# Influence of diets containing raw or extruded peas instead of soybean meal on meat quality characteristics in growing-finishing pigs

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**ABSTRACT**: An experiment was conducted to evaluate the effect of pea-based diet fed to growing and finishing pigs on performance, carcass and meat quality. Thirty pigs (Slovak White Meaty or crossbred Slovak White Meaty × Pietrain) were tested for the malignant hyperthermia (MH) syndrome using a DNA based test. Pigs were allotted to control and experimental groups (of 10 pigs each, equal for normal – NN and heterozygotes – Nn and equal for barrows and gilts) with 2 pigs per pen. Pigs receiving the control treatment were fed soybean meal diets. In all diets fed to experimental pigs the soybean meal was replaced by 30% of raw or extruded pea-based meal balanced on an isonitrogenous and isoenergetic level. Pig performance was monitored for the entire experimental period. At the conclusion of the experiment, carcass and meat quality were measured. The results did not show any effects of dietary treatments on average daily gain ($P > 0.05$). The evaluation of carcass composition showed no significant differences ($P > 0.05$) in backfat and lean percentage values between the control and experimental pigs. Chemical composition (total water, protein, intramuscular fat) and fatty acid profile did not differ among treatments ($P > 0.05$). The differences in the omega-6/omega-3 ratio were significant ($P > 0.05$) between animals fed the control ration with soybean meal and animals receiving the pea ration. No differences were observed between control and experimental pigs in pH (45 min and 24 h), colour (24 h), drip loss (24 h) and tenderness (5 day) measured with Warner-Bratzler instrument ($P > 0.05$). In conclusion, peas may replace the soybean meal in diets fed to growing and finishing pigs without negative influence on pig performance, carcass composition and meat quality.

**Keywords**: peas; extrusion; pigs; carcass and meat quality

Qualitative as well as quantitative composition of feeds can influence not only the amount and economics of production but also the quality of animal products. Quality of feed mixtures for farm animals depends mainly upon the composition of protein components. At present pea is incorporated into feed mixtures in increased amounts; it is a result of marked expansion of this commodity in the world. This worldwide trend is given by the progress in pea breeding for its higher yield and change in the seed composition (Castell et al., 1996; Zdunczyk et al., 1997; Stanek et al., 2004), mainly for a decrease in antinutritive substances. There exists a considerable variability in chemical composition between and within varieties of pea (Chrenková et al., 1995, 1996, 1998). The use of peas for small piglets (3 to 4 weeks) is limited, because feed intake decreases due to the presence of antinutritive substances in pea (Wagner, 1994; Kehoe et al., 1995; Jaikaran et al., 2001). However, Gatel et al. (1989, 1991) fed with success diets containing 20% of spring pea to 5–6 weeks old piglets. The addition of methionine on the 30% level was necessary to maintain the performance. Up to 50% of peas in diets can be used for pigs from 21 to 60 kg live weight (Jaikaran et al., 1995). Considering the proteinous character of

inhibitors of proteases they can be inactivated by heat treatment of peas (Gatel, 1994; Gilbert, 1998; O'Doherty and Keady, 2000). In spite of positive results of feeding peas that were reported by the above-mentioned authors as well as others, content of pea in our feed mixtures is low and the quality of its proteins is underestimated.

Different results of some meat quality para-meters were recently obtained by Christodoulou et al. (2006) and Stein et al. (2006) when peas based feeding was used; they need further experimental works.

The objective of this paper was to study the influence of soybean meal replacement by raw and extruded peas on performance and carcass and meat quality in fattened pigs.

## MATERIAL AND METHODS

### Animals, experimental design (diets and feeding) and sample preparation

In total 30 pigs were used in this experiment. They originated from lines of Slovak White Meaty or crossbred (Slovak White Meaty × Pietrain) pigs. The RYR-1 genotype (Fujii et al., 1991; Bauerová et al., 1999) of these animals was determined by a DNA based test (malignant hyperthermia syndrome; MH as normal – NN and heterozygotes – Nn). The pigs were divided into control and experimental groups (of 10 pigs each, with equal 6 MH normal – NN and 4 MH heterozygotes – Nn and with equal 5 barrows and 5 gilts). The pigs were individually weighed and penned in double boxes (with access to concentrates and water) at the institute facilities.

Complete feed mixtures contained soybean meal for the control group and 15% (C1) and 30% (C2) raw and extruded peas (P1, EP1 and P2, EP2, respectively) for pigs in experimental groups (Table 1). Extrusion of peas was performed under these conditions: continual pressure at 40 bars and temperature of the expander 130°C for 20 s. We used the data on ileal digestibility according to the Optimix programme to compose the feed mixtures (Table 1). The energy value of feed mixtures was calculated according to Kirchgessner (cited by Šimeček et al., 1994) for metabolisable energy. Feed mixtures were composed from the aspect of minimal differences in the content of crude protein and all other nut-rients (Table 2).

Pig weights were recorded at the beginning of the experiment, at the end of the growing period and at the conclusion of the experiment, and average daily gain (ADG) and feed conversion for the entire experimental period were calculated. At the end of the experiment, all pigs were fasted for 16 h (with water access). The animals with average live weight of 100 ± 5 kg were stunned, slaughtered and

Table 1. Composition of feed mixtures

| Ingredients (%) | Feed mixture | | | |
|---|---|---|---|---|
| | C1 | P1 × EP1 | C2 | P2 × EP2 |
| Wheat | 40.4 | 31.5 | 41.2 | 26.9 |
| Barley | 20.0 | 20.0 | 28.5 | 20.0 |
| Maize | 20.0 | 20.0 | 20.0 | 20.0 |
| Soybean meal | 15.4 | 8.9 | 7.4 | – |
| Rape-seed oil | 0.8 | 1.1 | – | 0.2 |
| Amino acids and minerals Premix | 3.4[a] | 3.5[b] | 2.9[c] | 2.9[d] |
| Native pea | – | 15.0 | – | 30.0 |
| Extruded pea | – | 15.0 | – | 30.0 |

[a]100 g contained: 0.350 g L-lysine.HCl 98; 0.005 g DL-methionine 99; 0.089 g L-threonine 98; 1.478 g DCP; 0.825 g limestone; 0.388 g fodder salt

[b]100 g contained: 0.357 g L-lysine.HCl 98; 0.032 g DL-methionine 99; 0.126 g L-threonine 98; 0.026 g L-tryptophan; 1.473 g DCP; 0.859 g limestone; 0.387 g fodder salt

[c]100 g contained: 0.353 g L-lysine.HCl 98; 0.075 g L-threonine 98; 1.479 g DCP; 0.466 g limestone; 0.340 g fodder salt

[d]100 g contained: 0.220 g L-lysine.HCl 98; 0.020 g DL-methionine 99; 0.083 g L-threonine 98; 0.028 g L-tryptophan; 1.404 g DCP; 0.543 g limestone; 0.334 g fodder salt

Table 2. Nutrient content and metabolisable energy (ME) in tested diets (g/kg DM)

| Characteristics | Feed mixture | | | | | |
|---|---|---|---|---|---|---|
| | C1 | P1 | EP1 | C2 | P2 | EP2 |
| Dry matter (DM) | 880.2 | 882.0 | 886.8 | 872.0 | 877.1 | 874.6 |
| Crude protein | 197.7 | 190.1 | 180.4 | 174.9 | 164.9 | 171.5 |
| Crude fibre | 36.1 | 34.2 | 33.3 | 38.6 | 41.4 | 45.0 |
| Crude fat | 31.7 | 32.6 | 31.9 | 20.9 | 21.3 | 20.3 |
| **Content of selected fatty acids in tested feed diets** (% of total FA) | | | | | | |
| C14:0 myristic acid | 0.11 | 0.13 | 0.11 | 0.10 | 0.11 | 0.14 |
| C16:0 palmitic acid | 11.86 | 11.43 | 10.95 | 13.61 | 12.60 | 12.96 |
| C16:1 palmitoleic acid | 0.83 | 0.57 | 0.47 | 0.58 | 0.59 | 0.64 |
| C18:0 stearic acid | 1.28 | 1.23 | 0.97 | 1.23 | 1.44 | 1.33 |
| C18:1 oleic acid | 32.79 | 37.84 | 37.98 | 25.71 | 29.29 | 29.94 |
| C18:2n-6 linoleic acid | 47.26 | 42.84 | 42.61 | 53.13 | 50.72 | 49.67 |
| C18:3n-3 linolenic acid | 5.53 | 5.69 | 6.72 | 4.90 | 4.87 | 5.04 |
| C20:4n-6 arachidonic acid | 0.35 | 0.27 | 0.21 | 0.44 | 0.39 | 0.29 |
| **Content of selected amino acids and minerals in tested feed diets** (g/kg DM) | | | | | | |
| Lysine | 11.1 | 11.0 | 11.8 | 9.1 | 10.1 | 9.6 |
| Methionine | 2.8 | 2.8 | 2.8 | 2.0 | 2.1 | 2.2 |
| Cystine | 2.8 | 2.6 | 2.6 | 2.4 | 2.2 | 2.2 |
| Threonine | 7.7 | 7.5 | 8.2 | 6.5 | 6.5 | 6.2 |
| Calcium | 6.9 | 7.1 | 7.0 | 4.4 | 5.7 | 6.0 |
| Phosphorus | 6.1 | 6.0 | 5.8 | 4.7 | 5.3 | 5.3 |
| ME (MJ/kg DM) | 15.22 | 15.29 | 15.26 | 12.33 | 12.40 | 12.41 |

C1, C2 = control feed mixture with soybean meal

P1, P2 = experimental feed mixture with 15% and 30% of raw peas

EP1, EP2 = experimental feed mixture with 15% and 30% of extruded peas

exsanguinated in a slaughterhouse of APRC Nitra (transportation about 200 m). At slaughter, hot carcass weight, backfat thickness, and loin muscle depth were recorded for each pig and the lean meat percentage was calculated. Carcass composition was estimated after death and refrigerated storage at 3–4°C for 24 h.

After 24 h chilling, the *longissimus* muscle (LD) was removed from the carcass (right side, last rib) and sliced into chops (2.5 cm thick). One wrapped sample was stored in a refrigerator for 5 days at 4°C.

## Chemical analysis

Total protein and intramuscular fat were measured with an Infratec analyser. Lipid extraction was done with petroleum ether. Fatty acid composition of muscles was determined by gas chromatography (GC 8000 TOP, CE Instruments). Fatty acids were analysed as methyl esters with FID on a DG-225 capillary column (length 30 m, ID 0.53 mm, thickness of stationary phase 1 μm). Fatty acids were calculated as % proportion (as relative content) in the total sum of fatty acids (C6–C24).

## Meat quality measurements

The pH value (45 min, 24 h) of the carcass (*longissimus* muscle between the 13$^{th}$ and 14$^{th}$ rib) was determined using a combined pH electrode (Ingold). Instrumental colour measurements (24 h) were recorded for $L^*$ (lightness; 0: black, 100: white) using

a spectrophotometer (Hunter Lab MiniScan). Drip loss analysis (24 h) was done according to Honikel (1998). Shear force (5 days) was determined in cooked samples (core temperature of 75°C) using a Warner-Bratzler apparatus.

### Statistical analysis

Data were analysed by the three-way analysis of variance with unequal subclass numbers with fixed effects, with main effects groups (control, peas, extruded peas), sex (barrows, gilts), genotype *RYR1* (NN, Nn) and group × sex and group × genotype interactions. No interactions and differences were observed between genotypes. For this reason subsequent analyses were focused only on differences between groups and sex by the two-way analysis of variance with group × sex interaction. The paper presents only differences among the analysed groups, which were verified by Tukey's *t*-test (Grofik and Fľak, 1990).

## RESULTS AND DISCUSSION

In the present experiment, all diets containing raw peas or extruded peas were balanced for essential AA, ensuring that the deficiencies of Met, Thr, or Lys did not limit performance parameters when these diets were administered (Table 2) with similarities reported by others (Stein et al., 2004). The content of crude protein in all experimental groups for the 1st phase of fattening was adequate to the crude protein requirement (180 g/kg DM) that is given in standards of nutrient requirements in pigs of the weight category 35–65 kg (Šimeček et al., 1994). Feed mixtures for the 2nd phase of fattening met the required standard as far as the crude protein content of 160 g/kg DM is concerned. The feed mixtures were composed on the basis of tabular values of ileal digestibility of amino acids. The requirement for amino acids is derived from the requirement for lysine and it is determined by its proportion in relation to other amino acids. The amount of lysine and of other essential amino acids in all feed mixtures did not fall below the recommended level (Cole and Van Lunen, 1994). Slight differences in the content of nutrients became evident in the content of ME in individual mixtures. They represented 15.2 MJ/kg during the 1st phase and 12.4 MJ/kg during the 2nd phase of fattening for all groups (Table 2).

Because of no significant interaction effects (treatment × genotype and treatment × sex) all

Table 3. Growth performance and carcass characteristics of growing-finishing pigs fed diets containing soybean meal (control) and pea diets ($n$ = 10 for group)

| Characteristics | Group | | | *P* |
|---|---|---|---|---|
| | control | raw peas | extruded peas | |
| Initial weight (kg) | 34.8 ± 1.6 | 32.6 ± 2.8 | 34.1 ± 2.17 | – |
| Length of first fattening period (at achieving 65 kg l.w.) (day) | 41 ± 4.75 | 46 ± 8.3 | 41 ± 11.49 | – |
| Average daily gain (g/day) | 740 ± 0.08 | 720 ± 0.14 | 810 ± 0.18 | – |
| Feed consumption per 1 kg gain (kg/kg) | 2.82 ± 0.38 | 3.15 ± 0.77[a] | 2.53 ± 0.33[b] | * |
| Length of 2nd fattening period (day) | 54.00 ± 5.81 | 48.00 ± 10.37 | 40.00 ± 11.43 | – |
| Final live weight (kg) | 103.20 ± 3.05 | 103.30 ± 2.83 | 97.00 ± 5.87[a,b] | * |
| Average daily gain (g/day) | 720 ± 109 | 840 ± 168 | 900 ± 243 | – |
| Feed consumption per 1 kg gain (kg/kg) | 3.90 ± 0.78 | 3.55 ± 0.59 | 3.32 ± 0.62 | – |
| Carcass weight (kg) | 83.90 ± 2.42[a] | 84.00 ± 2.2[a] | 78.85 ± 4.84[b] | * |
| Lean meat (%) | 53.7 ± 4.20 | 54.4 ± 3.88 | 53.8 ± 2.95 | – |
| Average back fat thickness ( mm) | 29.2 ± 5.80 | 26.7 ± 3.22 | 27.0 ± 3.47 | – |

P = probability

[a,b]$P < 0.05$, values represent means ± standard error of the mean (SE)

*significance of analysis of variance ($P < 0.05$)

results are presented only for the effect of treatment (Tables 3–5).

The slaughter weight, growth performance and carcass parameters are presented in Table 3. Daily weight gain was highest in the group fed EP but differences were not significant ($P > 0.05$). Performance characteristics such as feed conversion, lean meat and backfat were not influenced by the inclusion of peas and extruded peas in the diet. These results are in close agreement with earlier published data indicating that no differences in pig performance are recorded if pigs are fed diets containing field peas or pea-based diets (Stein et al., 2004, 2006; Petersen and Spencer, 2006).

Chemical composition, total water and total protein (Table 4) were not influenced and no significant differences between control and experimental groups were found out ($P > 0.05$). The values are comparable with results published earlier (Lahučký et al., 2005; Christodoulou et al., 2006). The intramuscular fat content is higher in comparison with results reported in other studies (Christodoulou et al., 2006) but comparable when Slovak White Meaty pigs were used (Lahučký et al., 2005). No significant differenc-

Table 4. Qualitative properties of the *longissimus dorsi* muscle of growing-finishing pigs fed diets containing soybean meal (control) and pea diets (mean ± standard deviation)

| Characteristics | Control | Raw peas | Extruded peas | *P* |
|---|---|---|---|---|
| **Parameters of meat quality** ($n = 10$) | | | | |
| pH (45 min) | 6.23 ± 0.42 | 6.23 ± 0.32 | 6.22 ± 0.40 | ns |
| pH (24 h) | 5.48 ± 0.19 | 5.59 ± 0.22 | 5.55 ± 0.17 | ns |
| Meat color $L^*$ (24 h) | 52.97 ± 6.35 | 49.71 ± 5.42 | 52.12 ± 4.72 | ns |
| Drip loss (%) (24 h) | 4.30 ± 2.55 | 4.88 ± 1.81 | 4.45 ± 2.08 | ns |
| Shear force (kg) (5 day) | 5.27 ± 1.08 | 5.30 ± 1.10 | 4.70 ± 0.99 | ns |
| **Chemical composition** | | | | |
| Total water (%) | 74.01 ± 0.37 | 73.88 ± 0.44 | 74.02 ± 0.53 | ns |
| Total protein (%) | 22.30 ± 0.27 | 22.18 ± 0.34 | 22.03 ± 0.26 | ns |
| Intramuscular fat (%) | 2.59 ± 0.62 | 2.82 ± 0.55 | 2.89 ± 0.67 | ns |
| Energy value (KJ/100 g) | 497.3 7± 35.53 | 509.64 ± 34.61 | 503.90 ± 32.24 | ns |
| **Representation of fatty acids in intramuscular fat** (% of total FA) | | | | |
| C14:0 myristic acid | 1.38 ± 0.16 | 1.42 ± 0.16 | 1.38 ± 0.17 | ns |
| C16:0 palmitic acid | 27.24 ± 1.01 | 27.38 ± 0.86 | 26.50 ± 1.79 | ns |
| C16:1 palmitoleic acid | 3.34 ± 0.66 | 3.37 ± 0.36 | 3.27 ± 0.44 | ns |
| C18:0 stearic acid | 11.17 ± 1.24 | 11.57 ± 1.39 | 11.43 ± 1.23 | ns |
| C18:1 oleic acid | 50.57 ± 1.78 | 50.76 ± 2.39 | 51.82 ± 2.35 | ns |
| C18:2n-6 linoleic acid | 5.34 ± 1.75 | 4.47 ± 0.98 | 4.37 ± 1.35 | ns |
| C18:3n-3 linolenic acid | 0.49 ± 0.16 | 0.51 ± 0.17 | 0.59 ± 0.31 | ns |
| C20:4n-6 arachidonic acid | 0.36 ± 0.18 | 0.25 ± 0.11 | 0.25 ± 0.19 | ns |
| ∑ SFA | 39.79 | 40.37 | 39.31 | ns |
| ∑ MUFA | 53.91 | 54.13 | 55.09 | ns |
| ∑ PUFA | 6.19 | 5.23 | 5.21 | ns |
| PUFA/SFA | 0.15 | 0.13 | 0.13 | ns |
| ω-6/ω-3 | 11.63 | 9.25 | 7.83[a] | * |

P = probability; ns = not significant $P \geq 0.05$; *[a]$P < 0.05$

SFA = saturated fatty acids include C14:0, C16:0, C18:0, C20:4

MUFA = monounsaturated fatty acids include C16:1, C18:1

PUFA = polyunsaturated fatty acids include C18:2ω-6, C18:3ω-3, C20:4ω-6

es in the intramuscular fat content were found out between control and experimental groups ($P > 0.05$). It is well known that the fatty acid profile of pork fat can be changed by feeding diets high in particular fatty acids (Wood et al., 2004). No significant differences in (saturated, mono- and poly-unsaturated) fatty acid composition (in the respective percentages) were observed between control pigs and pigs receiving peas (Table 4). A positive tendency in the proportion of omega-3 fatty acids (linolenic acid) was determined. The proportion of omega-6 fatty acids (linoleic and arachidonic acids) declined. The differences in the ratio of omega-6/omega-3 were significant between animals fed the control ration with soybean meal and animals fed the pea ration. The fatty acid composition is in agreement with results reported in British Landrace pigs by Fletcher et al. (1988) and later in German Saddle Back pigs by Nuernberg et al. (2000).

Parameters of meat quality such as lower $pH_1$ (pH measured after 45 min), higher drip loss and higher $L^*$ values are reliable for the definition of PSE (pale, soft, exudative) meat usually connected with the occurrence of porcine stress syndrome (PSS) and malignant hyperthermia (MH) syndrome. It is well known that PSS and MH are genetically associated with the occurrence of mutation in ryanodine receptor gene (*RYR1*) and can be detected by a DNA based test as was shown earlier (Fujii et al., 1990; Houde and Pommier, 1993; Lahucky et al., 1997, 2002; Bauerová et al., 1999). Meat quality characteristics in this study are summarized in Table 4. The supplementation of peas or extruded peas to feed mixture did not affect pH (45 min, 24 h) and percentage drip loss (24 h). Colour data were not different ($P > 0.05$) for $L^*$ as estimated 24 h *post mortem*. Water-holding capacity (WHC) defined by the value of drip loss was not significantly ($P > 0.05$) influenced by pea-based diet. A positive effect on the moisture loss of chops from pigs fed field peas was reported by Stein et al. (2006). Christodoulou et al. (2006) reported differences in ultimate pH and higher cooking loss in experimental pigs fed chickpea meal. The explanation of such differences could also be the lack of information about the frequency of mutation in *RYR1* (MH) gene of control and experimental pigs in those papers. It is also known that low ultimate pH (measured 24 h or 48 h after slaughter) is more connected with the occurrence of RN mutant (Rendement Napole, Hampshire factor) in the pig population (Monin and Sellier, 1985; Le Roy et al., 2000). In our study we did not observe any significant differences between control and experimental groups in pH ultimate values ($P > 0.05$). Tenderness is known to be another important aspect of carcass quality. In our experiment we used the value of shear force (measured with Warner-Bratzler instrument) as evaluation of meat tenderness. No significant differences were found between control and experimental pigs ($P > 0.05$). Replacing soybean

Table 5. Two-factor analysis of variance aimed at indicator growth and fattening of pigs

| Trait | | Group A $f_A = 2$ | Sex B $f_B = 1$ | Interaction AB $f_{AB} = 2$ | Error of experiment C $f_c = 24$ |
|---|---|---|---|---|---|
| Length of fattening period (days) | MS | 665.200 | 512.533 | 4.1333 | 192.450 |
| | F | 3.46$^{+}$ | 2.66 | 0.02 | |
| Final live weight (kg) | MS | 85.633 | 6.5333 | 5.0333 | 10.500 |
| | F | 8.16$^{++}$ | 0.62 | 0.48 | |
| Initial live weight (kg) | MS | 12.633 | 0.3000 | 5.7000 | 5.800 |
| | F | 2.18 | 0.05 | 0.98 | |
| Average daily gain 1st phase of fattening (g/day) | MS | 0.0218 | 1.837E-04 | 0.0045 | 0.0238 |
| | F | 0.92 | 0.01 | 0.19 | |
| Average daily gain 2nd phase of fattening (g/day) | MS | 0.0844 | 0.1757 | 0.0043 | 0.0297 |
| | F | 2.85 | 5.92$^{+}$ | 0.14 | |
| Feed consumption per 1 kg gain 1st phase of fattening (kg) | MS | 1381.71 | 128.464 | 32.5255 | 370.936 |
| | F | 3.72$^{+}$ | 0.35 | 0.09 | |
| Feed consumption per 1 kg gain 2nd phase of fattening (kg) | MS | 3483.00 | 5209.79 | 57.5387 | 720.365 |
| | F | 4.84$^{+}$ | 7.23$^{+}$ | 0.08 | |

$^{+}P < 0.05$, $^{++}P < 0.01$

meal by pea-based meal did not have a negative influence on tenderness. This was also supported by sensory evaluation (5 numbers, 5 scale panel) while no differences in odour and taste, tenderness and juiciness were found out (results not given). Our results did not demonstrate a negative influence of replacing soybean meal by pea-based meal on the values of pork quality. Table 5 shows the two-factor analysis of variance aimed at indicator growth and fattening of pigs between groups and sex.

Pea (*Pisum sativum* L.) is a good, traditional source of nitrogen and energy for pigs due to the high digestibility and palatability (Fan et al., 1994; Chrenková et al., 2001) without deterioration of health, production and carcass and meat quality (Thacker 2002; Stein et al., 2004, 2006), which is in agreement with presented results.

## Conclusion

Soybean meal can be replaced by (raw or extruded) pea-based meal in the amount of 30% for growing and finishing pigs. At these inclusion levels, pig performance, carcass and meat quality will not be negatively affected, provided that the diets containing pea-based meal are balanced for their contents of digestible AA and energy concentration.

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