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Evaluation of Un-fasted Pig Stomach Spent Feed as a Substitute in Finishing Pigs Diet

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ABSTRACT

Insufficient pre-slaughter fasting leaves serious amount of feed-like contents (designated here as un-fasted stomach spent feed, USSF) in the eviscerated pig stomach. This study was intended to evoke economical and environmental seriousness of USSF discharge by estimating its value as pig feed. For finishing pigs feeding trial, three levels (0, 5, and 10%) of USSF were blended with pig feed to prepare control and two treatment diets, respectively. A total of 42 (21 males, 21 females) crossbred (Landrace × Yorkshire × Duroc) finishing pigs weighing 81.5 ± 8.0 kg were employed to 28d feeding trial and *in vivo* digestibility trial by Cr_2O_3 indicator method with 7 males and 7 female pigs per treatment. *In vitro* total tract digestion of USSF showed 70.5% and 57.6% of DM and OM digestibilities, respectively which were poorer ($p<0.05$) than those of pig diet. There were no differences in body weight gain, daily feed intake and feed conversion ratio among treatments although 10% USSF substitution exerted relatively poor performance. *In vivo* apparent digestibilities of diets containing USSF 5% and 10% were lower ($p<0.05$) than that of 100% pig feed. There were no differences ($p>0.05$) in dressing percentage and carcass grade among treatments. Results of this study showed that 5% USSF substitution in finishing pigs diet did not exert any disadvantage in terms of production performance and carcass grade. This study implied that un-fasted slaughter causing excessive excretion of USSF should be avoided. If not avoidable, the USSF should not be wasted in abattoir but could be recycled as pig feed.

(**Key words :** Un-fasted pig stomach spent feed, Finishing pigs, Performance, Digestibility, Carcass grade)

INTRODUCTION

Hike in prices of feed grains is forcing feed formulators to consider even under-utilized feed ingredients. It also became rational to re-examine the cost effectiveness of by far, wasted feed resources. Together, reduction of waste disposal and cost of waste treatment have appeared as a critical way to decrease the production cost.

Unfortunately, in any local abattoir in Korea, it is not surprising to find serious amount of feed-like resources discharged from the stomach of slaughtered pigs, which have incurred expenditure on the waste treatment (Son, 2010). Theoretically, those resources resemble ingested pig feeds spent only by saliva and gastric juice. Therefore, it is designated as un-fasted stomach spent feed (USSF) which implies its significance as a resource equivalent to pig diet.

Not many surveys have reported how much USSF discharged from a pig stomach. It could be presumed to exceed 1 kg considering 3.1~3.5 kg of daily feed intake by finishing pig and slaughter within 4-5 hrs after last meal (Park and Lee, 2011). Nearly 50% of ingested feed remained in pig stomach until 180 mins (Johansen et al, 1996) ~ 220 mins (Chiang et al., 2008) after ingestion. A survey from a local abattoir in Korea reported surprisingly an average of 1.17 kg of USSF from a pig stomach (Son, 2010). Other surveys reported that 11.9% out of 1242 slaughtered pigs in England (Guise et al, 1995) and 9~3% pigs in Ireland (Davis et al, 1997) discharged more than 1 kg of USSF per stomach. These surveys indicated that serious amount of USSF discharged from slaughtered pigs although implementation of pre-slaughter fasting affected more or less.

Therefore, it is needed to seriously recognize how much value have been wasted due to no pre-slaughter fasting. In Korea recycling whole USSF as pig feed worth nearly 9,200 tons of pig feed every year. To recycle USSF as pig feed, however, safety examination and feeding value evaluation is a priority. A preliminary study found that the total numbers of coliform in USSF was lower whereas lactic acid bacterial

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population was higher than those in commercial pig feed, which therefore, can be recognized as generally safe (Lee et al, 2010). Relatively lower coliforms and higher number of lactic acid bacteria in stomach content was reported earlier (Nattress and Murray, 2000; Castillo et al., 2007; Siggers et al., 2008).

Value of USSF could be recognized by estimating its feeding value as a feed substitute. Ingested feed undergo action by saliva and gastric juice during mastication and maceration through mouth and stomach (DeRouchey et al, 2009). The feed become wet mass carrying small amount of exudates. The wet mass pH decreases gradually to 3.5-4.5 (Nielsen and Ingvartsen, 2000) along with gastric acid secretion. The acidic and pepsin hydrolysis of protein and salivary amylase action may induce chemical changes in feed mass (DeRouchey et al, 2009). In addition, earlier emptying of liquid exudates from stomach also affects the chemical composition of the USSF. By far, chemical composition or feeding value of USSF have not evaluated in our knowledge. It is certainly meaningful to evaluate the feeding value of USSF (Chiang et al, 2008). Therefore, this study was executed to evaluate the feeding value of USSF in finishing pigs.

MATERIALS AND METHODS

1. Experimental materials

The USSF (un-fasted stomach spent feed) used in this experiment was freshly collected from the stomach of about eviscerated 250 pigs at the local abattoir. After its transport with an icebox to keep 4℃ to laboratory, high moisture of USSF was dried for 2 days at 65℃ and kept in refrigerator for further feeding trial and digestibility assay. The particle size and uniformity of USSF and experimental diets were analyzed using sieve particle size analyzer and calculated by the established formula (Baker and Herrman, 1995).

2. Methods of experimentation

(1) *In vitro* digestibility assay

In vitro digestibility was conducted in three steps with multi-enzyme complex developed by Boisen and Fernandez (1997) to simulate digestive system of mono-gastric animals. Briefly, 0.5 g of finely ground USSF sample was weighed in 100 ml conical flasks. Then, 25 ml of phosphate buffer (0.1M, pH 6.0) was added to each flask and were mixed. Then, 10 ml of 0.2 M hydrochloric acid (HCl) was added to the mixture and pH was adjusted to pH 2.0. To the mixture was then added 1 ml of a freshly prepared pepsin solution containing 25 mg pepsin (from porcine stomach mucosa, 2235 units/mg solid). In order to prevent bacterial growth, 0.5 ml of chloramphenicol solution (chloramphenicol solution 0.5% prepared in ethanol) was added. Then, the flasks were incubated in a water bath at 39℃ for six hours (step 1).

After termination of pepsin digestion procedure, the mixture was added with 10 ml of phosphate buffer (0.2 M, pH 6.8) + 5 ml of a 0.6 M NaOH solution. The pH was adjusted to 6.8. This slurry was carefully mixed with 1 ml of freshly prepared pancreatin solution containing 100 mg pancreatin (porcine, grade IV, Sigma No. P-1750). The mixture was incubated at 39°C for four hours (step 2).

To the mixture, 10 ml of 0.2 M EDTA solution was added and then pH was adjusted to 4.8 with 30% acetic acid. The mixture was then carefully mixed with 0.5 ml of multi-enzyme complex containing a wide range of microbial carboanhydrases including arabinase, cellulase, β-glucanase, hemicellulase, xylanase and pectinase (Viscozyme L, V2010, Sigma Co.). The flasks were incubated under continuous magnetic stirring at 39℃ for eighteen hours. The undigested residues were collected using a filtration unit (Fibertec System M, Tecator, Sweden) in dried and pre-weighed glass filter crucibles. After consecutive washings with 10 ml of ethanol (96%) and 10 ml of acetone (99.5%), the undigested residues were dried at 130℃ for 2 hours and weighed (for obtaining values of dry matter digestibility) and then ashed in the muffle furnace at 500℃ for four hours (step 3).

(2) Feeding trial

A total of 42 crossbred finishing pigs (Landrace × Yorkshire × Duroc) with initial BW of 81.5 ± 8 kg were randomly allocated into three dietary treatments with same number of males and females per treatment for 28 days of feeding trial. All pigs were housed in concrete-floor pens in local swine farm. The commercial finishing pig feed was used as a basal diet (Table 1). Three levels (0, 5% and 10 %) of USSF were blended with the pig feed to prepare control and two dietary treatment diets (5:95 and 10:90), respectively. Water and feed were supplied to the pigs for *ad libitum* consumption during the entire experimental period. Body weight and feed intake were measured in the beginning and termination of feeding study to determine

Table 1. Formula and nutrients composition of the basal diet

Ingredients	%
Corn	66.89
Wheat bran	2.12
Corn germ meal	5.00
Coconut. Exp.	3.00
Palm kernel meal	3.00
Soybean meal	10.85
Rapeseed meal	3.00
Dried soy-curd	3.00
Beef tallow	1.00
Limestone	0.73
T.C.P	0.56
NaCl	0.25
Lysine-HC1	0.25
Threonine	0.06
Vitamin premix[1)]	0.10
Mineral premix[2)]	0.10
Choline-C1	0.10
Nutrients composition	**%**
Moisture	11.65
DE, kcal/kg	3,350
Crude protein	15.00
Crude fat	5.02
EFA	2.02
Lys.	0.85
Met.	0.26
Thr.	0.58
Trp.	0.16

[1)] Propvided the following per kilogram of diet: Vit. A, 18,000 IU; Vit. D3, 4,500 IU; Vit. E, 60 mg; Vit. K, 3.6 mg; Vit. B_1, 1,8 mg; Vit. B_2, 6 mg; Vit. B_6, 3 mg; Vit. B_{12}, 30 ug; Pantothenate, 15 mg; Niacin, 22.5 mg; Biotin, 0.1 mg; Folic Acid, 0.6 mg.

[2)] Propvided the following per kilogram of diet: Fe, 150 mg; Cu, 75 mg; Zn, 97.5 mg; Mn, 60 mg; I, 1.05 mg; Co, 0.3 mg; Se, 0.3 mg.

ADG, ADFI, and FCR.

(3) *In vivo* digestibility assay

At 4th week of feeding trial, the assay for *in vivo* digestibility in finishing pigs was conducted with experimental diets containing 0.3% of chromic oxide as the digestibility marker. The fecal sample was collected from the ground from six randomly selected finishing pigs for 2 days after 3 days initial feeding of experimental diet. The experimental unit for *in vivo* digestibility was a pig. Both collected diets and fecal samples was dried at 65℃ and stored at −20℃ for later chemical analysis.

(4) Chemical analyses

USSF, experimental diets and fecal samples were air-dried and ground using sample grinder (Cyclotec, Foss Co. Sweden). Dry matter (DM), ether extract (EE), and crude ash (CA) contents were analyzed according to the methods of the AOAC (1990). Crude protein (CP) was determined using an automatic nitrogen analyzer (Kjeltec 2300, Foss Co., Sweden). Chromic oxide contents in experimental diet and feces were determined according to the method described by Fenton and Fenton (1979).

(5) Carcass grade evaluation

After termination of feeding trial, all pigs were transported to a local slaughter house, slaughtered by electrical stunning, exsanguinated, dressed and longitudinally divided into 2 halves. Dressing percentage was calculated from carcass weight and live body weight. Backfat thickness was measured at position between the 12th and 13th rib using an ultrasonic device. The pork carcass categories for both quality and conformation were graded by expert registered in Korea Institute for Animal Products Quality Evaluation. More specifically, the quality was graded based upon marbling, lean color, and condition of belly streaks. Carcass weight, backfat thickness and their balance determined the conformation.

(6) Statistical analysis

Collected data were statistically analyzed based on a randomized complete design using the general linear model (GLM) procedure of SAS (Ver. 8, SAS Inst., Inc., Cary, NC). Differences at $P<0.05$ were considered significant. Differences among means were determined using a multiple-range test. The pig was the experimental unit for weight gain, *in vivo* digestibility and carcass trait.

RESULTS AND DISCUSSION

Photograph of wet, dried and USSF mixed with pig diet are shown in the Fig. 1. The fresh wet USSF appeared yellowish and pasty due to higher moisture content (>80%). However, the texture of dried USSF and USSF mixed pig diet were similar to that of commercial pig diet except more

Wet USSF Dried USSF 10% USSF : 90% Pig diet

Fig. 1. Photos of wet and dried USSF and its mixture with 90% mash pig diet.

yellowish color in USSF mixed pig diet. Average particle size of dried USSF was increased as compared to the size of given feed (Table 2). Particle size uniformity was also transformed and appeared to be more uniform (Table 2). These change suggested that the smaller particles in given diet were digested faster than bigger particles. Therefore, it was evident that the dried USSF does not have any remarkable difference on physical appearance. The fluidity and enzyme activityof stomach contents in growing-finishing pigs changes by type and particle size of ingested diet (Regina et al., 1999). This finding suggested that the chemical composition of USSF could be changed due to the composition of given feed. Consequently, chemical composition of USSF collected after slaughter from an abattoir may be varied due to the particle characteristics of the given feed.

The chemical composition of USSF and commercial pig diets is shown in Table 1. The crude protein content of USSF was similar to that of commercial finishing pig diet. However, considerably higher ether extract and lower crude ash and gross energy were observed in USSF, compared to those of pig feed. Although the crude fat content of USSF was two-fold (9.05 vs. 3.95) higher than that of commercial pig feed, GE of USSF was lower than that of commercial pig diet by about 5.6%. Lower energy value of USSF may be explained by a partial digestion of carbohydrate components in the stomach. Nearly 50% of ingested feed remained in pig stomach until 180 mins (Johansen et al., 1996) ~ 220 mins (Chiang et al., 2008) after ingestion. The chemical composition of ingested feeds may be changed due to digestive enzymes (pepsin, salivary amylase, and gastric lipase) in the mouth and stomach (DeRouchey et al., 2009). Zebrowska et al. (1983) reported that there was no significant

Table 2. Chemical composition and particle characteristics of dried un-fasted stomach spent feed and experimental diets

Nutrients	Blending ratio, USSF (%) : Pig diet (%)			
	100:0	0:100	5:95	10:90
Moisture (%)	6.62±0.07	6.14±0.01	6.16±0.01	6.18±0.01
Crude protein (%)	16.59±0.02	16.93±0.01	16.91±0.01	16.90±0.01
Crude ash (%)	4.64±0.02	6.14±0.04	6.07±0.02	5.99±0.02
Ether extracts (%)	9.05±0.02	3.95±0.04	4.21±0.01	4.47±0.01
Total CHO (%)	69.72±0.12	72.99±0.01	73.53±0.04	73.69±0.01
Gross energy (kcal/kg)	3,344±27	3,547±17	3,521±20	3,500±0.6
Average particle size (μm)	1,867	939	987	1,021
Particle uniformity (s.d[1)])	1.88	2.42	2.47	2.47

[1)] Standard deviation

production of monomeric fraction from dietary protein in the stomach. The small intestine is the main site of starch digestion and mostly absorbed at the end of the small intestine (Wilfart et al., 2008). Although gastric lipase plays a pivotal role in the hydrolysis of triacylglycerols from dietary fat ingredient in the stomach of pigs, the future digestion of fatty acid does not occur in the stomach (Chiang et al., 1989). The activity of gastric lipase in the stomach was barely increased at the weaning but remained its low level after weaning (Jensen et al., 1997). Relatively higher fat content in USSF is presumed to be resulted by poor lipase activity in the stomach of finishing pigs.

The *in vitro* dry matter and organic matter digestibilities of USSF blended with pig feed are presented in Table 2. Although there is only slight difference between USSF and pig feed in chemical composition, the dry matter and organic matter digestibilities of USSF were significantly lower ($p<0.05$) than those of commercial pig feed regardless of its size of *in vitro* gut simulation. Nutrients in ingested feed are digested and released through physical and chemical action in the stomach. In the small intestine, macronutrients (protein, starch, and lipids) can be degraded into amino acids, sugar units, and fatty acids, respectively. Degraded monomers are mostly absorbed in the small intestine (Bastianelli et al., 1996). Thus, lower *in vitro* digestibility of USSF might be due to prior digestion by digestive enzymes in the mouth and stomach. Therefore, both dry matter and organic matter digestibility of USSF + pig feed mixture were linearly decreased as the substitution level of USSF was increased due to lower digestibility of USSF.

Growth performances of the finishing pigs fed experimental diets containing USSF are presented in Table 3. Average daily feed intake was slightly decreased with increasing USSF substitution. However, there was no difference in average daily gain among treatments. The fresh USSF retrieved from stomach has carried a unique acidic odor probably due to digestion with gastric acids. Although the intensity was weakened by drying, this kind of pungent odor in USSF may induce the reduction of palatability of the diets. Odor emission is reduced by vaporization of volatile compounds with heat application(Bertrand et al., 2011). The USSF used in this experiment was dried at 65℃ prior to mixing with pig feed. Although most of acidic odor in USSF was apparently disappeared during drying, it is presumed still to carry palatability depressor which was detected by finishing pigs.

Table 3. *In vitro* nutrient digestibilities of un-fasted pig stomach spent feed

Digestibilities (%)		Blending ratio, USSF (%) : Pig diet (%)				
		100:0	0:100	5:95	10:90	SEM[1)]
Stomach	Dry matter	25.76[d]	37.27[a]	36.58[b]	35.98[c]	0.32
	Organic matter	19.07[d]	30.60[a]	31.70[b]	30.78[c]	0.28
Small intestine	Dry matter	67.48[d]	84.71[a]	83.91[b]	83.24[c]	0.43
	Organic matter	57.04[c]	80.04[a]	78.95[a]	77.51[b]	0.78
Large intestine	Dry matter	70.51[d]	88.22[a]	87.34[b]	86.18[c]	0.31
	Organic matter	57.57[d]	83.08[a]	81.91[b]	80.09[c]	0.45

[a, b, c, d] Means with different superscripts within the same row significantly differ ($p<0.05$).
[1)] Standard error of means.

Table 4. Effect of feeding USSF by substituting pig diet on performance of finishing pigs

Growth performances	Blending ratio, USSF(%) : Pig diet (%)			
	0:100	5:95	10:90	SEM[1)]
Average daily feed intake (kg)	3.18	3.10	2.90	
Average daily gain (kg)	0.94	0.98	0.86	0.18
Feed / Gain	3.46	3.27	3.59	0.79

[a, b, c] Means with different superscripts within the same row significantly differ ($p<0.05$).
[1)] Standard error of means.

Table 5. Nutrient digestibilities of USSF substituted experimental diets by finishing pigs

Item	Blending ratio, USSF (%) : pig diets (%)			
	0:100	5:95	10:90	SEM[1)]
Dry matter	80.16 [a]	78.36 [b]	78.81 [b]	0.58
Crude protein	72.89	72.54	73.20	0.81
Crude ash	49.51 [a]	41.42 [b]	40.85 [b]	1.85
Ether extracts	67.52 [a]	65.25 [b]	67.30 [a]	1.79
Gross energy	83.11 [a]	81.00 [b]	77.38 [c]	0.44

[a, b, c] Means with different superscripts in the same row significantly differ ($p<0.05$).
[1)] Standard error of mean.

Table 6. Effect of feeding USSF by substituting pig diet on carcass grade

Items	Grade	Blending ratio, USSF (%) : pig diet (%)			
		0:100	5:95	10:90	SEM[1)]
Dressing percentage (%)		75.90	75.88	75.88	0.05
Backfat thickness (mm)		21.36	22.50	20.86	3.34
Carcass evaluation (%)					
Conformation grade	A	28.6	42.92	35.75	
	B	35.75	21.45	14.3	
	C	35.75	35.7	50	
Quality grade	1+	0	0	0	
	1	64	64.5	57.0	
	2	36	35.5	43.0	

[1)] Standard error of means.

Nutrient digestibilities of USSF substituted experimental diets are shown in Table 4. There was a difference ($p<0.05$) in crude protein digestibility between diets substituted with USSF and control diet. Dry matter, crude ash, ether extracts and gross energy digestibilities in pigs fed diets substituted with USSF were lower ($p<0.05$) than those of control group. The lower *in vivo* digestibility of USSF matched the results of *in vitro* digestion. The lower *in vivo* digestibility of diets substituted with USSF was predicted since the portion of digestible nutrients in the diet was already hydrolyzed in the stomach.

The effect of feeding USSF by substituting pig diet on carcass grade is shown in Table 5. The feeding of USSF substituted diets in finishing pigs did not affect dressing percentage There was a slightly decrease in backfat thickness in pigs fed 10% USSF substituted diet compared to pigs fed diets without USSF. The proportion of higher grade (1+ and 1) carcass was lower in pigs fed 10% USSF substituted diet than that of other treatments. There were no differences among treatments in conformation grade. No reports are available about feeding USSF to the finishing pigs to compare the current results with others. Carcass quality of pork could be improved by dietary manipulation such as vitamin and minerals, dietary lipid, and feeding level and dietary protein to energy ratio (Ellis and McKeith, 1999). There was a remarkable change in dietary lipid due to USSF substitution in this study. Feeding food waste supplemented diet did not affect carcass lean content and quality scores in finishing pigs (Myer et al., 1999). However, pork taste such as flavor, chewiness, and juiciness of finishing pigs fed diets containing 40% of food waste was decreased (Westendorf et al., 1998). The same authors reported that the high moisture causing decrease in feed intake could be a major defect of food waste. Although the USSF was dried in this study, the feed intake was reduced by 10% USSF substituted diet. Those factors may contribute to quality of pork. However, in this study, there was no difference in pork quality that was induced by USSF feeding.

IMPLICATION

The result of this study implied that un-fasted pig stomach spent feed could be successfully recycled as a partial substitute of pig diet without any negative impact on production performance. However, ahead of its recycle appropriate pre-slaughter fasting should be the preponderant routine to reduce the wasteful discharge of USSF.

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