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SERUM HORMONE CONCENTRATIONS AND PERFORMANCE OF WEANED PIGLETS FED ON DIETS CONTAINING PEAS

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Two experiments were carried out in which raw, micronized or extruded peas (about 450 g/kg air dry diet) were fed to weaned piglets in place of some of the ground maize and soyabean oil meal. The diets were isonitrogenous and corrected for possible deficiencies of methionine and tryptophan. The results obtained indicated that extrusion did not improve nutrient availability of the peas, which supported the greatest weight gain in the raw state in Experiment 1 and micronized in Experiment 2. The performance was similar to that obtained with the standard diet. The growth rate of the piglets was significantly correlated with serum thyroid hormone concentrations in Experiment 1 and with serum IGF-I concentrations in Experiment 2. No significant differences in the insulin response to ingestion of the different diets were recorded and values for serum cortisol also varied widely between animals. The results are discussed with reference to present knowledge about the reactions of the organism, as expressed by metabolic hormone concentrations, to changes in dietary ingredients.

Key words: weaned piglets, hormones, insulin-like growth factor-I, peas

INTRODUCTION

Previous investigations on the possibility of using peas in diets for weaners showed that piglets fed on cull peas at 240 g/kg air dry diet achieved the same performance as those fed on the standard maize grain/soyabean oil meal based mixture provided the diets were supplemented with methionine and tryptophan (Živković et al. 1987; Živković and Cmiljanić, 1991). However, despite additional supplements of methionine and tryptophan, inclusion of the same raw peas at 354 g/kg air dry diet led to poorer feed consumption and a lower growth rate, although this level of peas was well tolerated by older pigs (Živković, 1987; Goodlad and Mathers, 1991).

Varieties of the white flowered subspecies *Pisum sativum hortense* have relatively low contents of tannins and lectins but levels of trypsin inhibitors were found to differ considerably between different varieties with consequent effects on ileal digestibility of protein (Gatel and Grosjean, 1990; Huisman et al. 1992; Gdala et al. 1992). Since proper treatment abolishes both trypsin inhibitory and lectin activity, the present investigation was undertaken to determine if micronization or extrusion of peas would improve the performance of weaners fed on diets containing peas as a major component. However, thermal processing also affects the carbohydrate fraction of seeds, particularly the starch, with possible alterations in the rate and site of digestion (Goodlad and Mathers, 1992).

Therefore, an attempt to determine the effect of such dietary changes on the insulin response and serum concentrations of other metabolic hormones as well as on piglet performance was made. A brief account of some of this work has been given previously (Živković et al. 1993).

MATERIALS AND METHODS

Animals and housing. Two experiments were carried out, each involving 48 weaned piglets of 6 – 7 weeks of age divided into eight groups of six animals on the basis of sex, body weight and origin. The piglets were female or castrated male crossbred animals (Swedish Landrace x Yorkshire). They were kept in mesh-floored pens and fed and watered ad libitum. Blood was sampled from 16 piglets in each experiment.

Diets. A new variety of pea, produced at the Institute of Agriculture and Horticulture, Novi Sad and registered in 1992, was used. Pisum sativum var. Junior is a white flowered spring pea producing spherical, smooth, medium-sized, creamy-yellow seeds. They were found to contain 267 g crude protein, 75 g crude fibre and 37 g ash by standard Weende procedures and 13.5 MJ metabolisable energy (ME) per kg dry matter (DM). Micronisation was carried out at 135^{0}C for 90 seconds and extrusion at 125^{0}C for 30 seconds at the Maize Institute, Zemun, both processes theoretically increasing the ME to 15.6 MJ/kg DM.

In the first experiment the diets were balanced to contain 202 g crude protein per kg air dry mixture and the same amounts of lysine, methionine + cystine and tryptophan as the control diet, which was a standard mixture based on ground maize grain and soyabean oil meal (Table 1). The same consignments were used in both experiments. In the second experiment the amino acid supplements were adjusted in accordance with the metabolizable energy content of the diets (AEC, 1972). Moreover, one third of the extruded peas in diet 4 was replaced with raw peas.

Table 1. Formulation (g/kg) and average daily nutrient intake of the diets used in the experiments

Diet		1	2	3	4
Ingredient					
Maize grain		632.4	367.2	393.8	393.3
Soyabean oil meal		290.2	85.9	82.7	82.8
Raw peas		0	468.8	0	0
					148.9*
Micronized peas		0	0	446.6	0
Extruded peas		0	0	0	446.6
					297.7*
Fish meal		40.0	40.0	40.0	40.0
Limestone		7.8	10.5	10.7	10.4
Dicalcium phosphate		16.6	13.0	12.4	12.9
Sodium chloride		3.0	3.0	3.0	3.0
Vitamin and mineral premix		10.0	10.0	10.0	10.0
DL Methionin	Expt. 1	0	1.12	0.45	0.63
	Expt. 2	0	0.57	0.63	0.55
DL Tryptophan	Expt. 1	0	0.52	0.31	0.36
	Expt. 2	0	0.30	0.38	0.32
Daily intake					
ME (MJ)	Expt. 1	12.6	13.9	15.6	15.4
	Expt. 2	14.0	12.2	15.0	12.5
Crude	Expt. 1	189	228	229	229
protein (g)	Expt. 2	210	197	220	189
Ether	Expt. 1	35	29	34	31
extract (g)	Expt. 2	39	25	32	26
Crude fibre	Expt. 1	28	49	54	49
(g)	Expt. 2	32	42	52	41

*Amount included in Experiment 2

Experimental procedure. One group of barrows and one group of female piglets was fed on one of the four diets for 29 days in Experiment 1 and 27 days in Experiment 2. Towards the end of each period two piglets of body weight close to the mean for their group were separated and placed in individual cages. Blood was taken from the retroorbital sinus at about 9.00 hours after a 16 hour fast and each piglet was then offered a portion of its respective diet. The time the piglet started to eat was noted and a further blood sample was taken 30 – 45 minutes later. Blood sampling was completed by 11.00 hours. The amount of feed consumed was determined.

Experiment 1 was carried out in June-July 1992 and Experiment 2 in October-November 1992.

Analytical methods. After separation of the serum by centrifugation, the hormones triiodothyronine (T3), thyroxine (T4) and cortisol were determind by radioimmunoassay using commercial kits in accordance with the instructuions (INEP, Diagnostics, Zemun). Insulin was measured using a homologous radioimmunoassay system which included porcine insulin standards. Insulin-like growth factor-I (IGF-I) was determined after separation of binding proteins by the method of Daughaday and coworkers (1982), which has been validated for porcine serum (Owens et al. 1990). Since porcine IGF-I has the same amino acid composition as human IGF-I (Simmen, 1991), the reagents used in the radioimmunoassay were rabbit inti-IGF-I (UCB-Bioproducts, Belgium) and recombinant human IGF-I (Serve Feinbiochemica, Germany). The latter substance was labelled with radioactive iodine (125-I) using the modification of the chloramine-T method described for insulin (Nikolić et al. 1989). The assay was standardised against a reference preparation of IGF-I (WHO 87/518), which gave 102.2 ± 2.4% of the expected values within the range of 81 – 1625 pM/l. Possible analytical bias between experiments was eliminated by determining samples from both experiments at the same time.

Statistical analysis. The results for each experiment were subjected to analysis of variance (AVNOVA) individually for preprandial and postprandial blocks with two factors (sex and diet). The statistical significance of the effects of these factors was estimated by the F-test (Snedecor and Cochran, 1967). Differences between individual diets were determined after calculation of the least significant difference (LSD). The effect of feeding was examined by Student's t-test for paired samples.

RESULTS

Animal well-being. During handling prior to blood sampling one piglet fed on the raw pea diet was inadvertently injured in Experiment 1. The results for this piglet, which was discovered to have a dislocated hip, were excluded from the statistical analysis where appropriate. In Experiment 2 one piglet refused to eat in the allotted time, so no postprandial values were obtained. All the other animals were alert and healthy.

Thyroid hormones. The mean serum concentrations of thyroxine (T4) and triiodothyronine (T3) found in the piglets fed on different diets are shown in Tables 2 and 3. There was a marked difference between the experiments concerning T4 concentrations, whereas T3 concentrations were within the same range in both trials. After feeding, T3 concentrations tended to increase, the effect being statistically significant in Experiment 1 (Table 2), while T4 levels fell slightly but significantly ($P<0.05$) in Experiment 1 and remained the same in Experiment 2. Analysis of variance indicated that the dietary treatments had statistically significant effects on preprandial T3 levels in both experiments. Namely, values for the piglets fed on raw peas were higher than those fed on micronized peas or the standard diet in Experiment 1 Table 2), while values for the piglets fed on the standard diet were higher than those fed on micronized and extruded peas in Experiment 2 (Table 3). Females had higher T3 levels than barrows. These effects were somewhat confounded by a strong sex x diet interaction in Experiment 2. Namely, female piglets exhibited low T3 levels only when fed on extruded peas. All significant differences between the diets and sexes disappeared after feeding in both experiments.

The somewhat low levels of thyroid hormones found in Experiment 1 compared with previous studies, coupled with a dramatic decrease when the fish meal supplement was replaced by yeast in a parallel investigation (Nikolić et al. 1993), led us to suspect that the sodium chloride supplement may have contained less than the declared amount of iodide. Therefore, salt from a different source was used in Experiment 2, although the other ingredients were the same. This appeared to have increased T4 without affecting T3 concentrations. Thus, values for T4 were in the lower and upper ranges of those given by other authors for this category of swine, while T3 levels were somewhat lower (De Wilde, 1984; Dauncey, 1990).

Table 2. Serum concentrations of thyroxine (T4), triiodothyronine (T3), cortisol, insulin and IGF-I before and 30 to 45 minutes after offering weaned piglets different diets. Experiment 1.

Parameter	T4 nmol/L	T3 nmol/L	Cortisol nmol/L	Insulin mIU/L	IGF-I μg/L
Mean values before feeding:					
Standard diet	30.4	0.40[a]	46.5	1.35	121
Raw peas	37.7	0.68[b]+	57.6+	3.37+	110
Micronized peas	33.1	0.47[a]	105.7	6.15	81
Extruded peas	34.4	0.52[a]	87.6	2.90	86
Barrows	32.7	0.43[a]+	88.3+	3.00+	80
Females	35.0	0.57[b]	64.3	3.84	119
Mean squares:					
Main effects	58.6*	0.033*	2646	20.3	1996
Diet	36.4	0.049*	2852	17.2	1426
Sex	20.9	0.069*	2157	2.6	6104
Interaction	93.4	0.005	2602	30.2	1199
Error	10.4	0.009	1542	9.1	2793
Mean values after feeding:					
Standard diet	29.2	0.51	46.7	52.6	105
Raw peas	33.7	0.79+	109.8+	60.0+	113
Micronized peas	32.2	0.54	97.0	86.9	80
Extruded peas	33.6	0.71	79.4	46.8	84
Barrows	31.3	0.59+	96.4+	72.3+	79
Females	33.1	0.66	68.4	52.4	112
Mean squares:					
main effects	48.8	0.094	3053	3335	1368
Diet	18.2	0.064	2744	1413	1040
Sex	13.3	0.020	2940	680	4189
Interaction	91.3	0.156	3401	6143	755
Error	16.6	0.034	971	1202	2369
Effect of feeding:					
t (df = 15)	2.72*	2.67*	0.32	4.57***	0.83

+Mean value excludes the injured piglet. Error degrees of freedom (df) reduced from 8 to 7.
* ** *** Differences statistically significant at $P<0.05$, <0.01 and <0.001 respectively
a, b Mean values with different superscripts are significantly different ($P<0.05$).

IGF-I and insulin. Mean serum concentrations of IGF-I and insulin before and after feeding the examined diets are also given in Tables 2 and 3. Values for IGF-I in piglets fed the standard diet were found to be similar in both experiments but piglets fed on the rations containing peas tended to exhibit lower IGF-I concentrations except for the group fed on raw peas in Experiment 1. The decrease was statistically significant in Experiment 2 (Table 3), although the significant interaction (sex x diet) indicated that this involved only the female piglets. Overall, the female piglets had higher serum concentrations of IGF-I than the barrows in both experiments. IGF-I levels were not affected by feeding.

Fasting insulin concentrations were low in both experiments (overall means 3,45 and 4,78 mIU/1 respectively) as found in our previous investigations (Nikolić et al. 1993). The response to feeding was highly significant (P<0.001 for the t-test in both cases) but more marked in the first than in the second experiment, as well as being very different between animals. No significant effect of diet or sex was noted.

Cortisol. The values for serum cortisol (Tables 2 and 3) varied widely within both experiments. Both increases and decreases were observed after feeding the piglets. No statistically significant differences in relation to feeding or sex were found in Experiment 1. The piglets fed micronized or extruded peas had lower preprandial serum cortisol concentrations than the piglets fed raw peas or the control ration (Table 3) in Experiment 2.

Table 3. Serum concentrations of thyroxine (T4), triiodothyronine (T3), cortisol, insulin and IGF-I before and 30 to 45 minutes after offering weaned piglets different diets. Experiment 2.

Parameter	T4 nmol/L	T3 nmol/L	Cortisol nmol/L	Insulin mIU/L	IGF-I μg/L
Mean values before feeding:					
Standard diet	71.2	0.72[c]	154[b]	8.7	115[b]
Raw peas	84.1	0.73[c]	163[b]	2.6	56[a]
Micronized peas	74.8	0.48[b]	99[a]	5.5	63[a]
Extruded peas	64.8	0.25[a]	64[a]	2.3	64[a]
Barrows	72.2	0.45[a]	111	3.9	53[a]
Females	75.1	0.64[b]	129	5.6	96[b]
Mean squares:					
Main effects	203.6	0.154**	5199**	27.7	3439**
Diet	260.6	0.213**	8782*	35.6	2960*
Sex	31.6	0.137*	1371	11.6	7539**
Interaction	204.4	0.100*	2893	25.3	2551*
Error	93.8	0.014	1475	32.7	432
Mean values after feeding:					
Standard diet	72.9	0.83	157	25.0	109[b]
Raw peas	81.3	0.69	148	13.1	56[a]
Micronized peas	71.5	0.47	104	22.2	65[a]
Extruded peas	73.3	0.51	78	29.7	57[a]
Barrows	72.0	0.56	107	17.8	50[a]
Females	76.3	0.67	132	27.8	93[b]
Mean squares:					
main effects	149.4	0.082	3500	285.6	2937**
Diet	63.2	0.109	5315	332.4	2468**
Sex	69.0	0.040	2319	874.6	6853**
Interaction	262.3	0.068	2079	42.5	2101*
Error	84.5	0.068	8143	126.7	239
Effect of feeding: t (df = 15)	0.22	1.15	0.27	4.49***	0.45

+ One piglet failed to eat during the allotted time. Error degrees of freedom (df) reduced from 8 to 7.
* ** ***Differences statistically significant at P<0.05, P<0.01 and <0.001 respectively
a, b, c Mean values with diferent superscripts are significantly different (P<0.05).

Body weight gain and rate of eating. There were no statistically significant differences in the amount of feed consumed during the 30 – 45 minute period allowed, either between the sexes or between the different diets in Experiment 1, nor were significant differences observed in the rate of feed intake by the selected piglets (Table 4). As a whole average daily feed consumption over the 29 day period was somewhat greater for the groups fed the diets containing peas than for the control piglets in Experiment 1 (Table 1). In Experiment 2 only consumption of the diet with micronized peas exceeded that of the control ration. Feed intake of raw and extruded peas was lower. Differences were also found among the piglets selected for blood sampling. Namely, the barrows ate less of diet 3 and the female piglets ate less of diet 2 (Table 4).

Table 4. Total and rate of feed consumption between blood collections and gain in body weight of the piglets during the experiments.

Parameter	Feed consumed		body weight gain (g/day)$^{+}$	
	g	g/min.	n = 16	n = 48^{+}
Experiment 1:				
Standard diet	260	7.8	498	476
Raw peas	253	7.6	548	542
Micronized peas	230	6.6	503	524
Extruded peas	163	5.0	498	469
Barrows	229	6.8	492	
Females	224	6.7	532	
Mean squares:				
Main effects	4425	3.81	5579	
Diet	7875	6.42	2392	
Sex	100	0.01	6400	
Interaction	2416	2.47	8493	
Error	3525	4.05	4383	
Experiment 2:				
Standard diet	205^{b}	5.6^{bc}	456	495
Raw peas	147^{ab+}	4.5^{ab+}	368	391
Micronized peas	140^{a}	4.0^{a}	430	448
Extruded peas	270^{c}	6.6^{c}	360	364
Barrows	181^{+}	4.8	377	
Females	204	5.6	429	
Mean squares:				
Main effects	11148**	6.10**	7685	
Diet	13989**	5.22**	8878	
Sex	1859	2.57	10810	
Interaction	11403**	8.16**	5451	
Error	1329	0.65	4261	

$^{++}$ Taken from Živković et al. (1993).
$^{+}$ One piglet failed to eat during the allotted time. Error degrees of freedom (df) reduced from 8 to 7.
* ** *** Differences statiistically significant at P<0.05, <0.01 and <0.001 respectively
$^{a, b, c}$ Mean values with different superscripts are significantly different (P<0.05).

During Experiment 1 the piglets fed on the diets containing raw peas tended to gain weight faster than those fed on the standard diet, whereas the reverse trend was observed in Experiment 2 (Table 4). None of the differences were statistically significant. The average daily gains of the piglets selected for blood sampling reflected the gains for the groups as a whole, which were highest in the piglets offered raw peas in Experiment 1 and in those fed on the control diet in Experiment 2. In each experiment the lowest average daily gains were found in the piglets offered extruded peas. The ratio of crude protein intake to weight gain was lowest in piglets fed on the control diet and highest in those offered extruded peas in both experiments. Each diet was utilised more efficiently in Experiment 1 than in Experiment 2.

Significant correlations. In an attempt to understand some of the underlying mechanisms involved, statistically significant correlations were sought among the parameters examined. In Figure 1 it may be seen that preprandial T3 and T4 concentrations were closely correlated at similar slopes in both experiments. Preprandial cortisol concentrations were also correlated with thyroid hormone levels especially in Experiment 2 (Figure 1). The respective coeficients(r) in Experiment 1 were 0.437 (T4) and 0.484 (T3) which approached

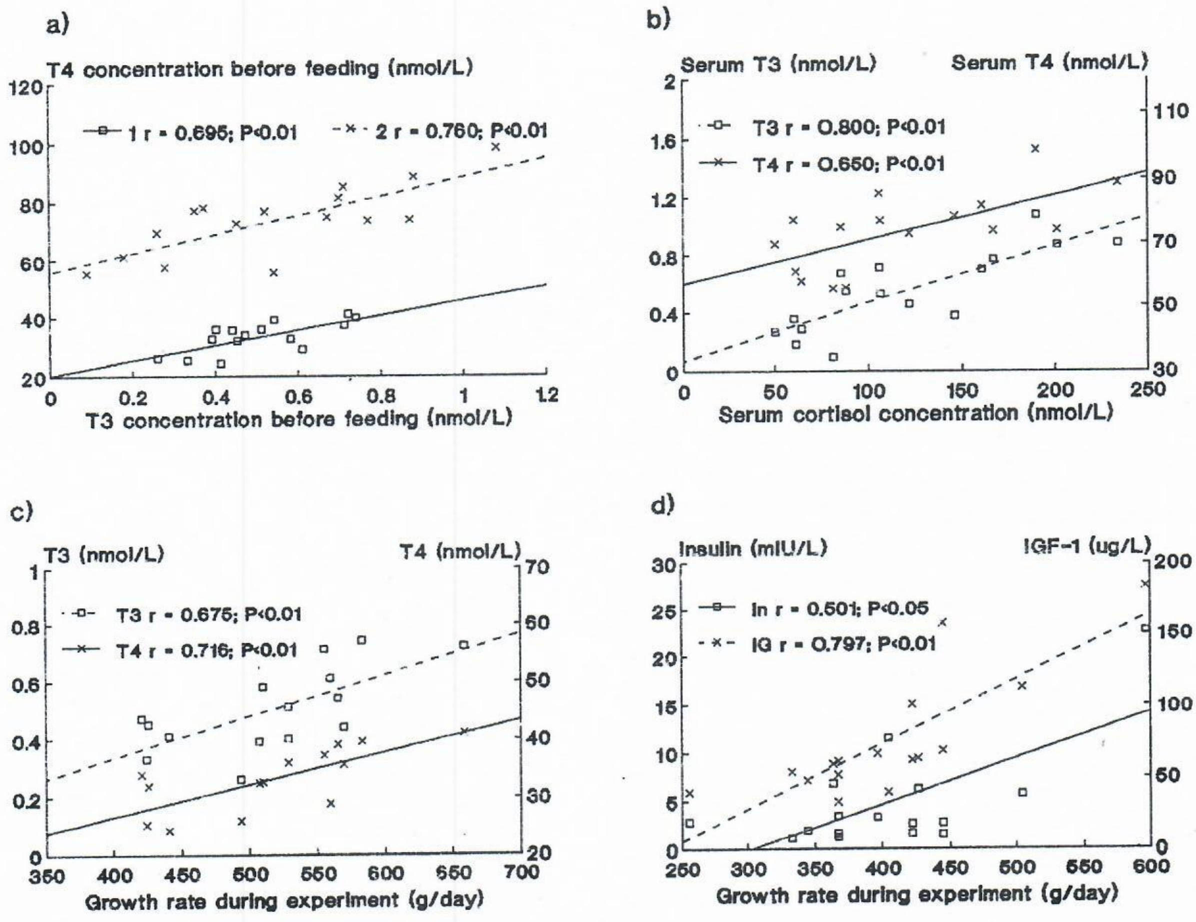

Figure 1. Some statistically significant correlations between various parameters measured in weaned piglets fed on maize based diets with soyabean oil meal and peas: a) between T3 and T4 in both experiments; b) between cortisol and thyroid hormones before feeding in Experiment 2; c) between weight gain and serum T3 and T4 before feeding in Experiment 1 and d) between weight gain and serum insulin and IGF-I before feding in Experiment 2.

statistical significance. Significant postprandial correlations between T3 and T4 and between T3 and cortisol remained but the associations were less close. Both postprandial serum insulin concentrations and the insulin response were positively correlated with the amount of feed consumed and the rate of intake in Experiment 2 only ($r = 0.723 - 0.799$).

In Experiment 1 where methionine and tryptophan supplements were added to the pea containing diets in amounts to provide the same overall dietary contents as the standard diet on an air dry basis, the weight gain was significantly correlated only with thyroid hormone levels (Figure 1). However, in Experiment 2 this association was much less marked ($r = 0.140$ for T4 and 0.440 for T3) and growth rate was positively correlated with preprandial insulin and IGF-I concentrations (Figure 1).

DISCUSSION

Concerning relationships between hormone levels and growth rate, the results obtained in Experiment 1 indicate that intake of metabolisable energy may have been the overiding factor influencing weight gain. Thus, Dauncey (1990) clearly showed the positive effect of increasing energy intake on thyroid hormone levels in piglets, which was confirmed in our recent investigation (Nikolić et al. 1993). Therefore, the fact that the fastest weight gain was associated with the highest levels of T3 in the piglets fed on the diet containing raw peas, suggests that this diet provided a greater intake of ME than calculated in Table 1. Namely, micronization and extrusion did not actually improve nutrient utilisation, despite the apparent theoretical increase in ME content. Since the intake of the isonitrogenous pea containing diets was uniform, differences in performance may be related to changes in nutrient availability. Thus, the poorest feed conversion ratio was found with the diet containing extruded peas (Živković et al. 1993).

Serum IGF-I levels have been shown to be correlated with nitrogen retention in swine (Fletcher et al. 1990; Taylor et al. 1991). The fact that the lower weight gains and somewhat inferior performance of the piglets fed the pea containing diets coincided with lower serum IGF-I concentrations suggests that some aspect of protein metabolism may have been the dominant influence in Experiment 2. It may be pointed out that the greatest feed intakes and gains in both experiments among the pea containing diets coincided with the largest amino acid supplements. In rats protein restriction per se and deficiencies of single amino acids have been found to decrease liver IGF-I mRNA expression and induce the synthesis of IGF binding protein-1, which, like the other five binding proteins, significantly modifies the action of both IGFs (McCusker et al. 1989; Walton et al. 1989; Thissen and Underwood, 1992; Straus et al. 1993). The complex interactions between the somatotropin-IGF-I axis and thyroid hormones in controlling mammalian growth are also slowly being unravelled (Näntö-Salonen et al. 1993).

In somewhat older pigs white flowered raw peas were found to be highly digestible in barley based diets (Gdala et al. 1992; Abrahamsson et al. 1993).

According to Huisman and coworkers (1992) the true digestibility of raw pea protein in small piglets is over 0.9. The apparent digestibility was somewhat lower due to secretion of endogenous (and ? bacterial) protein. Goodlad and Mathers (1991) also found that raw peas were highly digestible in young pigs including the cell wall material. It seems that, although pea proteins are largely digested in the small intestines, non-starch polysaccharides from peas reach the caecum and large intestines where they are fermented, leading to increased amounts of volatile fatty acids in the peripheral blood. Goodlad and Mathers (1992) observed that pressure cooking peas in an equal volume of water increased the concentration of starch resistant to pancreatic a-amylase and therefore probably partially altered the rate and site of starch digestion in the rat even though the treatment may have improved the accessibility of pea starch to a-amylase by breaking the thick walled parenchyma cells and gelatinising the starch. In Experiment 2 the most favourable results were obtained after micronization, a dry process which may have burst the starch containing cells without leading to retrogression of amylose.

The direct effects of the micronization and extrusion processes on the quality of the nutrient constituents of the peas were not examined here. Nevertheless, piglet performance and serum hormone concentrations suggested that, while micronization offered no consistent benefit, extrusion which necessitates the addition of moisture, appeared to have had a negative effect. Anattempt to assess carbohydrate availability from the insulin response was made because it has been reported that this is lower and slower with legume containing diets and may be altered by thermal treatments. Peak concentrations of insulin after meal ingestion occur at 30 – 45 minutes (Rerat et al. 1985; Christensen and Just, 1988; Ponter et al. 1991), which was why this interval was chosen and carefully adhered to here. However, the enormous individual differences between animals disguised any effects of diet. The lower response in Experiment 2 may reflect less insulin secreted from the pancreas or a higher liver uptake. However, Simoes Nunes and Malmlöf (1992) showed that the hepatic extraction coefficients for insulin produced in pigs given maize starch and casein based diets were higher than 0.5 but not related to the amount secreted. Cortamira and coworkers (1991)related low insulin responses to dietary tryptophan deficiency which was circumvented here by the dietary supplement. While insulin is known to stimulate 5 -deiodination of T4, Matzen and coworkers (1990) obtained no evidence indicating that changes in thyroid hormones were associated with increases in insulin induced by intake of carbohydrate or protein in man. Namely, no explanation can be offered for the exaggerated insulin response in three animals in Experiment 1.

Possible reasons for the wide differences found between cortisol levels in individual animals were fully discussed previously (Nikolić et al. 1993)) and have recently been related to differences in birth weight (Klemcke et al. 1993).

Again, about half the piglets appeared to be resistant to both nutritional and environmental stress as indicated by serum cortisol concentrations below 100 nmol/1.

Overall the results obtained here confirm that large amounts of a suitable variety of pea appropriately supplemented with additional methionine and tryptophan may be successfully included in diets for weaners in place of part of the maize and soyabean ingredients. Micronization of the peas offered no consistent benefit, while extrusion appeared to decrease nutrient utilisation. Although measurement of the insulin response to feeding provided no assistance, determination of preprandial thyroid hormone levels and IGF-I concentrations pointed towards possible factors affecting piglet performance.

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KONCENTRACIJA HORMONA U SERUMU I PROIZVODNI REZULTATI KOD ODBIJENE PRASADI HRANJENE OBROCIMA SA GRAŠKOM

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SADRŽAJ

Izvršena su dva ogleda u kojima su odbijena prasad hranjena sirovim ili mikroniziranim ili ekstrudiranim graškom (oko 450 g/kg vazdušno suvog obroka) umesto dela kukuruzne prekrupe i sojine sačme. Obroci su imali gotovo iste količine sirovih proteina i bili su dopunjeni nedostajućim količinama metionina i triptofana do nivoa kontrolnog obroka. Dobijeni rezultati pokazali su da ekstrudacija graška nije poboljšala iskorišćavanje hranljivih materija iz graška. Razmatrajući obroke sa graškom, prasad hranjena sirovim graškom u prvom ogledu i prasad hranjena mikroniziranim graškom u drugom ogledu pokazali su najpovoljnije proizvodne rezultate, koji su bili slični onima u ishrani standardnom smešom. Nađena je statistički značajna korelacija između prirasta prasadi i nivoa tiroksina i trijodotironina u prvom ogledu, u kome su koncentracije tireoidnih hormona u serumu bile nešto niže. U drugom ogledu, u kome je mogući marginalni deficit joda korigovan, postojala je signifikantna korelacija između prirasta prasadi i koncentracije insulinu-sličnog faktora rasta (IGF-I). Sastav ispitivanih obroka nije uticao na promene u koncentracijama insulina posle hranjenja. Nivoi kortizola u serumu su se razlikovali u širokom opsegu između individualnih životinja. Dobijeni rezultati diskutovani su u odnosu na dosadašnja saznanja o odgovoru organizma životinje na promene u sastojcima obroka, koji se pokazuje preko nivoa hormona u krvi.