B151

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Seinäjoen ammattikorkeakoulun julkaisusarja
B. Raportteja ja selvityksiä 151

Samu Palander[1], Hilkka Siljander-Rasi[2],
Jarmo Valaja[2] & Kirsi Partanen[2]

[1]Seinäjoki University of Applied Sciences, Food and Agriculture, Seinäjoki, Finland
[2]Natural Resources Institute Finland, Jokioinen, Finland

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Seinäjoki 2020

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SeAMK julkaisut:
Seinäjoen ammattikorkeakoulun kirjasto
Kalevankatu 35
60100 Seinäjoki
p. 020 124 5040
kirjasto@seamk.fi

ISBN 978-952-7317-20-4 (verkkojulkaisu)
ISSN 1797-5573 (verkkojulkaisu)

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SEINÄJOKI UNIVERSITY OF APPLIED SCIENCES

ABSTRACT

There is an increasing interest in possibilities to replace imported soybean products as protein source for pigs. Therefore, digestibility of wet and dried potato protein concentrate (WPPC and DPPC), by-products of the potato starch industry, and the effects of WPPC on performance and carcass quality of pigs were investigated in two experiments. In Exp. 1, the apparent total tract digestibility of crude protein (CP) and the apparent ileal digestibility of CP and amino acids (AA) in WPPC and DPPC were estimated using cannulated pigs. Exp. 2 was a performance trial using growing-finishing pigs (27 to 110 kg). The experiment included a control diet based on barley and soybean meal (179 gkg^{-1}) and three diets in which 25 %, 50 %, or 75 % of the protein provided by soybean meal in the control diet was substituted by WPPC. In Exp. 1, the apparent AA digestibility of WPPC was lower than that of DPPC ($P<0.05$ for most AA). In Exp. 2, no significant differences in average daily gain, back fat and back muscle thickness or meat percentage were observed between the control and the PPC diets. However, feed conversion ratio improved with increasing levels of WPPC ($P<0.01$). In addition, carcass yield was quadratically affected by the WPPC level. The study concludes that at least 75 % of soybean protein of pig diets may be replaced with PPC without any negative effect on performance.

Keywords: digestibility, performance, pig, potato protein

TIIVISTELMÄ

Kotimaiset vaihtoehdot tuontialkuperää olevien soijatuotteiden korvaajiksi proteiinilähteinä sikojen rehuissa ovat kasvavan mielenkiinnon kohteena. Tutkimuksessa tarkasteltiin tuoreen ja kuivatun perunaproteiinin sulavuutta sekä tuoreen perunaproteiinin vaikutusta lihasikojen tuotantotuloksiin ja ruhon laatuun. Ensimmäisessä kokeessa raakavalkuaisen näennäinen kokonaissulavuus sekä raakavalkuaisen ja aminohappojen näennäinen ohutsuolisulavuus määritettiin ohutsuolikanyloiduilla sioilla. Toinen koe oli tuotantokoe, jossa lihasiat kasvatettiin 110 kg:n elopainoon. Kokeessa oli ohra-soijarouhepohjainen kontrolliruokinta ja kolme koeruokintaa, joissa soijarouhetta oli korvattu tuoreella perunaproteiinilla siten, että 25 %, 50 % tai 75 % siitä valkuaismäärästä, joka kontrolliruokinnassa saatiin soijarouheesta, korvattiin koerehuissa perunaproteiinista tulevalla valkuaisella. Tuoreessa perunaproteiinissa oli matalampi aminohappojen sulavuus kuin kuivassa. Päiväkasvussa, selkäsilavassa, selkälihaksen paksuudessa ja ruhon lihaprosentissa ei ollut merkitseviä eroja ruokintojen välillä. Rehunmuuntosuhde kuitenkin parani perunaproteiinin osuuden lisääntyessä, ja perunaproteiinitaso vaikutti käyräviivaisesti myös teurasprosenttiin. Tutkimusten perusteella voidaan todeta, että vähintään 75 % soijavalkuaisesta voidaan lihasikojen ruokinnassa korvata perunaproteiinilla.

Avainsanat: sulavuus , tuotantotulokset, sika, perunaproteiini

TABLE OF CONTENTS

1 INTRODUCTION

There is an increasing interest in possibilities to replace imported soybean products as protein source for pigs. Common potato (*Solanum tuberosum*) and potato products have traditionally been considered as possible pig feed ingredients (see e.g. Whittemore 1977; Edwards & Livingstone 1990). Industrial processing of potato to produce starch for use in human food and for industrial purposes creates fibre-rich pulp and high-moisture liquid potato fruit juice as a by-product. The high-moisture fraction can be further processed to produce potato protein concentrate (PPC) (Friedman 2006).

Literature on the feed use of these ingredients is scarce. After heat treatment, potato starch is a potential energy source (Kerr et al. 1998a; Sun et al. 2006). In addition, the resistant starch fraction of potato may even have positive effects by reducing skatole formation (Claus et al. 2003; Lösel et al. 2006). Regarding potato protein fraction, Nestares et al. (1993) have reported that the amino acid (AA) profile of PPC is adequate for growth of rats, and the results of Kerr et al. (1998b) and Pedersen and Lindberg (2004) indicated that dried PPC (DPPC) is useful as an alternative to animal protein sources in piglet diets.

The objective of the present study was to compare nutrient digestibility of wet PPC (WPPC) produced on a pilot scale and that of a commercial DPPC and to examine the effects of different levels of WPPC as a soybean protein replacement on growth and carcass characteristics of pigs.

2 MATERIAL AND METHODS

2.1 Experimental design and experimental animals

The digestibility experiment, Experiment 1 (Exp. 1), was designed according to a Latin square containing two feeding treatments and two experimental periods. Four castrated pigs fitted with post-valvular T-caecum cannulae according to van Leeuwen et al. (1991) were housed individually in metabolism pens of 1.43 m x 1.23 m. The pigs, used in a previous digestibility experiment, weighed approximately 59.5 (±3.11) kg. The animals were randomly allocated to the dietary treatments for the experimental periods according to a change-over design, thus obtaining two replicates per treatment per period. Each experimental period consisted of seven d of accustoming, four d of total faeces collection, and two d of ileal digesta collection (in two one-day periods separated by one day). The care of the animals and the procedures used followed accepted guidelines and had been evaluated and approved by an ethical committee according to local legislation (L 20.1.2006/62).

The performance experiment, Experiment 2 (Exp. 2), was a completely randomized design with 8 treatments arranged factorially (two sexes and four feeding treatments). 112 pigs (56 gilts and 56 castrates) weighing 26.7 (±1.84) kg were housed in groups of two pigs in pens (2.5 m x 1.0 m) littered with wood shavings. The pigs were allocated to four feeding groups in a total of 14 pens, each with two gilts or two castrates thus forming seven replicates for each sex x feeding combination. Taking the variable genetic backgrounds (Landrace, Yorkshire, Duroc and crossbred) into account, the pigs were evenly allocated to feeding groups.

2.2 Feeds and feeding

The pilot-scale process to produce WPPC (Finnamyl Oy, Kokemäki, Finland) consisted of separating potato juice from starch and pulp by decanting, precipitating protein from the potato juice fraction in acidic pH (4.5 to 5.2) using sulphur dioxide and heat (75 to 88 °C) and further separating the excess water by decanting and evaporation to reach a dry matter (DM) content of approximately 220 gkg^{-1}. In Exp. 1, two semi-purified starch-based diets were used, containing either the WPPC or commercial DPPC (Avebe Feed, Veendam, the Netherlands) as the sole source of protein (Table 1). The diets contained 160 g crude protein (CP) and 13 g lysine (Lys) per kg DM. WPPC was stored frozen, melted, and served mixed with the dry ingredients and water as wet feed (DM to water ratio approximately 1:2). The diets contained chromic oxide (0.6 gkg^{-1} DM) as a marker. The pigs were fed twice daily, 100 g DM per one kg of metabolic body weight according to a regimen described by Partanen et al. (2007), and the feed intake was recorded. Water was freely available. In Exp. 1, the consumption of the DPPC-containing feed was lower than that of WPPC. Daily DM consumption (±SD) was 2200 (±179.0) g for the WPPC diet and 1949 (±369.4) g for the DPPC diet, but the difference was not significant, (p>0.1, obviously due to the small number of observations). One of the pigs refused to eat the DPPC diet, which resulted in a missing observation for the period.

In Exp. 2, the diets were based on barley, soybean meal, and WPPC, and they met the feeding requirements of pigs according to the Finnish Feeding Recommendations (MTT Agrifood Research, 2006). The calculated calcium, digestible phosphorus, and ileal digestible Lys, methionine+cysteine (Met + Cys), and threonine (Thr), contents were 8.7, 3.0, 10.3, 6.0, and 6.2 gkg^{-1} DM in the diet used for the first 5 weeks and 8.1, 2.7, 7.6, 4.9, and 4.6 gkg^{-1} DM in the diet used from 5 weeks (55 kg live weight) to slaughter, and the calculated net energy (NE) content was 10.14 $MJkg^{-1}$ diet DM (Schiemann et al. 1972). The ingredient compositions of the experimental diets are shown in Table 2. The AA digestibilities of WPPC determined in Exp. 1 were used for the diet formulation. Soybean meal (179 gkg^{-1}) was the main protein source used in the control diet. In the other diets (25WPPC, 50WPPC, 75WPPC), 25%, 50%, and 75% of CP from soybean meal was replaced by CP from WPPC (Finnamyl Oy, Kokemäki, Finland). The dry ingredients of the diets were mixed and steam-pelleted (4 mm diameter). The WPPC was stored frozen, melted in smaller amounts, and stored cold after melting (for less than two weeks). The pelleted feed mixtures were mixed with WPPC and water and served as wet feed (DM to water ratio approximately 1:2). The daily feed ration was gradually (weekly) increased from 13.95 MJd-1 in the first week to 29.76 MJd^{-1} in the tenth week and thereafter. Feed was offered two times daily and water was freely available. One random pig in the control group and two in the 25WPPC group died or were culled during the experiment, and these were removed from the calculation of the performance results.

Table 1. Composition of the semi-purified experimental diets (gkg^{-1} on dry matter basis), Experiment 1.

Diet		
Ingredient	1	2
Potato protein concentrate, wet	232.6	
Potato protein concentrate, dry		183.5
Barley starch	638.7	687.0
Sucrose	40.0	40.0
Cellulose	50.0	50.0
Vitamin-mineral premix[a]	6.0	6.0
Monocalcium phosphate	21.8	23.1
Calcium carbonate	10.3	9.8
Chromich oxide	0.6	0.6
Calculated composition		
Crude protein	160.0	160.0
Lysine	13.0	13.0
Analysed composition		
Crude protein	167.1	165.7
Lysine	14.3	15.1

[a]Contained (per kg of diet): Na 1.44 g, Mg 520 mg, Fe 138 mg, Cu 32 mg, Zn 128 mg, Mn 34 mg, Se 0.40 mg, I 0.34 mg, retinol 2.3 mg, cholecalciferol 0.019 mg, tocopherol 71 mg, thiamine 2.8 mg, riboflavin 6.9 mg, pyridoxine 4.0 mg, cobalamin 0.029 mg, biotin 0.29 mg, pantothenic acid 20 mg, niacin 29 mg, folic acid 4.7 mg

Table 2. Composition of the experimental diets for growing pigs (gkg^{-1} on dry matter), Experiment 2.

Ingredient	10 to 15 weeks				15 weeks to slaughter			
	Wet potato protein concentrate level[a]							
	0%	25%	50%	75%	0%	25%	50%	75%
Ground barley	785.6	794.6	802.6	811.4	854.9	860.3	866.2	870.9
Soybean meal	179.1	134.0	90.0	45.0	114.6	86.0	57.0	29.0
Potato protein concentrate		36.0	72.0	108.0		23.0	46.0	69.0
Lysine	3.4	3.2	3.0	2.8	2.2	2.1	2.0	1.9
Threonine	0.9	0.7	0.5	0.4	0.2	0.1		
DL-methionine	0.8	0.6	0.5	0.4				
Calcium carbonate	15.8	15.8	15.7	15.7	15.1	15.1	15.0	15.0
Monocalcium phosphate	10.1	10.8	11.4	12	8.7	9.1	9.5	9.9
Vitamin-mineral premix[b]	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Calculated composition								
Crude protein	199	203	204	205	171	172	172	173
Ileal digestible lysine	10.3	10.3	10.3	10.3	7.6	7.6	7.6	7.6
Ca	8.7	8.7	8.7	8.7	8.1	8.1	8.1	8.1
P	6.7	6.7	6.7	6.7	6.2	6.2	6.2	6.2
Analysed composition								
Ash	55.4	56.9	58.4	54.8	54.2	52.8	50.9	52.6
Crude protein	197.1	198.4	199.2	201.4	171.3	169.5	167.3	172.3
Crude fat	19.8	20.4	20.3	20.2	21.4	20.4	19.6	20.3
Lysine	12.5	11.2	15.0	15.8	10.7	9.5	10.2	11.1
Threonine	9.3	11.0	10.6	10.6	7.0	9.4	8.4	7.8
Methionine	3.6	4.6	5.0	4.8	3.0	3.2	3.7	3.3
Cystein	3.1	4.9	4.4	3.5	3.2	2.8	3.5	3.5

[a]Proportion of protein from soybean meal replaced with potato protein
[b]Contained (per kg of diet): Na 1.03 g, Mg 373 mg, Fe 99 mg, Cu 23 mg, Zn 92 mg, Mn 24 mg, Se 0.29 mg, I 0.24 mg, retinol 1.6 mg, cholecalciferol 0.014 mg, tocopherol 51 mg, thiamine 2.0 mg, riboflavin 4.9 mg, pyridoxine 2.9 mg, cobalamin 0.021 mg, biotin 0.21 mg, pantothenic acid 14 mg, niacin 21 mg, folic acid 3.4 mg

2.3 Sampling

In both experiments, samples of feed mixtures, DPPC and WPPC were collected during the course of the trial. In addition, in Exp. 1, faeces were collected for four days in plastic bags fitted around the anus according to van Kleef et al. (1994) and frozen. Ileal digesta were collected from the cannulae on two days according to a periodical regimen (in two-hour periods) as described by Partanen et al. (2007). The samples were collected from the cannulae in plastic bags, which were continuously changed and frozen during the collection period.

2.4 Measurements and analyses

In Exp. 1, the pigs were weighed at the beginning and at the end of the experiment. In Exp. 2, the pigs were weighed individually at the beginning of the experiment and after five weeks, weekly from the eighth week, and before slaughter. After the weekly weighing, the pigs which had reached the live weight of 98 kg were slaughtered. After slaughter, Hennessy GP (Hennessy GP Grading Probe, Auckland, New Zealand) measurements of backfat depth (BF1 between the 13th and 14th costal, 6 cm from medial axis; BF2 between the last costal and the first lumbar vertebra, 8 cm from medial axis) and *longissimus dorsi* muscle depth (*MD*) at the point of *BF2* were carried out. The meat percentage of the carcasses was calculated according to the formula given by European Commission (2005):

$$\textit{meat percentage} = 56.713 - 0.271 \times BF1 - 0.620 \times BF2 + 0.258 \times MD$$

Standard feed analyses were carried out according to AOAC (1990): Samples of DPPC and WPPC, the dry feed mixtures, faeces, and ileal digesta were analysed for dry matter (drying at 105 °C for 20 h; WPPC after freeze drying), ash (method 942.05), ether extract after hydrolysis with 3M HCl, crude fibre (method 962.09) and nitrogen (using a Leco FP 428 nitrogen analyser [Leco Corp., St Joseph; USA], method 968.06). AA (excluding tryptophan) were determined with a Biochrom 20 amino acid analyser (Pharmacia Biotech Ltd, Cambridge, UK) according to European Commission (1998). In addition, the WPPC used in Exp. 2 was analysed for lactic acid according to Haacker et al. (1983) and for pH according to Luh Huang and Schulte (1985).

In Exp. 1, the diets as well as the digesta and feaces samples were analysed for chromium according to Williams et al. (1962), and the coefficients of apparent ileal digestibility (CAID) and apparent total tract digestibility (CATTD) of nutrients were calculated considering chromic oxide as an indigestible marker.

2.5 Statistics

In Exp. 1, the results were subjected to an analysis of variance using the GLM procedure of SAS and a Latin square design:

$$digestibility = \mu + protein\ source_i + periodj + \varepsilon_{ij}$$

where μ is the overall mean and ε represents the unexplainable error). In Exp. 2, the data were subjected to an analysis of variance using the MIXED procedure of SAS considering the mean result of a pen as the experimental unit with a model:

$$parameter = \mu + feeding_i + sex_j + feeding*sex_{ij} + \varepsilon_{ijk}$$

where μ is the overall mean and ε represents the unexplainable error). In addition, the effect of the replacing ratio of soybean meal by WPPC was tested using orthogonal polynomial contrasts (linear and quadratic).

3 RESULTS

3.1 Chemical composition of the feeds

The WPPC used in Exp. 1 contained 217 g DM kg^{-1} and CP 643 gkg^{-1} DM, and the WPPC used in Exp. 2 contained 227 g DM kg^{-1} and CP 681 gkg^{-1} DM (Table 3). The average pH was 5.2, and the lactic acid content 0.13 gkg^{-1} DM. The calculated NE content of WPPC was 9.58 MJkg^{-1} DM.

Table 3. Chemical composition of potato protein concentrates used in Experiment 1 and 2 (gkg^{-1} dry matter).

	Experiment 1		Experiment 2
	Wet[a]	Dry[b]	Wet[a]
Ash	92.1	6.4	48.7
Crude protein	642.5	865.7	681.4
Crude fat	45.6	33.5	20.6
Crude fibre	7.2	14.8	53.9
Lactic acid	n.a.	n.a.	0.13
Essential amino acids g/100g crude protein			
Arg	5.7	5.6	4.9
His	2.6	2.6	2.6
Ile	5.9	6.0	6.7
Leu	12.1	13.1	10.5
Lys	8.8	9.3	9.5
Met	2.2	2.4	3.1
Phe	7.3	7.6	6.3
Thr	6.6	7.0	6.7
Val	6.8	6.6	8.6

[a] Avebe feed, Veendam, The Netherlands
[b] Finnamyl Oy, Kokemäki, Finland
n.a. = not analyzed

3.2 Apparent digestibility of crude protein and amino acids

CATTD of CP tended to be higher for DPPC than for WPPC (0.94 vs. 0.80; 0.05<P<0.1). Similar trends were observable for CAID of CP (0.66 vs. 0.88;

0.05<P<0.1) and indispensable AA (P<0.1 for all and P<0.05 for most AA). CAID of AA ranged from 0.55 (cystine) to 0.81 (arginine) for WPPC and from 0.77 (cystine) to 0.94 (methionine) for DPPC (Table 4).

Table 4. Digestibility of crude protein and essential amino acids (and cystine) in potato protein concentrates (Experiment 1).

	Dry potato protein concentrate[a]	Wet potato protein concentrate[b]	SEM[c]	*p*
CP[d], ATTD[e]	0.94	0.80	0.010	0.079
CP[d] AID(SID)[f]	0.88(0.93)	0.66(0.72)	0.010	0.051
AA[g], AID(SID)[f]				
Arg	0.93(0.96)	0.81(0.84)	0.046	0.040
Cyss	0.79(0.85)	0.55(0.59)	0.012	0.055
His	0.90(0.93)	0.71(0.74)	0.071	0.041
Ile	0.92(0.94)	0.72(0.74)	0.044	0.025
Leu	0.93(0.95)	0.75(0.77)	0.010	0.058
Lys	0.90(0.92)	0.72(0.74)	0.003	0.042
Met	0.94(0.96)	0.75(0.77)	0.001	0.005
Phe	0.93(0.95)	0.75(0.77)	0.008	0.049
Thr	0.89(0.92)	0.68(0.72)	0.006	0.033
Val	0.90(0.94)	0.71(0.75)	0.009	0.054

[a]Avebe feed, Veendam, The Netherlands
[b]Finnamyl Oy, Kokemäki, Finland
[c]Pooled SEM related to the sample size of n = 4 for wet potato protein concentrate, and due to feed refusals n = 3 for dry potato protein concentrate
[d]crude protein
[e]apparent total tract digestibility
[f]apparent ileal digestibility; in parentheses, an estimate of standardized ileal digestibility is shown, based on a correction with the average basal endogenous loss presented by AFZ et al. (2000)
[g]amino acids

3.3 Growth performance

In Exp. 2, the pigs ate and performed normally, with a daily gain (±SD) of 960 (±68.5) g in the growing period (5 weeks) and 1028 (±73.7) g in the finishing period. Total NE consumption per pig tended to decrease linearly with increased levels of WPPC (P=0.09; data not shown), but DM intake was not significantly affected. Consequently, feed conversion ratio improved at increased WPPC levels (P<0.05 for the growing period; P<0.01 for the finishing period and for the entire experiment) (Table 5). Castrates gained more weight ($P<0.01$) and consumed more feed ($P<0.05$) than gilts. No significant interacting effects of feeding and sex on growth or feed intake were observed.

3.4 Carcass quality

A quadratic dependence on WPPC level was noticeable for carcass weight ($P<0.05$), the highest carcass weight being in the 25WPPC group (Table 6). Typical sex-related differences were present in fat depths ($P<0.001$ for BF1 and $P<0.01$ for BF2), back muscle depth ($P<0.05$), and meat percentage ($P<0.001$), the gilts performing significantly better, and no interactions between feeding and sex were observed.

Table 5. Performance of pigs fed diets with different levels of wet potato protein concentrate (Experiment 2).

	Potato protein proportion[a]										
	0		25%		50%		75%		P		
	gilts	cast-rates	gilts	cast-rates	gilts	cast-rates	gilts	cast-rates	SEM[b]	L[c]	Sex
Daily gain, first 5 weeks (kg)	0.951	0.948	0.942	1.006	0.940	0.969	0.944	0.979	0.026	ns	ns
Daily gain, finishing (kg)	1.008	1.010	0.986	1.082	1.030	1.049	0.992	1.067	0.027	ns	0.01
Daily feed consump-tion, first 5 weeks (kg)	1.75	1.77	1.74	1.75	1.730	1.710	1.740	1.700	0.040	ns	ns
Daily feed consump-tion, finishing (kg)	2.65	2.71	2.59	2.7	2.670	2.680	2.500	2.690	0.050	ns	0.02
Feed conversion, first 5 weeks (feed dry matter to gain g/100g)	1.84	1.87	1.85	1.74	1.84	1.76	1.84	1.74	0.02	0.08	ns
Feed conversion, finishing (feed dry matter to gain g/100g)	2.63	2.68	2.63	2.50	2.59	2.55	2.52	2.52	0.04	0.002	ns
Feed conversion, total (feed dry matter to gain g/100g)	2.38	2.39	2.35	2.22	2.33	2.27	2.28	2.25	0.03	0.001	0.02

[a] proportion of protein from soybean meal replaced with wet potato protein concentrate
[b] pooled SEM (n = 7 pens of 2 pigs for a feeding×sex combination)
[c] linear effect of potato protein proportion (no significant quadratic, cubic or feed×sex interaction effects)

Table 6. Carcass characteristics of pigs fed diets with different levels of wet potato protein concentrate (Experiment 2).

	Potato protein proportion[a]											
	0		25%		50%		75%		P			
	gilts	cast-rates	gilts	cast-rates	gilts	cast-rates	gilts	cast-rates	SEM[b]	L[c]	Q[d]	Sex
Carcass weight (kg)	79.2	78.2	80.9	80.1	80.3	79.6	79.8	79.2	0.72	ns	0.03	ns
Slaughter loss percentage (of live weight)	27.3	28.4	26.3	27.9	27.2	27.6	27.2	28.3	0.45	ns	0.07	0.001
Backfat and muscle depth (mm)												
BF1 [e]	11.2	13.4	11.2	13.3	10.7	12.3	11.3	12.6	0.60	ns	ns	<0.001
BF2 [e]	11.1	12.8	11.1	12.5	11.2	12.1	11.1	12.9	0.60	ns	ns	0.001
M1 [e]	51.9	47.2	52.0	51.7	52.0	49.7	50.6	49.4	1.42	ns	ns	0.03
Meat percentage (of carcass)	60.2	57.8	60.2	58.7	60.3	58.7	59.8	58.0	0.65	ns	ns	<0.001

[a] proportion of protein from soybean meal replaced with wet potato protein concentrate
[b] pooled SEM (n = 7 pens of 2 pigs for a feeding×sex combination)
[c] linear effect of potato protein level
[d] quadratic effect of potato protein proportion (no significant cubic or feed×sex interaction effects)
[e] BF1 backfat between the 13th and 14th costal, 6 cm from the medial axis; BF2 backfat between the last costal and the first lumbar vertebra, 8 cm from medial axis; M1 *longissimus dorsi* muscle depth at the point of BF2

4 DISCUSSION

In the present experiments, the average Lys content of the WPPC ranged from 54 to 65 gkg^{-1} DM (8.1 to 9.5 g Lys per 100 g of CP). The figures were higher than those reported by Kerr et al. (1998b) or Infosvin (2006) for conventional and low-glycoalkaloid DPPC, respectively. The CP and especially Lys contents of the WPPC determined in the current feeding experiment (Exp. 2) were higher than those measured in the pre-sample taken before diet formulation. Therefore, 50WPPC and 75WPPC grower diets contained more Lys than the control grower diet (Table 2).

Low fibre, high CP, and especially relatively high essential AA concentrations could make PPC a remarkable candidate for replacing soybean products as a protein source for pigs. However, the variability in composition among batches have to be taken into account. Pastuszewska et al. (2009) reported that the chemical composition of PPC was quite uniform even between factories but that variability occurred in glycoalkaloid content. The AA profile of potato protein seems favourable for pig nutrition, but considerably lower AA digestibility in the investigated pilot WPPC than in the commercial DPPC has to be taken into account in diet formulation. Relevant scientific information is scarcely found in the literature. Some feed tables list digestibility coefficients for DPPC (National Research Council 1998; Infosvin 2006), and the figures found in these as well in the report of Lenis et al. (1992) are mostly in accord with those in the present experiment for DPPC. Standardized ileal digestibility is often preferred for diet formulation. In the current experiment, endogenous loss was not measured, but estimates of standardized digestibility have been calculated using correction by average basal endogenous CP and AA loss presented by AFZ et al. (2000) and are shown in Table 4. The figures for standardized digestibility of DPPC are in accord with or slightly higher than those found in literature (AFZ et al. 2000). However, the remarkably lower CP and AA digestibilities of WPPC in the present experiment were more comparable to those of cereals (or even lower) than to those found for DPPC or those typical for common protein sources like soybean meal or fish meal. On the basis of the current data, no straightforward reason for the lower digestibility of AA of WPPC can be found. The simple precipitation and concentration process used in the pilot plant to produce WPPC for the experiment should be evaluated and the parameters used in the process should be optimized. The dependence of potato protein digestibility on thermal processing and the suggestion that this is related to protease inhibitor inactivation has been reported by Livingstone et al. (1980). According to the study by Boltshauser and

Stoll (1991), both heating and enzyme supplementation improve potato nutrient digestibility. In addition, the findings of Bartova and Barta (2008) and Løkra (2008) concerning the effects of conditions like pH, temperature, and the drying process on the functional properties of proteins derived from potato juice may by applicable here.

Friedman (2006) reviewed the possible adverse effects of glycoalkaloid (chaconines and solanines) consumption and stated that glycoalkaloids have an important role for nutritional quality of potato protein, although low toxicity of orally ingested glycoalkaloids seem to be evident mainly due to excretion, hydrolysis and poor absorption. According to Kerr et al. (1998b) growth and feed conversion of piglets may be lower when high-glycoalkaloid PPC is used as a protein source compared to low-gycoalkaloid PPC (total glycoalkaloids 303.0 vs. 15.6 g/100 g). Therefore, analysing glycoalkaloid content is recommendable, and Alt et al. (2005) have reported an optimized method for gycoalkaloid analysis. In the present experiment, the glycoalkaloid content of DPPC and WPPC was not analysed and can only be speculated. No remarkable differences in growth or feed consumption compared to the control group were observed in Exp. 2, and feed conversion even improved with increased WPPC levels, which fact does not indicate problems related to glycoalkaloids. However, some problems probably occurred in Exp. 1 resulting in uneven feed consumption, although the differences, probably, were not significant because of the small number of observations.

The observed significant linear improvement in feed conversion ratio with increased WPPC may naturally be associated with increased Lys intake in 50WPPC and 75WPPC grower diets. However, the intake of ileal digestible Lys met the recommendations in all diets, and the finisher diets were relatively similar regarding calculated AA intake. Sundrum et al. (2000) found that supplementing an organic diet with PPC resulted in improved growth and feed intake values comparable to those observed in the conventional AA supplemented diet. Thus, PPC supplementation as a high-quality protein source may even serve as an alternative to free amino acid supplementation.

In the present study, carcass weight and proportional carcass yield were highest when 25% of the CP of soybean meal had been replaced with WPPC, suggesting a significant curvilinear effect of the WPPC level on these parameters, but this trend remains mostly unexplainable. Backfat and muscle measurements for example could reflect lean and fat growth of the body also associated with feed conversion and carcass yield. However, when comparing the data in Tables 5 and 6, no similar trends in other parameters related to growth and growth composition are visible (in addition to the discussed linear improvement of feed conversion with increased WPPC levels). In the report of Sundrum et al. (2000) the muscle thicknesses of pigs fed a PPC-supplemented organic diet were also comparable to those of pigs fed a conventional diet.

Adverse effects of PPC have also been reported, suggesting that poorly digestible protein of PPC may be associated with formation of undesirable amine metabolites such as putrescine or cadaverine in the hindgut, especially in combination with potato starch (Taciak et al. 2017). Hindgut fermentation or sensory quality of meat were, however, not analysed in the present experiment.

5 CONCLUSIONS

In conclusion, CP and AA digestibilities were lower for the WPPC than for the DPPC diets. Optimum WPPC process conditions for AA digestibility may need further investigation. Technical aspects related to uneven monthly supplies, storage methods, and the optimal dry matter content for handling and transfer may also need further consideration. On the basis of the current results, WPPC may be used to replace at least 75% of the protein of soybean meal in a diet of growing pigs.

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Seinäjoen ammattikorkeakoulun kirjasto
Kalevankatu 35, 60100 Seinäjoki
puh. 020 124 5040
kirjasto@seamk.fi

ISBN 978-952-7317-20-4 (verkkojulkaisu)
ISSN 1797-5573 (verkkojulkaisu)

SEINÄJOEN AMMATTIKORKEAKOULU
SEINÄJOKI UNIVERSITY OF APPLIED SCIENCES