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Hans H. Stein
South Dakota State University

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Hans H. Stein, Ph.D.
Department of Animal and Range Sciences
South Dakota State University

Summary

Field peas (*Pisum sativum* L.) have a nutrient profile intermediate between corn and soybean meal. The digestibility of most nutrients in field peas is similar to that in soybean meal, and the concentration of digestible energy in field peas is similar to that in corn.

Although the digestibility of most nutrients may be improved by thermal treatment, field peas are usually fed to swine without prior heat treatment. Pigs tolerate field peas well and the palatability of diets containing field peas is not different from diets containing only corn and soybean meal.

Recent research with U.S.-grown field peas indicates that field peas may be included in diets fed to nursery pigs from 2 weeks post-weaning at an inclusion level of 15 to 20%. At this concentration, no negative effects on pig performance have been reported. It is possible that higher inclusion levels may be used, but research to confirm this hypothesis remains to be conducted.

In diets fed to growing and finishing pigs, field peas may be included at levels sufficient to replace all protein supplied by soybean meal in the diets. Field peas do not influence feed intake, average daily gain, or the gain to feed ratio.

Lower carcass drip losses and a more desirable color of the longissimus muscle have been reported for pigs fed diets containing field peas, but other carcass characteristics have not been influenced by field peas. Likewise, the palatability of pork chops and ground pork patties is not changed by the inclusion of field peas in the diets.

Limited research has been conducted in the U.S. with field peas in diets fed to sows. However, based on data from studies conducted in Europe, field peas may be included in diets fed to gestating and lactating sows at levels of up to 20%.

Based on the current body of research, it is recommended that, if field peas are competitively priced, they may be included in diets fed to all categories of swine. The price that can be paid for field peas depends on the price of both corn and soybean meal.

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Field peas have been grown for centuries in many parts of the world, mainly for human consumption. During the last 25 years, markets for field peas in livestock feeding also have developed in Canada, Australia, and Western Europe. In the U.S., field peas have been included in diets fed to swine in the Pacific Northwest for several decades; but in the Midwest, where the majority of the pigs are produced, very few field peas have been used.

Rapidly increasing production of field peas in the upper Midwest, however, has increased the interest in feeding field peas to swine. This publication summarizes the current knowledge about feeding field peas to swine. Conclusions are based mainly on research conducted with field peas in the U.S., but results from Canada, Europe, and Australia are included where appropriate.

Classification of Peas

All peas belong to the same botanical species, *Pisum sativum* L. For feeding to swine, only peas harvested at maturity are used. Such peas are usually designated as "field peas" or "dry peas" and they have seeds that are round. In contrast, peas used for canning may have wrinkled seeds. The chemical composition of wrinkled peas is different from the composition of round peas.

Field peas may have white or green seeds, but this does not influence the nutritional value. Peas with colored flowers contain anti-nutritional factors called tannins; white-flowered peas do not. Therefore, only white-flowered varieties are grown in the U.S. Peas imported from Australia may originate from colored-flower varieties.

Most peas grown in the U.S. are spring varieties. Spring peas often have lower concentrations of trypsin inhibitors than winter peas, but newer varieties of winter peas also have low trypsin inhibitor concentrations and are expected to have the same nutritional value as spring peas.

Nutrient and Energy Composition and Digestibility

Only limited research has been conducted in the U.S. to investigate the digestibility of energy and nutrients in field peas by pigs. However, considerable work has been conducted in France and Canada.

Amino Acid Digestibility

Field peas have a moderate concentration of crude protein. Pea protein has a relatively high concentration of lysine but low concentration of methionine, cysteine, and tryptophan compared with soybean protein (Table 1). The ileal digestibility of most amino acids in U.S.-grown field peas is comparable to the digestibility of amino acids in soybean meal.[1] However, the digestibility of methionine, cysteine, and tryptophan in field peas is lower than in soybean meal (Table 1) and the digestibility of threonine tends to be lower in field peas than in soybean meal. Ileal digestibility values for amino acids in U.S.-grown field peas concur with published reports on the digestibility of amino acids in field peas grown in Europe,[2] Australia,[3] and in Canada.[4,5]

The reason why certain amino acids have lower digestibilities than others may be related to their location within the pea seed. Albumin, which has a relatively high concentration of methionine, threonine, and tryptophan, is less digestible than other proteins in the seed.[6] This may explain why lower digestibilities for these amino acids have been reported.

The effect of thermal treatment on the ileal digestibility of amino acids has been investigated in a few experiments. For field peas grown in Canada[7] and in the U.S. (Stein et al., unpublished), improvements of 4 to 6 percentage units in the apparent and standardized ileal digestibilities for most amino acids have been reported as a result of extrusion or micronization. The amino acids that have the lowest digestibility in raw field peas (i.e., methionine, threonine, and tryptophan) have the largest improvement in digestibility upon thermal treatment.

Table 1. Amino acid composition of the protein and amino acid and protein digestibility in field peas and soybean meal (as fed basis).[a]

INGREDIENT:	FIELD PEAS			SOYBEAN MEAL		
Item	% of ingredient	% of crude protein	SID [b]	% of ingredient	% of crude protein	SID [b]
Crude protein	22.8	100	79.9	47.5	100	84.5
Arginine	1.87	8.20	92.8	3.48	7.32	93.0
Histidine	0.54	2.37	88.3	1.28	2.70	89.7
Isoleucine	0.86	3.77	83.4	2.16	4.55	86.3
Leucine	1.51	6.62	85.7	3.66	7.71	86.1
Lysine	1.50	6.58	88.1	3.02	6.36	88.4
Methionine	0.21	0.92	77.9	0.67	1.41	89.1
Cysteine	0.31	1.36	67.3	0.74	1.56	83.9
Phenylalanine	0.98	4.30	86.9	2.39	5.05	86.9
Tyrosine	0.71	3.11	84.7	1.82	3.83	87.2
Threonine	0.78	3.42	80.2	1.85	3.90	85.9
Tryptophan	0.19	0.83	54.3	0.65	1.37	78.5
Valine	0.98	4.30	78.2	2.27	4.78	82.7

[a] Data for amino acid concentration and composition are from NRC (1998). Data for SID of protein and amino acids are from Stein et al., 2004.[1]
[b] SID = standardized ileal digestibility (%).

Carbohydrate Digestibility

The carbohydrate fraction in field peas grown in Europe mainly consists of sucrose (3–4%), alpha-galactosides (3–4%), starch (40–45%), and non-starch polysaccharides (15–20%), whereas the concentration of lignin is less than 1%.[8,9] Unpublished data from South Dakota State University indicate that the concentration of starch and non-starch polysaccharides in field peas grown in the U.S. is similar to the values reported for European-grown field peas. The apparent ileal digestibility of sucrose is close to 100%, and the apparent ileal digestibility of starch in European-grown field peas is between 85 and 97%.[8,9] In raw U.S.-grown field peas, the apparent ileal digestibility of starch is approximately 90%, but this value increases to approximately 95% if the field peas are extruded at 115 to 155°C (Table 2).

The alpha-galactosides (i.e., raffinose, stachyose, and verbascose) require the enzyme alpha-galactosidase for digestion. This enzyme is not

synthesized by mammals, but there is some intrinsic alpha-galactosidase present in field peas. Intestinal microbes also may produce this enzyme; alpha-galactosides are, therefore, relatively well digested by swine and have an apparent ileal digestibility of 78%.[8] The non-starch polysaccharides (i.e., ADF and NDF) have a low digestibility in the small intestine, but due to the microbial fermentation in the hindgut, the total tract digestibility of the non-starch polysaccharides is between 80 and 87% in both raw and extruded field peas (Stein et al., unpublished; Table 2).[9]

Phosphorus Digestibility

Field peas contain approximately 0.40% phosphorus.[10,11] Of the total concentration of phosphorus, 45 to 52% is bound in the phytate complex and, therefore, has a low digestibility by swine and poultry.

However, the unbound phosphorus is highly digestible and the overall digestibility of phosphorus in U.S.-grown field peas fed to growing pigs is 55% (Table 3). For European-grown field peas, apparent total tract digestibility values of 42 to 51% have been reported.[12,13] The digestibility of phosphorus can be improved by 10 to 15 percentage units if microbial phytase is added to diets containing field peas (Table 3).[11,13]

Thus, the digestibility of phosphorus in field peas is considerably greater than in corn and soybean meal and the addition of field peas to diets will reduce the need for inorganic sources of phosphorus. Excretion of phosphorus in the manure will also be reduced if field peas are included in the formulas.

Energy Digestibility

The concentration of gross energy in field peas grown in the U.S. is comparable to that in corn.[1] Likewise, the digestibility of energy and the concentration of digestible energy (DE) in field peas are not different from corn (Table 4). The value for DE in field peas grown in the U.S. (3,864 kcal DE per kg DM) is also comparable to values reported for field peas grown in Canada (3,862 kcal DE per kg DM)[14] and in Europe (3,904 kcal DE per kg DM).[15] However, the concentration of metabolizable energy in field peas is slightly lower than in corn. As shown in Table 2, the digestibility of energy can be improved by 2 to 3 percentage units if field peas are extruded prior to feeding.

Inclusion of Field Peas in Diets Fed to Swine

Several experiments investigating the effects of including field peas in diets fed to swine have been published. Although conditions may vary, the results from these experiments indicate that pigs tolerate field peas well and that the inclusion of field peas in a diet has no negative influence on the palatability of the diet.

Field Peas Fed to Weanling Pigs

In an experiment at South Dakota State University, field peas were included in diets fed to weanling pigs in concentrations of 0, 6, 12, or 18%. Pigs were weaned at an age of 20 days and fed a common diet during the initial 2 weeks post-weaning before being offered the experimental diets. Results of the experiment showed no negative effects of field peas on feed intake, daily gain, or the gain:feed ratio (Table 5). These data concur with research conducted at North Dakota State University.[16]

Research with Canadian-grown field peas indicated that the inclusion of 30% field peas in diets fed to weanling pigs resulted in a reduced gain:feed ratio during the initial 2 weeks after weaning but not during the remaining nursery period.[7]

Based on these results, it is recommended that field peas should not be included in diets fed to weanling pigs during the initial 2 weeks post-weaning. After this period, 15 to 20% field peas may be included in the diets without negatively affecting pig performance. If the field peas are extruded or micronized, it may be possible to include higher concentrations without any impact on pig performance.[7, 17]

Table 2. Effects of thermal treatment on the digestibility (%) of starch, NDF, ADF, and energy in field peas fed to growing pigs.[a]

	Extrusion				SEM [b]	P-Value	
Item	None	75°C	115°C	155°C	–	Linear effect	Quadratic effect
APPARENT ILEAL DIGESTIBILITY							
Starch	89.8	92.1	94.7	95.9	0.79	0.001	0.50
Energy	71.5	76.4	79.3	79.0	1.43	0.001	0.09
APPARENT TOTAL TRACT DIGESTIBILITY							
Starch	99.2	99.6	99.7	98.6	0.45	0.50	0.20
NDF	81.3	85.2	86.3	73.2	6.83	0.50	0.30
ADF	79.5	83.2	84.8	71.9	7.71	0.60	0.40
Energy	89.0	91.8	93.3	91.7	0.78	0.02	0.01

[a]Unpublished data from South Dakota State University (N = 6).
[b] SEM = standard error of the mean.

Table 3. Apparent total tract digestibility (ATTD) of calcium and phosphorus in field peas without and with added microbial phytase.[a]

Diet:	Peas without	Peas with	SEM [c]	P-value
Item	phytase	phytase [b]		
ATTD, calcium, %	72.8	78.1	3.39	0.07
ATTD, phosphorus, %	55.0	65.9	4.64	0.004

[a]Data (N = 6) from Stein et al., 2006a.[11]
[b]Microbial phytase (Rhonozyme, DSM, Passippani, N.J.) added in the amount of 695 units per kilogram (315 units per lb) of diet.
[c]SEM = standard error of the mean.

Table 4. Energy concentration in field peas and corn.[a]

Ingredient:	Field Peas	Corn	SEM [b]	P-value
Item				
Apparent digestible energy in DM, kcal	3,864	3,879	27	0.68
Metabolizable energy in DM, kcal	3,741	3,825	24	0.04

[a] Data (N = 6) from Stein et al., 2004[1]
[b] SEM = Standard error of the mean.

Field Peas Fed to Growing-Finishing Pigs

Field peas grown in the U.S. have been included in diets fed to growing-finishing pigs (22–110 kg) at a level of 36–45% without any negative impact on pig performance, dressing percentage, or carcass composition.[1,17] In a more recent experiment, field peas were included in the grower period (25–50 kg) at 66%, in the early finisher period (50–85 kg) at 48%, and during the late finishing period (85–125 kg) at 36%.[18]

At these inclusion levels, all soybean meal in the diets was replaced by field peas. The performance of pigs fed these diets was compared with that of pigs fed a corn-soybean meal-based control diet or diets containing corn, soybean meal, and 36% field peas in all three phases.

Results showed that pig performance was not influenced by the inclusion of field peas in the diets. This was true for all of the three phases (data not shown) and overall for the entire experiment (Table 6). Likewise, no negative effects of the field peas were observed on carcass composition, carcass quality, or the palatability of pork chops or ground pork patties from pigs fed these diets.

It is concluded, therefore, that field peas may be included in corn-based diets fed to growing-finishing pigs at levels necessary to provide all the amino acids needed by the pigs.

Table 5. Growth performance of weanling pigs fed diets containing field peas.[a,b,c]

Field peas, %:	0	6	12	18	SEM [d]	P-value Linear effect	P-value Quadratic effect
RESPONSE							
Average initial weight, kg	7.81	7.81	7.79	7.79	0.68	0.98	0.99
Average finished weight, kg	19.65	20.02	19.90	19.17	1.33	0.79	0.68
Average daily gain, kg	0.423	0.436	0.433	0.407	0.025	0.64	0.44
Average daily feed intake, kg	0.66	0.66	0.70	0.64	0.05	0.91	0.54
Average gain:feed, kg/kg	0.62	0.64	0.62	0.64	0.015	0.66	0.67

[a] Data from Stein et al., 2004.[1]
[b] Each mean represents six observations with five pigs per pen.
[c] One kilogram = 2.2 lb.
[d] SEM = standard error of the mean.

Table 6. Growth performance and carcass quality of growing-finishing pigs fed diets without or with field peas.[a,b,c]

Field peas (%) [e]	0/0/0	36/36/36	66/48/36	SEM [d]	P-value
RESPONSE					
Initial weight, kg	22.9	22.7	22.7	0.55	0.49
Average daily feed intake, kg	2.74	2.6	2.82	0.079	0.12
Average daily gain, kg	0.872	0.86	0.889	0.0247	0.59
Average gain:feed ratio, kg/kg	0.319	0.332	0.318	0.0087	0.38
Final weight, kg	129	124.1	129.2	3.18	0.59
Dressing, %	76.2	75.4	75.8	0.34	0.2
Longissimus muscle depth, cm	6.17	5.92	6.08	0.087	0.21
Longissimus muscle area, cm^2	46.1	44.5	46.3	0.86	0.36
10th rib back fat, cm	2.32	2.40	2.41	0.134	0.81
Lean meat, %	51.8	51	51.3	0.636	0.67
Marbling score	1.07	1.07	1.04	0.089	0.97
pH, longissimus muscle	5.42	5.41	5.44	0.046	0.37
Drip loss, %	3.38	2.51	1.95	0.322	0.02
Pork chop tenderness [f]	5.5	5.57	5.47	0.253	0.92
Pork chop juiciness [g]	5.3	5.46	5.27	0.159	0.65
Pork pattie juiciness [g]	5.59	5.55	5.48	0.195	0.93

[a] Data from Stein et al., 2006b.[18]
[b] Each mean represents eight observations with two pigs per pen.
[c] One kilogram = 2.2 lb. One cm = 0.3937 inches. One cm^2 = 0.155 $inch^2$.
[d] SEM = standard error of the mean.
[e] Numbers represent the inclusion rate (%) of field peas in diets fed from 22 to 50 kg, 50 to 85 kg, and 85 to 125 kg, respectively.
[f] Tenderness score: 8 = extremely tender; 1 = extremely tough.
[g] Juiciness score: 8 = extremely juicy; 1 = extremely dry.

Field Peas Fed to Reproducing Swine

Research at North Dakota State University suggested that the inclusion of 10% field peas in diets fed to lactating sows resulted in increased litter weight gain and a tendency for reduced pig mortality during the lactation period.[17] There are no data available from studies in which U.S.-grown field peas have been fed to gestating sows.

However, data from France suggested that the inclusion of 16% field peas in gestating diets and 24% in lactating diets had no negative effects on sow or pig performance.[19] Data from Germany indicated that if field peas are included in diets fed to gestating and lactating sows at levels of 10 or 20%, there is no impact on sow reproductive performance. However, if the inclusion level was 30%, sow performance was reduced.[20] There are no data available on the types of field peas used in the latter study or on the concentration of anti-nutrititional factors in the peas. If peas containing a relatively high concentration of trypsin inhibitors or other anti-nutritional factors were used, then that might explain why some negative results were obtained at the higher inclusion level of field peas.

Based on the above results, it is concluded that field peas may be used in diets fed to gestating and lactating sows at an inclusion level of up to 20%.

Formulating Diets with Field Peas

General Principles

Pigs require certain dietary levels of digestible indispensable amino acids and digestible phosphorus. These requirements are determined by the physiological stage of the animal; i.e., the

stage of growth of a growing pig or the reproductive stage of a breeding animal.[10]

When formulating diets, it is necessary to meet the requirements for all indispensable amino acids. In corn-soybean meal-based diets, lysine and tryptophan are often the first limiting amino acids. If the requirements for these two amino acids are met, the requirements for all other indispensable amino acids are usually also met. Because of the relatively low concentrations of digestible methionine, cysteine, and threonine in field peas, it is necessary to pay careful attention to the concentrations of these amino acids in the diets if field peas are used, and it is often necessary to include crystalline sources of methionine, threonine, and tryptophan to formulate a diet balanced in all indispensable amino acids. In contrast, the inclusion of crystalline lysine and inorganic sources of phosphorus may be reduced because of the relatively high concentrations of these nutrients in field peas.

As a rule of thumb, 3% field peas will replace approximately 2% corn and 1% soybean meal in diets fed to swine if crystalline sources of methionine, threonine, and tryptophan are included to balance the indispensable amino acids. At the same time, the inclusion level of crystalline lysine and monocalcium phosphate (or dicalcium phosphate) is reduced.

In experiments where field peas were successfully included in diets fed to swine, these principles for diet formulation were followed. Poor pig performance has been reported from experiments in which field peas were used without appropriate inclusion of crystalline amino acids. However, once the indispensable amino acids in the diets were balanced, this problem was ameliorated and normal pig performance was restored.

Examples of Diets Containing Field Peas

Diets for growing pigs (i.e., 20 to 50 kg) were formulated using corn and soybean meal; corn, soybean meal, and field peas; or corn and field peas (Table 7). All diets were formulated to meet minimum requirements for digestible amino acids and digestible phosphorus.[10] Calcium, salt, vitamins, and micro minerals were included at similar levels in all diets.

Table 7. Example of diet formulations for growing pigs using field peas.[a,b]

DIET: Item	NRC requirement[c]	Corn-soybean meal	Corn-soybean meal-field peas	Corn-field peas
INGREDIENTS, %				
Corn	-	73.00	49.64	34.55
Soybean meal (48%)	-	21.40	9.00	-
Field peas	-	-	36.00	60.00
Choice white grease	-	3.00	2.9	2.93
Limestone	-	0.95	1.05	1.15
Monocalcium phosphate	-	0.92	0.65	0.50
L-lysine HCL	-	0.13	0.02	-
DL-methionine	-	-	0.07	0.14
L-threonine	-	-	0.03	0.06
L-tryptophan	-	-	0.04	0.07
Salt	-	0.40	0.40	0.40
Vitamin premix	-	0.05	0.05	0.05
Micro mineral premix	-	0.15	0.15	0.15
ENERGY AND NUTRIENTS [d]				
Energy, kcal ME/kg	-	3,472	3,472	3,472
SID protein, %	-	13.44	13.46	13.21
Calcium, %	0.60	0.61	0.60	0.60
Phosphorus, %	-	0.55	0.48	0.44
Digestible phosphorus, %	0.23	0.23	0.23	0.23
SID arginine, %	0.33	0.94	1.08	1.16
SID histidine, %	0.26	0.39	0.38	0.36
SID isoleucine, %	0.45	0.59	0.55	0.52
SID leucine, %	0.83	1.36	1.21	1.09
SID lysine, %	0.83	0.83	0.83	0.86
SID methionine, %	0.22	0.24	0.26	0.29
SID methionine + cysteine, %	0.47	0.50	0.47	0.47
SID phenylalanine, %	0.49	0.71	0.67	0.63
SID threonine, %	0.52	0.52	0.52	0.52
SID tryptophan, %	0.15	0.16	0.15	0.15
SID valine, %	0.56	0.68	0.63	0.58

[a] Diets formulated for growing pigs (20 – 50 kg).
[b] Diets were formulated based on metabolizable contents of energy (ME), standardized ileal digestible contents of amino acids, and apparent total tract digestible contents of phosphorus in corn, soybean meal, and field peas. All data for corn and soybean meal were from NRC (1998), whereas data for field peas were from Stein et al., 2004[1] and Stein et al., 2006a.[11]
[c] Data from NRC, 1998.[10]
[d] ME = metabolizable energy; 1 kg = 2.2 lb; SID = standardized ileal digestible. 1 ton = 2,000 lb = 907 kg of soybean meal

It appears from Table 7 that, as the concentration of field peas in the diet increases, crystalline sources of methionine, threonine, and tryptophan are needed to meet the requirements for these amino acids, whereas the inclusion levels of crystalline lysine and of monocalcium phosphate are reduced. By following these principles, diets that contain equal concentrations of digestible indispensable amino acids and of digestible phosphorus were formulated. The diets will, therefore, result in equal pig performance.

Economic Considerations

Decisions on whether or not to use field peas in diets fed to swine should be based on economic considerations because pig performance and carcass quality are not influenced by the inclusion of field peas in the diets.

To estimate the price of field peas that can be paid without increasing total diet costs, the costs of corn, soybean meal, monocalcium phosphate, and crystalline amino acids need to be taken into account. This is most easily accomplished

by formulating diets using a least-cost formulation software package.

If the costs of monocalcium phosphate and crystalline amino acids are constant, the data in Table 8 may be used to indicate when field peas are competitively priced. It appears from Table 8 that the cost of field peas can increase by $0.15 per bushel (27.27 kg) if the cost of soybean meal is increased by $25 per ton (907 kg). Likewise, the price that can be paid for field peas may increase by $0.20 to 0.25 per bushel (27.27 kg) if the price of corn increases by $0.25 per bushel (25.45 kg). If the costs of crystalline amino acids or of monocalcium phosphate are different from those used in the example, slightly different relationships may be obtained. Therefore, the competitiveness of field peas in diets fed to swine should be calculated for each specific situation.

Table 8. Maximum cost of field peas ($/bushel) at different costs of corn and soybean meal.[a,b,c]

	Soybean meal (48%), $ per ton [d]					
Corn, $ per bushel [e]	175	200	225	250	275	300
1.50	2.50	2.60	2.75	2.90	3.05	3.20
1.75	2.75	2.90	3.00	3.15	3.30	3.45
2.00	2.95	3.10	3.20	3.40	3.50	3.65
2.25	3.15	3.30	3.40	3.60	3.75	3.85
2.50	3.35	3.50	3.60	3.80	3.95	4.05

[a] For each combination of costs for corn and soybean meal, the price indicated for field peas will result in identical diet costs for a corn-soybean meal-based diet and a corn-field pea-based diet.

[b] Diets were formulated assuming the following costs of other ingredients: choice white grease, $0.34/kg; limestone, $0.052/kg; monocalcium phosphate, $0.38/kg; L-lysine HCL, $1.84/kg; DL-methionine, $3.25/kg, L-threonine, $4.07/kg; L-tryptophan, $37.40/kg. Changes in the costs of these ingredients may change the price that can be paid for field peas.

[c] 1 bushel of field peas = 60 lb = 27.27 kg.

[d] 1 ton = 2,000 lb = 907 kg of soybean meal.

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