70	0.13
Leucine	0.884	0.816	3.41	0.60
Phenylalanine[c]	0.727	0.589	2.10	0.50
Tryosine	0.780	0.493	2.14	-
Arginine	0.550	0.578	3.31	0.20
Valine	0.759	0.542	2.06	0.50
Histidine	0.277	0.243	1.10	0.18
Nonessential				
Alanine	0.470	0.532	1.83	-
Aspartic acid	0.678	0.702	5.70	-
Glutamic acid	3.300	2.780	8.26	-
Glycine	0.439	0.444	1.58	-
Proline	1.500	1.190	2.12	-
Serine	0.577	0.517	2.35	-

[a]National Research Council, 1973 Nutrient Requirements for swine.
[b]Methionine can fulfill the total requirement while cystine can meet at least 50%of total requirement.
[c]Phenylalanine can fulfill total requirement while tyrosine can fulfill 30% of total requirement.

Table 9. Percentage composition of summer-fallow Finnaska barley diets in Trials I and II. (air-dry basis)

	Trial I						Trial II					
Ingredient	1	2	3	4	5	6	A	B	C	D	E	F
Barley	96.8	93.0	96.34	96.24	96.17	96.13	95.80	93.0	96.69	96.64	96.58	96.52
Soybean meal		3.8						3.8				
L-Lysine HCI			0.46	0.46	0.46	0.46			0.11	0.11	0.11	0.11
L-Threonine				0.10	0.10	0.10				0.05	0.05	0.05
L-Isoleucine					0.07	0.07					0.06	0.06
DL-Methionine						0.04						0.06
Dicalcium phosphate	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Limestone	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vitamin-antiobiotic premis	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Trace mineral salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calculated Analysis												
Crude protein	14.91	16.0	14.91	14.91	14.91	14.91	14.91	16.0	14.91	14.91	14.91	14.91
Lysine	0.3444	0.431	0.700	0.700	0.700	0.700	0.344	0.431	0.429	0.,129	0.429	0.428
Threonine	0.454	0.504	0.452	0.551	0.551	0.551	0.454	0.504	0.453	0.503	0.503	0.503
Isoleucine	0.429	0.488	0.427	0.426	0.496	0.496	0.429	0.488	0.428	0.428	0.488	0.488
Methionine+cystine	0.486	0.515	0.484	0.483	0.483	0.503	0.486	0.515	0.485	0.485	0.484	0.514

Table 10. Percentage composition of continuous-crop Finnaska barley diets in Trials III and IV. (air-dry basis)

	Trial III							Trial IV						
Ingredient	A	B	C	D	E	F	G	1	2	3	4	5	6	7
Barley	96.8	87.1	96.40	96.36	96.25	96.09	91.53	96.8	87.1	96.52	96.39	96.23	96.04	91.48
Soybean meal		9.7							9.7					
L-Lysine HCl			0.40	0.40	0.40	0.40	0.40			0.28	0.28	0.28	0.28	0.28
L-Threonine				0.04	0.04	0.04	0.04				0.13	0.13	0.13	0.13
L-lsoleucine					0.11	0.11	0.11					0.16	0.16	0.16
DL-Methionine						0.16	0.16						0.19	0.19
L-Glutamic acid							3.02							3.02
L-Glycine							1.54							1.54
Dicalcium phosphate	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Limestone	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vitamin-antibiotic premix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Trace mineral salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calculated Analysis														
Crude protein	13.07	16.03	13.07	13.07	13.07	13.07	16.05	13.07	16.03	13.07	13.07	13.07	13.07	16.05
Lysine	.390	.610	0.700	0.700	0.699	0.699	0.681	0.390	0.610	0.607	0.606	0.606	0.605	0.587
Threonine	.412	.544	0.410	0.450	0.450	0.449	0.430	0.412	0.544	0.411	0.540	0.540	0.539	0.520
lsoleucine	.390	.544	0.388	0.388	0.497	0.497	0.497	0.390	0.544	0.389	0.388	0.548	0.547	0.529
Methionine+cystine	.420	.511	0.418	0.418	0.418	0.477	0.477	0.420	0.511	0.419	0.418	0.418	0.512	0.492

are listed in Table 9.

Trial III-Forty-nine Duroc pigs weighing an average of 48.2 pounds were allotted on the basis of weight and sex to two replicates of three and four pigs per pen for group feeding of seven diet treatments: (A) basal continuous-crop Finnaska barley diet, (B) a 16 per cent crude protein Finnaska-soybean meal positive control, (C) diet A plus 0.40 per cent lysine, (D) diet C plus 0.04 per cent threonine, (E) diet D plus 0.11 per cent isoleucine, (F) diet E plus 0.16 per cent DL-methionine and (G) diet F plus 3.02 per cent glutamic acid and 1.54 per cent glycine. Diets B and G were isonitrogenous. Composition and calculated analyses for diets A through G are shown in Table 10.

Trial IV-Fifty-six Duroc pigs weighing an average of 56.0 pounds were allotted on the basis of weight and sex to two replicas of four pigs per pen for group feeding of seven diet treatments: (1) basal continuous-crop Finnaska barley diet, (2) a 16 per cent crude protein Finnaska-soybean meal positive control, (3) diet 1 plus 0.28 per cent lysine, (4) diet 3 plus 0.13 per cent threonine, (5) diet 4 plus 0. 16 per cent isoleucine, (6) diet 5 plus 0.19 per cent DL-methionine, and (7) diet 6 plus 3.02 per cent glutamic acid and 1.54 per cent glycine. Diets 2 and 7 were isonitrogenous. Composition and calculated analysis of diets I through 7 are shown in Table 10.

Results and Discussion

The barleys produced for this study by summer-fallow and continuous-crop cultural techniques (table 7) contained 28 and 12.5 per cent more protein, respectively, than did the average 'Lower 48' barley reported to contain 12 per cent protein (Matz 1970). When the Alaska-grown barleys were compared to Pacific Northwest and Peace River barleys containing an average of 10 per cent protein, the summer-fallow and continuous-crop Alaska barleys contained 54 and 35 per cent more protein, respectively, than did the two barleys, that represent the most probable sources of imported barley for livestock feeding in Alaska. The higher protein content of summerfallow Finnaska was similar to Wooding's results (unpublished 1980) for several barley varieties grown for several seasons on summer fallow soil in Fairbanks. The level of protein obtained from continuous-crop Finnaska may be slightly higher than could routinely be expected but which may be obtained provided described cultural techniques were used (i.e., soil testing, fertilization, seeding times, and rates). Yields were estimated from bin storage capacity as 53 and 66 bu/acre for summer-fallow and continuous-crop barley, respectively. Yields usually decrease as a result of continuous cropping, so little experimental value was placed on these yields since the modem combine used to harvest the continuous-crop was far more efficient than that used the previous year.

Barley has been reported to be limiting or low in relation to requirements of growing pigs for all of the above supplemented amino acids, but research reports vary (Chung and Beanies 1974, Robinson and Lewis 1963). Chung and Beanies (1974) report a growth response from supplemental lysine and threonine. Amino acid composition for Finnaska barley produced by both cultural techniques and the amino acid requirements for growing pigs are listed in Table 8. Lysine, threonine, isoleucine, methionine/cystine, and tryptophan are the amino acids most often listed as limiting for general pig growth for cereal grains. As the protein content of Finnaska increased using fallow. lysine and cystine contents were reduced, but threonine, isoleucine, and, to a lesser degree, methionine contents were increased. As protein increases, lysine content has been reported to decrease in barley varieties (Whitehouse 1970, Munch et al. 1969).

The inverse relationship of protein and lysine appeared similar for Finnaska, but the increase of the other three amino acids remained difficult to explain with the analyses available in the experiment. Surprisingly, the threonine content in summer fallow Finnaska exceeded the N.R.C. requirement and was only slightly limited in the continuous crop Finnaska. lsoleucine was below the required level for growing pigs when barley was produced by either summer fallow or continuous cropping; methionine/cystine was adequate in barley produced by continuous cropping.

Trial I-Supplementation of the basal summer-fallow barley with lysine resulted in an improvement in both the daily gain and the feed efficiency when compared to the basal and the 16 per cent barleysoybean meal positive control (table 11). Threonine supplementation at 0.10 per cent above the required level, in addition to lysine, did not improve growth, indicating that its level in the barley tested may have been adequate without supplementation. Although amino acid analysis indicated that isoleucine was deficient and that methionine/cystine was slightly below the required level, no improvement in gain or feed efficiency was noted when these two amino acids were added to the basal plus lysine diet. Although a slight increase in average daily gain was noted with

Table 11. Performance of growing pigs fed a fortified Finnaska barley (summer-fallow) diet supplemented with L- Lysine, L-Threonine, L-Isoleucine and DL-Methionine, Trials I and II.

	Trial I						Trial II					
Item	1	2	3	4	5	6	A	B	C	D	E	F
Number of pigs	12	12	12	12	12	12	10	10	10	10	10	10
Initial weight/lb.	44.08	43.08	44.50	43.75	43.83	44.08	55.8	56.5	57.6	55.6	55.0	56.5
Final weight/lb.	125.7	129.4	126.0	126.5	125.8	127.8	125.0	127.2	127.6	127.0	130.0	128.6
Daily gain/lb.	0.80	1.13	1.53	1.53	1.58	1.56	0.81	1.32	1.29	1.27	1.26	1.26
Feed/gain	4.11	3.16	2.84	2.83	3.00	2.89	4.19	3.31	3.33	3.38	3.35	3.39

Table 12. Performance of growing pigs fed a fortified Finnaska barley (continuous-crop) diet supplemented with L- Lysine, L-Threonine, L-Isoleucine and DL-Methionine, Trials III and IV.

	Trial III							Trial IV						
Item	A	B	C	D	E	F	G	1	2	3	4	5	6	7
Number of pigs	7	7	7	7	7	7	7	8	8	8	8	8	8	8
Initial weight/lb.	45.4	49.4	49.8	47.0	49.2	47.6	49.4	51.7	48.6	51.0	49.0	48.2	49.9	49.8
Final weight/lb.	121.6	127.6	127.3	127.0	126.0	125.5	126.4	126.3	125.2	126.3	124.5	123.2	127.5	127.2
Daily gain/lb.	0.92	1.52	1.44	1.53 -	1.46	1.27	1.19	0.91	1.44	1.26	1.36	1.35	1.14	1.23
Feed/gain	5.02	3.32	3.46	3.32	3.40	3.47	3.55	5.94	3.47	3.65	3.36	3.60	3.80	4.04

isoleucine supplementation, the change was nonsignificant. This lack of growth response following supplementation was also reported by Chung and Beanies (1974) but with much lower levels of isoleucine in the basal diet than were reported for summer fallow Finnaska. A lack of response to methionine supplementation may be explained by a narrow difference in the levels in the basal diet and N.R.C. requirements. In addition, methionine supplementation in barley diets was reported by Chung and Beanies (1974) to elicit no growth response and to depress growth when included in milo diets (Eckert and Allee 1974). Our results indicate that a reassessment of isoleucine requirement for a growing pig may be in order.

Trial II-The supplementation of a basal barley diet with levels of amino acids to equal a 16 per cent barley- soybean meal diet improved the rate and efficiency of gain to equal the growth response of the barley-soybean meal control and to exceed significantly the growth of pigs fed a basal diet (table 11). Supplementation with lysine produced a significant response but isoluecine and methionine provided no response above that obtained for lysine although the basal diet was slightly deficient in both those amino acids. Threonine in the basal diet exceeded the requirement and supplementation to equal a barley-soybean meal 16 per cent protein diet had no effect on growth. The lack of response from isoleucine and methionine supplementation supports the conclusion derived from Trial I that the requirements may need to be reevaluated for growing pigs. Both the rate and efficiency of gain in Trial II were reduced compared to those in Trial I for the basal diet plus one through four amino acids. This response was expected since the standard barley-soybean meal 16 per cent protein control diet did not contain sufficient lysine, isoleucine, and methionine/cystine to meet N.R.C. requirements as did similar rations in Trial I.

The results of Trials I and II indicate that barley diets should be balanced to meet lysine requirements and that, the higher the protein level (such as that produced by summer-fallow cultural practices), the less effective a protein supplement such as soybean meal becomes when we balance to meet protein requirements rather than specific amino acids requirements. Further, supplementation with crystalline lysine was more economical than balancing lysine requirement with imported soybean meal. The use of lysine in growing pig diets in Alaska would reduce the amount of imported soybean meal required as well as the additional cost of transportation of the meal.

Trial III-A basal continuous-crop barley diet was deficient in the following amino acids: lysine, slight threonine, isoleucine, and methionine/cystine (table 12). Supplementation with all four amino acids improved growth when compared to the basal barley diet. Threonine improved the rate of gain and feed efficiency when supplemented to a basal-lysine diet but not significantly. The addition of isoleucine had no response when compared to a diet supplemented with lysine and was slightly below the growth response of a threonine supplemented diet. Methionine supplementation decreased the rate of gain but had no effect on feed efficiency. Addition of nonessential amino acids, glycine and glutamic acid, in the presence of lysine, threonine, isoleucine, and methionine depressed both the rate and efficiency of gain, indicating that nonessential amino acids were sufficient in a 13.5 per cent crude protein continuous-crop. barley. Therefore, one may conclude that further additions of nonessential amino acids may have contributed to an amino acid imbalance. The slight response due to supplemental threonine would substantiate the work at other universities (Chung and Beanies 1974) that threonine is the second limiting amino acid in barley following lysine. The threonine diet approached the growth performance obtained by a 16 per cent protein barley-soybean meal diet. The superior performance of 16 per cent protein barley-soybean meal diet indicated that additional amino acids other than those studied may be limiting in continuous-crop barley.

Trial IV- Supplementation of a barley basal diet with lysine, threonine, isoleucine, and methionine significantly improved growth rate and feed efficiency compared to a basal barley diet when these amino acids were supplemented at a rate equal to a 16 per cent barleysoybean meal positive control (table 12). However, supplementation with lysine alone was not adequate to equal the rate and efficiency of gain from the 16 per cent barley-soybean meal positive control. Threonine supplementation improved feed efficiency compared to the 16 per cent positive control but did not elicit daily gains equal to that of the control. This further substantiates that threonine is second limiting in lower-protein barley. Isoleucine supplementation of a basal lysine-threonine diet had no effect on rate and efficiency of gain. Methionine supplementation reduced both the rate and efficiency of gain. The lack of response from isoleucine and the depressed response from methionine corresponds with conclusions made in Trials I and 11 that isoleucine requirements should be reevaluated for growing pigs and that methionine supplementation may have no effect and may even reduce growth performance as reported by researchers at other universities (Katz and Baker 1975). Supplementation of two nonessential amino acids, glycine and glutamic acid, depressed feed efficiency and daily gain when compared to the 16 per cent positive control, lysine supplementation, threonine supplementation, and isoleucine supplementation.

The results of Trials III and IV would indicate that Finnaska barley produced by continuous crop cultural practices resulting in a protein content of 13.5 per cent or less was limited in lysine and threonine for growth and that supplementation with isoleucine, methionine, or nonessential amino acids, glycine and glutamic acid, were of no benefit. The superior performance by the barley-soybean meal 16 per cent positive control would indicate that barley with lower protein should be supplemented with total protein from a natural source rather than crystalline amino acids. Fish meal, a by-product of the seafood-processing industry, may prove to be the cheapest substance available to Alaska pig farmers for use in meeting the total protein requirement with lysine and threonine as well as providing those nonessential amino acids not identified by this study.

Section III
Summary and Conclusions

The following are some generalizations that can be made about barley varieties and their protein contents:

1. Barleys tend to be higher in protein when grown in Arctic and subarctic regions. The long photoperiod enables plants to take up greater amounts of soil nitrogen and assimilate it into grain protein. Soil nitrogen must be available to plants in adequate amounts, however, in order for this phenomenon to occur.
2. Malting barleys are selected and bred for low protein content. Higher protein content usually results in lower starch content. Brewers and distillers buy malting barley for starch and not for protein.
3. Feed barley varieties are developed primarily for yield with little emphasis placed on protein content. In general, feed barleys have a greater range in protein content than do malting barley varieties.
4. Some research is currently being conducted to develop high-protein barley varieties in Sweden and Montana, but a monetary value for such a product has not been established.
5. Currently, high-protein feed barley does not receive a premium price when sold at a grain elevator.
6. The cost of additional nitrogen fertilizer for production of higher protein content from continuous cropping of barley may be offset by the savings gained by substituting crystalline lysine or Alaska marine by-products for lysine in order to balance rations to avoid the expense of importing soybean meal.

In summary, the following are agronomic practices that will increase the likelihood or probability of higher than normal protein content of barley:

1. Grow the crop on land that has been summer-fallowed the previous year. If continuous cropping is practiced, make sure the straw and stubble are tilled under in the fall of the year.
2. Plant seed of a high-protein variety such as Lidal.
3. If the soil pH is acid, apply lime to adjust the pH so that it falls between 6.5 and 7.0.
4. Apply part of the nitrogen fertilizer as a topdressing 2 to 4 weeks after seedling emergence.
5. Apply higher rates of nitrogen fertilizer to ensure that adequate amounts of nitrogen are available for protein assimilation in the grain.

Conclusions

Effect of Cultural Techniques on Value of Finnaska Barley for Growing Pigs

Prior to listing the conclusions, consideration should be given to the fact that this study was based on one barley variety and although chemical analyses of other varieties are similar, there is no feeding data on other varieties to substantiate the results reported for Finnaska. However, we may infer that results would be similar with other varieties until continued research either supports or refuses the following conclusions.

1. Lysine was the first limiting amino acid in both summer-fallow (15.4 per cent protein) and continuous-crop (13.5 per cent protein) Finnaska barley.
2. Threonine was the second limiting amino acid, only in continuouscrop barley with lower protein content.
3. Isoleucine and methionine were deficient in barley in both cropping systems when calculated from the chemical analyses, but supplementation failed to improve growth rate of pigs weighing 44 to 125 pounds.
4. Supplementation of high-protein barley such as that produced from summer-fallow cultural practices, can be accomplished nutritionally and economically with crystalline synthetic lysine or high-lysine natural protein supplements such as Alaskan marine by-products, the best natural protein source for lysine. Lysine supplementation, not to exceed recommended levels of inclusions in the diet, should be based on per-unit price.
5. Supplementation of lower-protein barley, such as that produced by continuous-cropping cultural techniques or poor fertilization practices, should be done with natural protein sources that supply the cheapest source of lysine whether it be soybean meal or marine byproducts.
6. Supplementation of barley rations with protein from any source is preferable to a barley-mineral-vitamin diet as shown by the poor growth response elicited from the basal diets in Trials I through IV.
7. Avoid the importation of barley with a low protein content similar to those produced in the Peace River Area of Canada and the Pacific Northwest when domestic barleys are available and competitively priced for formulation of swine rations.

Recommendations

1. All barley should be analyzed for crude protein, lysine, and dry matter content, and, if to be fed on the farm of origin or sold as high protein barley from summer-fallow production, the barley should be stored separately whenever possible and used in ration formulation with a minimum of imported, protein supplements similar to soybean meal with their high transportation cost.

2. Point to consider when barley is an export product. The Japanese are the world's largest producer of synthetic lysine and therefore may find a higher-protein barley r equiring only ly sine to balance the protein more desirable than competitive barleys from either the Pacific Northwest or specific areas of Canada.

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