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Use of Fermented Potato Pulp in Diets Fed to Lactating Sows

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Abstract: Fermented potato pulp is a by-product obtained from the potato-starch industry. There could be great economical and environmental advantages if it could be exploited for use as a new feed resource. This study was conducted to evaluate the dietary effect of adding 5% fermented potato pulp to diets fed to lactating sows on sow and litter performance, blood metabolites and hormones. On day 110 of gestation, 80 mixed parity sows (256.0±4.3 kg BW and 3.2±0.2 parity) were moved into a farrowing room and allotted to one of two corn-soybean meal based diets supplemented with either 0 or 5% fermented potato pulp in a completely random design experiment. Each treatment had 40 replicates and the sows were fed the dietary treatments until weaning following 28 days of lactation. Sow lactation weight loss tended to decrease ($p = 0.09$) and feed intake tended to increase ($p = 0.06$) when sows were fed fermented potato pulp. The weaning to estrus interval was shorter ($p = 0.05$) and litter weight gain was also higher ($p = 0.03$) for sows fed fermented potato pulp. Dietary treatments did not affect plasma glucose, insulin, non-esterified fatty acids, insulin-like growth factor I and follicle-stimulating hormone. Sows fed fermented potato pulp had higher ($p = 0.02$) plasma urea nitrogen and luteinizing hormone ($p = 0.01$) than sows fed the control diet. Feeding potato pulp tended to decrease ($p = 0.06$) creatinine and increase ($p = 0.07$) estradiol concentrations in sows plasma. These results demonstrate that feeding lactating sows diets containing 5% fermented potato pulp had a positive effect on sow and litter performance.

Key words: Fermented potato pulp, lactating sows, performance, blood metabolites, hormones, China

INTRODUCTION

Corn, soybean meal and wheat bran are the most common ingredients used in lactating sow diets in China because of their high nutritional value and economic benefits (Ministry of Agriculture of the People's Republic of China, 2004). However, as the size of the swine industry increases, the supply of these three raw materials will become more and more inadequate. Exploitation of new feed resources is an effective approach to resolve this issue.

Potato by-products represent an opportunity for livestock feeders because they are an inexpensive but energy-dense dietary ingredient (Szasz *et al*., 2005). More than 80 million tons of potatoes were produced in China in 2009 which accounted for approximately a quarter of the total production in the world (National Bureau Statistics of China, 2010). Even though <10% of the potatoes produced in China were processed in the potato starch industry, an estimated 5 million ton of potato pulp are generated each year (National Bureau Statistics of China, 2010). Additionally, disposal of potato pulp in landfills would be a waste of resources and can be both an economical and environmental problem. Feeding potato pulp to livestock could be the most effective method for its disposal.

The feeding of potato by-products in cattle diets has been discussed and applied by many research groups (Nelson *et al*., 2000; Busboom *et al*., 2000; Radunz *et al*., 2003; Szasz *et al*., 2005; Pen *et al*., 2005). Potato pulp contains starch, cellulose, hemicelluloses, pectin, proteins, free amino acids and salts (Mayer and Hillebrandt, 1997). Fermentation is an effective process whereby starch and sugar can be transformed by microbes into fermentation products including lactic acid, volatile fatty acids and alcohol (Prescott *et al*., 1996). Feeding diets containing fermented liquid feed has been shown to increase pig performance and improve the environment in the gastrointestinal tract (Rijnen *et al*., 2001; Van Winsen *et al*., 2001; Demeckova *et al*., 2002; Canibe and Jensen, 2003; Missotten *et al*., 2010). However, information on the effects of feeding fermented potato pulp during lactation on sow and pigletperformance is lacking. Therefore, the present study

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was conducted to investigate the effects of feeding fermented potato pulp to lactating sows on sow and litter performance as well as blood metabolites and hormones.

MATERIALS AND METHODS

The animal welfare committee of China Agricultural University (Beijing, China) approved the animal care protocol used for this experiment.

Acquisition of fermented potato pulp: The whole fermented potato pulp was obtained from the Heilongjiang Songtian Potato Industry Corporation (Suihua, China) and analyzed for crude protein, crude fiber, ether extract, ash, calcium and phosphorus (Table 1).

Animals, dietary treatment and management: Eighty, mixed parity, Landrace x Large White crossbred sows (256.0±4.3 kg BW and 3.2±0.2 parity) were moved into a farrowing room on day 110 of gestation. The sows were randomly allotted to one of two corn-soybean meal based lactation diets (Table 2) supplemented with either 0 or 5% fermented potato pulp in a completely random design experiment. The control diet was based on corn, soybean meal and 5% wheat bran and fermented potato pulp was used to replace the 5% wheat bran in the experimental diet. Each treatment had 40 replicates and the sows were fed the experimental diets throughout a 28 days lactation.

During lactation, the sows were housed in individual farrowing crates equipped with a piglet creep area fitted with a heat pad and an infrared heat lamp. The experimental diets were provided 3 times daily at 0630, 1200 and 1700 h. Starting the day after farrowing, the amount of feed provided was gradually increased until maximum intake was reached at 7 days postpartum. Any feed remaining in the feed trough was weighed daily to determine actual feed intake. The diets were formulated to provide 3.24 Mcal kg^{-1} of ME, 17.80% crude protein and 0.90% total lysine. Levels of all other nutrients met or exceeded those recommended by Ministry of Agriculture of the People's Republic of China (2004). Sows and piglets had free access to water provided by nipple drinkers throughout the experimental period.

Sows were weighed within 48 h of farrowing and at weaning to assess body condition and weight changes during lactation. Parity, farrowing date, litter size (number after cross-fostering and at weaning) and pre-weaning deaths were recorded. Piglets were weighed and litter weight was recorded on day 2 post partum and at weaning. Piglets were subjected to routine management procedures including iron injection, clipping of teeth and tails as well as ear notching. Creep feeding was initiated at day 7 from birth.

After weaning at 28 days, sows were moved back to the breeding barn and housed in gestation stalls. Detection of estrus was conducted once a day by using boar stimuli for 15 min. The weaning to estrus interval was recorded when sows were first observed to show a positive response to the back-pressure test (immobilization reflex).

Table 1: Analyzed nutrient composition of fermented potato pulp (as fed basis)

Nutrient compositions	Concentration (%)
Moisture	35.20
Crude protein	9.20
Crude fiber	8.60
Ether extract	1.90
Ash	2.40
Calcium	0.05
Phosphorus	0.37

Chemical analysis: Analysis for the proximate principles and calcium and phosphorus were carried out according to the Association of Official Analytical Chemists (AOAC, 2000). Amino acids were quantified using an automatic amino acid analyzer (L-8800, Hitachi Incorporated, Tokyo, Japan). Lysine and threonine were analyzed following acid hydrolysis with 6 N HCl for 24 h at 110°C while methionine and cystine were analyzed after cold formic acid oxidation overnight with subsequent hydrolysis.

Table 2: Ingredient composition and chemical analysis of diets containing fermented potato pulp fed to sows (as fed basis)

	Fermented potato pulp (%)	
Composition and chemical analysis	0	5
Ingredients (%)		
Corn	63.50	63.50
Soybean meal (43% CP)	26.00	26.00
Wheat bran	5.00	-
Fermented potato pulp	-	5.00
Soybean oil	1.50	1.50
Limestone	1.64	1.64
Salt	0.60	0.60
Dicalcium phosphate	0.84	0.84
L-Lysine HCl (98%)	0.08	0.08
Vitamin trace mineral premix[1]	0.84	0.84
Nutrient level[2]		
ME[3] (Mcal kg^{-1})	3.24	3.24
Lysine: ME ratio (g $Mcal^{-1}$)	2.81	2.77
Crude protein (%)	17.99	17.58
Lysine (%)	0.91	0.90
Methionine+Cystine (%)	0.56	0.54
Threonine (%)	0.65	0.63
Calcium (%)	0.96	0.96
Total phosphorus (%)	0.46	0.46

[1]Premix supplied per kg of diet: vitamin A, 12,000 IU; vitamin D_3, 2,000 IU; vitamin E, 24 IU; vitamin K_3, 2.0 mg; vitamin B_1, 2.0 mg; vitamin B_2, 6.0 mg; vitamin B_6, 4.0 mg; vitamin B_{12}, 24 μg; niacin, 30 mg; pantothenic acid, 20 mg; folic acid, 3.6 mg; biotin, 0.40 mg; choline, 0.40 g; ferrum, 96 mg; copper, 8.0 mg; zinc, 120 mg; manganese, 40 mg; iodine, 0.56 mg; selenium, 0.40 mg and phytase, 120 mg; [2]Analyzed composition; [3]Calculated ME values derived from values determined with finishing pigs

Blood sample collection and processing: Blood samples were collected from 15 sows per treatment via jugular vein puncture on day 21 of lactation immediately before the morning feeding. Approximately 10 mL of blood was collected for analysis of blood metabolites and hormones. Blood samples were collected in lithium heparin coated vacuum filled tubes (Greiner Bio-One GmbH, Kremsmunster, Australia), placed in an ice box for transportation to the laboratory and centrifuged at 3000×g for 15 min at 4°C. Plasma samples were stored at -20°C until analysis.

Plasma concentrations of glucose, creatinine, urea nitrogen and non-esterified fatty acids were analyzed using commercial colorimetric kits (BioSino Bio-Technology and Science Incorporated, Bejing, China) and an Automatic Biochemical Analyzer (Hitachi 7160, Hitachi Incorporated, Tokyo, Japan). Plasma insulin, insulin-like growth factor 1, estradiol, luteinizing hormone and follicle-stimulating hormone kits (Beijing Sino-uk Institute of Biological Technology, Beijing, China) were used and their concentrations were measured by radioimmunoassay using an Automatic Radioimmunoassay Counter (R-911, University of Science and Technology of China Industrial Incorporated, Hefei, China).

Statistical analysis: Data were analyzed as a completely random design using the t-test procedure of SAS Institute (1996) V8.2 (SAS Institute Incorporated, Cary, NC). The $p<0.05$ were considered statistically significant and $p<0.10$ were considered indicative of a significant trend.

RESULTS AND DISCUSSION

Sow lactation weight loss tended to decrease ($p = 0.09$) and feed intake tended to increase ($p = 0.06$) when sows were fed fermented potato pulp. The weaning to estrus interval was shorter ($p = 0.05$) for sows fed potato pulp (Table 3).

Table 3: Effect of fermented potato pulp on reproductive performance of mixed parity sows

	Fermented potato pulp (%)			
Mixed parity sows	0	5	SEM[1]	p-value
Number of sows	40.00	40.00	-	-
Average parity	3.10	3.23	0.20	0.75
Lactation length (day)	27.95	27.45	0.18	0.18
Feed intake (kg day^{-1})	5.24^x	5.50^y	0.07	0.06
Body weight at farrowing (kg)	252.71	259.37	4.31	0.44
Body weight at weaning (kg)	236.36	245.55	4.42	0.30
Lactation weight loss (kg)	-16.35^x	-13.82^y	0.75	0.09
Weaning to estrus interval (day)	5.00^a	4.50^b	0.10	0.05

$^{a, b}$Means within a row with different superscript differ ($p<0.05$); $^{x, y}$Means within a row with different superscripts tend to differ ($p<0.10$); [1]SEM = Standard Error of Mean

Potato pulp contains starch, cellulose, hemicelluloses, pectin, proteins, free amino acids and salts which are poorly utilized by lactating sows (Mayer and Hillebrandt, 1997). However, by fermenting potato pulp, these products are transformed by microbes into the fermentation products lactic acid, volatile fatty acids and alcohol (Prescott *et al*., 1996) and fermented diets are well utilized by sows (Demeckova *et al*., 2002).

The fermented potato pulp used in this study contained 9.2% crude protein, 8.6% crude fiber and 1.9% ether extract. Untreated wet potato pulp has been shown to contain 0.5% crude protein (Mayer, 1998) indicating that the nutrient level was increased by the fermenting process. According to the content of crude fiber, fermented potato pulp can be used as a bulk material in diets fed to lactating sows. The high moisture content of the fermented potato pulp dictates that diets containing fermented potato pulp must be mixed fresh every day.

Feeding potato pulp tended to increase feed intake with the feed intake of sows fed fermented potato pulp being approximately 5% higher than those fed the unsupplemented diet. Scholten *et al*. (1999) summarized a limited number of experiments in a review and also reported that fermented by-products and fermented compound diets may improve feed intake. Fermentation products such as lactic acid may convey upon the feed a lactic acid flavor (Scholten *et al*., 1999) and this flavor may be preferred by sows thus explaining the increased feed intake of sows observed in the present study.

The increase in lactation feed intake appeared to result in lower lactation weight loss for sows fed fermented potato pulp. Previous research has shown that higher feed intakes in lactation reduced body weight and condition loss by sows during lactation (Armstrong *et al*., 1986; Revell *et al*., 1998; Eissen *et al*., 2003; Sulabo *et al*., 2010). Therefore, feeding fermented potato pulp may be an effective way to help maintain body condition of sows.

The reduction in lactation weight loss for sows fed fermented potato pulp was reflected in shorter weaning to estrus intervals for these sows. Vesseur *et al*. (1994) observed that sows losing >7.5% of their body weight during lactation exhibited a prolonged weaning to estrus interval. Similar findings were reported by Koketsu *et al*. (1996). Thaker and Bilkei (2005) evaluated data from 1677 sows and found that the subsequent reproduction performance of sows decreases as weight loss increases during lactation. The litter weight gain was

Table 4: Effect of fermented potato pulp on growth performance of litters

Growth performance	Fermented potato pulp (%) 0	5	SEM[1]	p-value
Number of piglets suckling	10.82	10.98	0.12	0.54
Number of piglets weaned	9.28	9.63	0.12	0.16
Preweaning mortality (%)	14.23	12.30	1.13	0.37
Litter birth weight (kg)	15.89	15.72	0.25	0.75
Litter weaning weight (kg)	75.09	78.43	1.01	0.10
Total litter weight gain (kg)	59.29[x]	62.74[y]	0.99	0.08
Daily litter weight gain (kg day $^{-1}$)	2.12[a]	2.28[b]	0.03	0.03

[a, b]Means within a row with different superscript differ ($p<0.05$); [x, y]Means within a row with different superscripts tend to differ ($p<0.10$); [1]SEM = Standard Error of Mean

Table 5: Effect of fermented potato pulp on plasma metabolites in mixed parity sows

Mixed parity sows	Fermented potato pulp (%) 0	5	SEM[1]	p-value
Glucose (mmol L^{-1})	5.3	5.1	0.09	0.17
Urea nitrogen (mmol L^{-1})	4.1[a]	4.7[b]	0.13	0.02
Creatinine (mmol L^{-1})	115.2[x]	106.5[y]	2.33	0.06
Non-esterified fatty acids (µmol L^{-1})	498.3	487.4	6.96	0.44

[a, b]Means within a row with different superscript differ ($p<0.05$); [x, y]Means within a row with different superscripts tend to differ ($p<0.10$); [1]SEM = Standard Error of Mean

higher (p = 0.03) for sows fed potato pulp (Table 4). Good maternal ability in sows is characterized by high piglet growth rate and low mortality (Wulbers-Mindermann *et al*., 2002). In the present study, litter average daily gain was higher for sows fed fermented potato pulp which implies that fermented potato by-product had a positive effect on milk production of the sows.

Dietary treatment did not affect plasma glucose or non-esterified fatty acid levels (Table 5). Feeding potato pulp increased plasma urea nitrogen (p = 0.02) and tended to decrease (p = 0.06) plasma creatinine.

Plasma urea nitrogen can represent a sensitive response criterion for protein utilization (Soltwedel *et al*., 2006) and its concentration is closely associated with the amount of feed offered (Kraetzl *et al*., 1998). The higher concentration of plasma urea nitrogen on day 21 of lactation for sows fed fermented potato pulp could be a result of the higher feed intake of the sows rather than body protein tissue degradation.

Plasma creatinine is an indicator of muscle catabolism (Yang *et al*., 2009). Its concentrations tended to decrease when sows were fed fermented potato pulp. This is likely a reflection of the fact that sows fed fermented potato pulp lost less weight in lactation and therefore were presumably catabolizing less muscle tissue. Feeding potato pulp significantly increased plasma luteinizing

Table 6: Effect of fermented potato pulp on plasma metabolic hormones in mixed parity sows

Hormones	Fermented potato pulp (%) 0	5	SEM[1]	p-value
Insulin (µIU mL^{-1})	17.1	19.2	0.68	0.13
Insulin-like growth factor 1 (ng mL^{-1})	180.7	187.3	3.44	0.34
Estradiol (pg mL^{-1})	27.3[x]	29.4[y]	0.57	0.07
Luteinizing hormone (mIU mL^{-1})	6.3[a]	7.0[b]	0.14	0.01
Follicle-stimulating hormone (mIU mL^{-1})	10.6	11.1	0.24	0.28

[a, b]Means within a row with different superscript differ ($p<0.05$) [x, y]Means within a row with different superscripts tend to differ ($p<0.10$) [1]SEM = Standard Error of Mean

hormone (p = 0.01) and tended (p = 0.07) to increase estradiol levels (Table 6). Levels of insulin, insulin-like growth factor 1 and follicle-stimulating hormone were unaffected by treatment.

Estradiol is secreted primarily from the ovarian follicles (Yang *et al*., 2000b). Sows fed fermented potato pulp had higher plasma estradiol concentrations than those fed the control diet, implying that nutrient intake could modulate follicular development during lactation. Similar results were reported by Yang *et al*. (2000b) where the researchers found that high lysine intake enhanced serum estradiol concentration during late lactation. Moreover, a high lysine intake increased the proportion of large follicles at proestrus (Yang *et al*., 2000a). In the present study, it can be concluded that increasing plasma estradiol during late lactation may provide a positive effect on ovarian function. The shorter weaning to estrus interval may confirm this hypothesis.

Luteinizing hormone plays an important role in the reproductive performance of sows. Tokach *et al*. (1992) and Shaw and Foxcroft (1985) found that the elevated plasma luteinizing hormone concentrations shortened the weaning-to-estrus interval in sows. The improved return to estrus after weaning was presumed to be associated with an increased secretion of luteinizing hormone.

However, inadequate nutrient intake might reduce the release of luteinizing hormone during lactation (Armstrong and Britt, 1987; Kemp *et al*., 1995; Zak *et al*., 1997; Yang *et al*., 2000b; Yang *et al*., 2009). The data showed that fermented potato pulp intake increased luteinizing hormone concentration on day 21 of lactation which might explain the shorter weaning-to-estrus interval.

CONCLUSION

In this study, feeding fermented potato pulp during lactation increased sow feed intake, daily litter weight gainand improved sow body condition. Moreover, plasma urea nitrogen, estradiol and luteinizing hormone increased and creatinine decreased when sows were fed fermented potato pulp. Feeding fermented potato pulp to sows would therefore, appear to be an effective means of utilizing a previously under utilized resource.

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