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Effect of Dietary Broken Rice and Cassava Chips on Growth, Nutrient Digestibility and Nitrogen Retention in Growing Kadon Pigs

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Abstract: The aim of this study was to determine the effects of dietary Broken Rice (BR) and Cassava Chips (CC) on growth, nutrient digestibility and nitrogen retention in growing Kadon pigs in a parallel design. There were 4 measurement periods over the entire experiment lasting 56 days. Slaughter and meat characteristics were determined at the end of the experiment. For the entire experimental period there was no significant diet effect on Average Daily Gain (ADG), but ADG on the CC diet was on average 12% lower. In the pigs fed the BR diet the digestibilities of Dry Matter (DM), Organic Matter (OM), Crude Protein (CP), crude fat (EE, ethereal extract) and carbohydrates (NFE, nitrogen-free extract) were all higher. The higher digestibility of OM in the pigs fed on the BR diet was associated with a higher digestibility of gross energy in the diet. The higher digestibility CP in the pigs fed the BR diet was reflected by a smaller fecal Nitrogen (N) output, but N retention in the 2 groups of pigs was similar. This study shows that the carbohydrates in BR are more easily digested than those in CC. The higher amount of protein and the higher digestible carbohydrate content of BR, in combination with the actual prices and availability of BR and CC, will determine which carbohydrate source will be used in pig production, including on small-holder farms.

Key words: Kadon pigs, broken rice, cassava chip, digestibility, nitrogen retention

INTRODUCTION

Pig production in the small-holder sector of North-Eastern Thailand relies heavily on the use of the indigenous Kadon pig. In this breed of pigs we have compared 4 carbohydrate sources as to digestibility of macronutrients and nitrogen metabolism. In that study, the pigs were fed on diets containing either Ground Corn (GC), Rice Bran (RB), Broken Rice (BR) or Cassava Chips (CC). The feeding of BR and CC was found to induce the highest and second highest digestibilities.

The type of dietary carbohydrate may influence diet palatability and nutrient utilization in pigs (Bach Knudsen and Jorgensen, 2001) and it can alter the gut microflora (Pluske, 2001). An increase in available carbohydrates in the diet through using feedstuffs rich in starch may improve growth rate of pigs. Recent studies provide evidence that an increase in available carbohydrate in the diet improved growth performance in growing-finishing pig (Camp *et al*., 2003). Khajarern and Khajarern (1986) reported that growing-finishing pigs fed a diet containing cassava had poorer average daily gain and feed conversion ratio than did their counterparts fed on diets containing broken rice or sorghum diets, but the differences failed to reach statistical significance. The positive results for broken rice in our earlier study and in the literature prompted us to further compare and contrast BR and CC as feedstuffs for growing Kadon pigs.

The aim of this study was to determine the effects of dietary broken rice and cassava chips on growth, nutrient digestibility and nitrogen retention in growing Kadon pigs. To a certain extent, this study repeats our earlier work, but the measurements were made over a longer period of time in a parallel design. Furthermore, slaughter and meat characteristics were determined at the end of the experiment.

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MATERIALS AND METHODS

Animals: The experiment was performed with 16 male growing Kadon pigs with average body weight of 10.4±1.8 kg. The pigs (8 pigs per diet) were fed one of the 2 experimental diets. The pigs were individually penned in metabolic cages and had free access to water from nipple drinkers. The experiment was conducted in the period of November and December, 2005.

Experimental design: The 16 pigs were arranged in a randomized parallel design and were fed the diets based on either BR or CC. The experimental period lasted 56 days. There were four measurement periods of is 14 days each. Each period consisted of 9 days for feed intake measurements followed by 5 days for sample collection.

Diets and feeding: The carbohydrate source for the experimental diets were Broken Rice (BR) and Cassava Chips (CC) that were available locally. The ingredient composition of the diets is shown in Table 1. The BR diet contained 68% BR and the CC diet contained 58% CC. The experimental diets were formulated to contain the same amount of crude protein by adding extra soybean meal to the CC diet. The amounts of added vitamins and minerals were identical for the 2 diets. Pigs were fed ad libitum twice daily at 07.00 am and 16.30 pm, with the daily allowance being equally divided between the 2 meals.

Measurements: Feed consumption was measured as the difference between the amount of feed offered and refused. Pigs were weighed at the beginning and at the end of each measurement period just before the morning meal. Changes in live weight were used to estimate the Average Daily Gain (ADG). Feed Conversion Ratio (FCR) was calculated as the ratio of the amount of consumed feed to 1 kg gain of body weight. For the determination of total tract digestibility, feces were collected in plastic bags attached to the pigs. The bags were changed at least twice daily and stored frozen (-20°C) pending analysis. Urine was collected in containers via the funnels underneath the cages. Urine was removed twice each day and stored at -20°C until the time of analysis. To prevent nitrogen (N) losses during collection and storage, 10 mL of 25% H_2SO_4 was added to each container every day. Diets and feces were dried at 60°C in a forced-air oven for 96 h and ground to pass through a 1-mm screen. All samples were analyzed for proximal components (AOAC, 1990) in duplicate. Urine was used to determine N excretion.

At the end of the experiment, four pigs per group were slaughtered. Carcass characteristics were evaluated according to the Thai style of carcass cutting (Jaturasitha, 2004). The weights of the head, tail, liver, kidney, spleen, heart, lungs, full digestive tract and hot carcass weight were recorded. The characteristics measured included dressing percentage, thickness of back fat and loin proportion. The loin muscles (*longissimus dorsi*) were collected to determine the proximate composition. The pH value of muscle was determined using the meat pH meter (Model HI99163, Hanna Instruments, Portugal) at 45 min (pH_1) and at 24 h (pH_U) after slaughter. The right loin muscle was collected and stored at -20°C until analysing the remaining meat quality parameters. The meat samples were dried at 60°C for 72 h in a forced-hot-air oven to quantify the percentage of moisture and were then analyzed for crude protein, crude fat and ash (AOAC, 1990).

Statistical analysis: The effects of dietary carbohydrate were evaluated for statistical significance by the Student's t-test (SPSS, 1998). All results are expressed as means±SD. The level of statistical significance of diet effects was preset at $p<0.05$.

RESULTS AND DISCUSSION

The experimental diets containing either BR or CC as carbohydrate source were isinotrogenous, but analysis showed that the CC diet contained more crude fiber, both

Table 1: Ingredient and calculated composition of the experimental diets for the growing Kadon pigs

Ingredient	BR	CC
Broken rice	68.0	0.0
Cassava chip	0.0	58.0
Soybean meal	30.0	40.0
Salt	0.1	0.1
Di-calcium phosphate	0.5	0.5
L-lysine	0.3	0.2
DL-methionine	0.1	0.2
Premix*	1.0	1.0
Total	100.0	100.0
DM (% as fed basis)	89.34	90.53
OM	96.60	94.01
CP	16.19	16.50
EE	2.52	1.94
CF	3.80	7.22
NFE	74.09	68.35
Calculated ME, kcal	3.232	3.203

*1 kg of vitamin and mineral premix contained: vitamin A 650 mg (325,000 IU); vitamin D_3 750 mg (75,000 IU); vitamin E 150 mg (75 IU); vitamin B_{12} 1 mg; vitamin K_3 80 mg; riboflavin 300 mg; niacinamide 1,200 mg; pantothenic acid 540 mg; choline chloride 6,000 mg; Fe 4,700 mg; Zn 6,500 mg; Mn 4,500 mg; Co 20 mg; Cu 1,400 mg ; I 45 mg and carrier material 973.164 g

Table 2: Analyzed composition of the experimental diets

Item	BR	CC
Dry matter,%	87.7	87.9
Organic matter,% of DM	95.3	93.3
Crude protein,% of DM	17.4	17.8
Crude fat,% of DM	2.6	1.4
Crude fibre,% of DM	2.4	4.4
Ash,% of DM	4.7	6.7
Nitrogen-free extract,% of DM	71.5	69.1
Gross energy, kcal $kgDM^{-1}$	4.203	4.124

Table 3: Effects of carbohydrate source on growth performance in growing pigs

Period	Performance	BR	CC	p value
Period I	Initial BW, kg	14.51±1.09	14.55±2.26	0.97
	Final BW, kg	20.06±1.66	19.66±2.72	0.73
	ADG, g d^{-1}	346.88±126.07	319.53±75.55	0.61
	DMI, g d^{-1}	666.50±141.22	736.07±138.72	0.37
	FCR	2.13±0.69	2.37±0.55	0.44
Period II	Initial BW, kg	20.06±1.66	19.66±2.72	0.89
	Final BW, kg	25.35±2.21	23.70±2.01	0.14
	ADG, g d^{-1}	395.54±88.47^{b}	288.39±86.56^{a}	0.03
	DMI, g d^{-1}	820.72±154.64	747.71±166.05	0.38
	FCR	2.13±0.41	2.76±0.78	0.07
Period III	Initial BW, kg	25.35±2.21	23.70±2.01	0.14
	Final BW, kg	30.03±3.14	27.7±2.33	0.11
	ADG, g d^{-1}	333.93±109.31	285.71±50.65	0.28
	DMI, g d^{-1}	920.48±202.92	1010.57±141.58	0.32
	FCR	3.02±1.02	3.60±0.58	0.19
Period IV	Initial BW, kg	30.03±3.14	27.70±2.33	0.11
	Final BW, kg	32.56±3.46	30.39±3.05	0.18
	ADG, g d^{-1}	215.31±88.49	244.05±83.59	0.56
	DMI, g d^{-1}	823.76±176.92	903.54±226.71	0.50
	FCR	4.15±1.23	3.98±1.47	0.19
Over all	Initial BW, kg	14.51±1.90	14.55±2.26	0.97
	Final BW, kg	32.56±3.46	30.39±3.05	0.18
	ADG, g d^{-1}	326.38±119.04	287.11±75.40	0.13
	DMI, g d^{-1}	807.36±186.86	845.67±197.88	0.44
	FCR	2.81±1.17	3.13±1.04	0.28

^{a,b}Means in the same row with different superscripts differ significantly ($p<0.05$)

Table 4: Effects of carbohydrate source on nutrient digestibility in growing Kadon pigs

Period	Digestibility,%	BR	CC	p value
Period I	DM	90.43±2.47^{b}	83.68±3.68^{a}	0.0010
	OM	92.00±2.02^{b}	85.83±3.01^{a}	0.0004
	CP	87.34±3.73^{b}	80.21±5.10^{a}	0.0071
	EE	63.55±7.20^{b}	43.80±14.61^{a}	0.0062
	CF	42.38±10.94	43.36±14.45	0.8815
	NFE	96.06±1.35^{b}	93.57±1.32^{a}	0.0022
	Ash	58.79±12.44	51.51±13.84	0.2874
	Energy	90.12±2.25^{b}	82.54±3.87^{a}	0.0005
Period II	DM	91.64±1.72^{b}	83.08±3.14^{a}	0.00003
	OM	93.01±1.59^{b}	85.45±2.73^{a}	0.0000
	CP	89.18±2.49^{b}	78.68±5.03^{a}	0.0003
	EE	74.81±5.82^{b}	40.72±13.76^{a}	0.0001
	CF	42.32±12.08	35.76±16.80	0.3871
	NFE	95.98±0.91^{b}	93.02±1.84^{a}	0.0021
	Ash	59.38±7.22^{b}	45.59±11.92^{a}	0.0166
	Energy	91.58±1.62^{b}	82.19±3.61^{a}	0.0001
Period III	DM	91.19±1.59^{b}	85.33±1.83^{a}	0.00001
	OM	92.39±152^{b}	93.62±1.05^{a}	0.0000
	CP	87.52±1.89^{b}	81.96±2.70^{a}	0.0004
	EE	68.88±6.52^{b}	35.65±6.59^{a}	0.0000
	CF	44.80±5.27	46.64±7.01	0.5643
	NFE	95.53±134	95.35±0.79	0.6354
	Ash	66.42±4.19^{b}	47.04±6.94^{a}	0.0000
	Energy	90.57±1.62^{b}	85.11±2.12^{a}	0.0001
Period IV	DM	92.46±1.23^{b}	85.69±3.11^{a}	0.0030
	OM	93.62±1.05^{b}	88.62±2.81^{a}	0.0030
	CP	87.87±2.25	83.23±5.01	0.0762
	EE	76.51±4.42^{b}	53.13±10.20^{a}	0.0015
	CF	55.22±8.01	51.14±16.87	0.6046
	NFE	96.28±0.53^{b}	93.58±1.23^{a}	0.0019
	Ash	67.94±7.20^{b}	52.78±11.77^{a}	0.0251
	Energy	91.86±0.98^{b}	85.74±3.08^{a}	0.0037
Over all	DM	91.33±1.81^{b}	84.37±3.05^{a}	0.0000
	OM	92.67±1.57^{b}	86.75±2.67^{a}	0.0000
	CP	87.98±2.66^{b}	80.87±4.63^{a}	0.0000
	EE	70.70±7.81^{b}	42.67±12.78^{a}	0.0000
	CF	45.89±10.42	43.76±14.51	0.5150
	NFE	95.95±1.08^{b}	93.90±1.58^{a}	0.0000
	Ash	62.98±8.93^{b}	49.00±11.18^{a}	0.0000
	Energy	91.00±1.77^{b}	83.77±3.45^{a}	0.0000

^{a,b}Means in the same row with different superscripts differ significantly ($p<0.05$), DM = Dry Matter, OM = Organic Matter, CP = Crude Protein, EE = Ether Extract, CF = Crude Fiber, NFE = Nitrogen-free Extract, Ash = Inorganic matter

Table 5: Effects of carbohydrate source on calculated nutrient intake in growing Kadon pigs

Period	Nutrient	BR	CC	p value
Period I	DMI, g	666.50±141.22	736.07±138.72	0.3371
	OMI, g	635.10±134.57	681.32±134.97	0.5039
	CPI, g	116.70±24.41	131.43±25.68	0.2592
	EEI, g	18.33±3.26[b]	10.29±1.94[a]	0.0001
	CFI, g	16.10±3.07[a]	32.96±6.12[b]	0.0000
	NFEI, g	449.07±99.27	484.93±97.29	0.4776
	AshI, g	31.41±6.65[a]	49.05±9.84[b]	0.0012
	Energy I, kcal	2779.97±605.22	3002.29±596.73	0.4716
Period II	DMI, g	820.72±154.64	747.71±166.05	0.3782
	OMI, g	786.38±145.96	693.48±156.45	0.2398
	CPI, g	143.77±26.67	135.10±29.03	0.5438
	EEI, g	23.33±3.26[b]	10.48±2.20[a]	0.0000
	CFI, g	18.13±4.28[a]	32.79±7.45[b]	0.0005
	NFEI, g	558.04±109.35	502.01±110.29	0.3249
	AshI, g	34.04±8.81[a]	47.28±11.75[b]	0.0242
	Energy I, kcal	3480.19±640.07	3059.54±692.51	0.2278
Period III	DMI, g	920.48±202.92	1010.57±141.58	0.3226
	OMI, g	877.75±193.00	925.96±147.44	0.5840
	CPI, g	161.02±34.97	180.91±24.78	0.2127
	EEI, g	24.72±4.62[b]	13.94±1.99[a]	0.0001
	CFI, g	22.14±4.88[a]	44.15±6.88[b]	0.0000
	NFEI, g	624.04±137.35	677.99±89.69	0.3705
	AshI, g	42.73±9.92[a]	66.04±10.55[b]	0.0005
	Energy I, kcal	3893.31±839.18	4086.44±654.02	0.6161
Period IV	DMI, g	809.15±168.94	903.54±226.71	0.5017
	OMI, g	771.02±160.98	770.70±238.95	0.5987
	CPI, g	142.30±28.39	162.94±39.65	0.3158
	EEI, g	22.85±4.41[b]	13.06±2.88[a]	0.0007
	CFI, g	19.81±4.25[a]	40.00±10.04[b]	0.0030
	NFEI, g	559.15±121.74	602.74±153.48	0.5879
	AshI, g	38.82±8.34[a]	60.16±15.11[b]	0.0163
	Energy I, kcal	3506.88±739.40	3745.01±928.79	0.6246
Over all	DMI, g	807.36±186.86	845.87±197.88	0.4380
	OMI, g	770.60±177.89	782.21±186.35	0.8043
	CPI, g	140.90±31.91	151.91±35.11	0.2058
	EEI, g	22.29±4.47[b]	11.87±2.68[a]	0.0000
	CFI, g	19.02±4.57[a]	37.31±8.74[b]	0.0000
	NFEI, g	547.20±129.08	564.53±133.80	0.6088
	AshI, g	36.68±9.24[a]	55.33±13.72[b]	0.0000
	Energy I, kcal	3412.13±791.43	3455.21±825.08	0.8359

[a,b]Means in the same row with different superscripts differ significantly ($p<0.05$)

calculated (Table 1) and analyzed (Table 2) than did the CC diet. The CC diet also contained more ash even though the calcium and phosphorus concentrations in the two experimental diets were similar (Table 2). The higher fiber content of the CC diet will tend to lower the digestibilities of carbohydrates and protein, which should be taken into account when interpreting the results.

In period 2, the ADG of the pigs was significantly lower when CC instead of BR was present in the diet (Table 3). However, for the entire experimental period there was no significant diet effect on ADG, albeit that ADG on the CC diet was on average 12% lower. This outcome corroborates the results of Khajarern and Khajarern (1986), using growing-finishing pigs (17-100 kg) and also showing that those fed the diet containing cassava tended to have poorer ADG and FCR than their counterparts fed on diets containing either broken rice or sorghum diets. The pigs fed on the CC diet tended to higher feed intake. The lower group mean ADG and higher Dry Matter Intake (DMI) in the pigs fed on the CC diet led to a higher group mean FCR.

In the pigs fed the BR diet the digestibilities of Dry Matter (DM), Organic Matter (OM), Crude Protein (CP), Crude Fat (EE, Ethereal Extract) and carbohydrates (NFE, Nitrogen-Free Extract) were all higher, when compared with the pigs fed the CC diet (Table 4). An exception was the digestibility of Crude Fiber (CF), this parameter being similar for the 2 dietary groups. The higher digestibility of OM in the pigs fed on the BR diet was associated with a higher digestibility of gross energy in the diet. Clearly, this study shows that the carbohydrates in BR are more easily to digested than those in CC also shows in Table 5. In addition, the type of carbohydrate may have affect the digestibility of other components of the diet as well. The present results in the native, Thai Kadon pig are similar to those published for commercial pigs (Khajarern and Khajarern, 1986). The lower digestibility of the CC diet was associated with a tendency towards a higher feed intake, the increase in DMI being on average 4.7% for the entire experimental period. The increase in feed intake was associated with a 6.7%-lower final Body Weight (BW), but the lowering was not statistically significant.

Table 6: Effects of carbohydrate source on nitrogen balance in Kadon growing pigs

	BR	CC	p value
Period I			
N intake (g d^{-1})	18.67±3.91	21.03±4.11	0.259
N fecal out put (g d^{-1})	2.33±0.86[a]	4.23±1.59[b]	0.013
N absorbed (g d^{-1})	16.34±3.40	16.80±3.14	0.785
N urine output (g d^{-1})	3.33±0.95	3.56±1.58	0.721
N retention (g d^{-1})	13.02±3.28	13.24±2.12	0.878
N absorbed /N intake (%)	69.23±5.75	63.51±5.94	0.070
Period II			
N intake (g d^{-1})	23.00±4.27	21.62±4.65	0.544
N fecal out put (g d^{-1})	2.55±0.91[a]	4.45±0.89[b]	0.001
N absorbed (g d^{-1})	20.45±3.52	17.16±4.53	0.129
N urine output (g d^{-1})	4.60±1.65	5.80±1.70	0.173
N retention (g d^{-1})	15.86±2.60[b]	11.37±3.80[a]	0.017
N absorbed /N intake (%)	69.48±6.44[b]	52.58±8.74[a]	0.001
Period III			
N intake (g d^{-1})	25.76±5.60	28.95±3.96	0.213
N fecal out put (g d^{-1})	3.24±0.92[a]	5.22±1.07[b]	0.001
N absorbed (g d^{-1})	22.53±4.86	23.73±3.37	0.576
N urine output (g d^{-1})	3.06±0.92	3.54±2.11	0.615
N retention (g d^{-1})	19.47±4.99	20.19±2.81	0.728
N absorbed /N intake (%)	75.36±7.76	69.75±7.10	0.178
Period IV			
N intake (g d^{-1})	22.77±4.54	26.07±6.34	0.316
N fecal out put (g d^{-1})	2.79±0.80	4.50±1.80	0.070
N absorbed (g d^{-1})	19.98±3.88	21.57±4.94	0.212
N urine output (g d^{-1})	3.46±2.92	3.36±1.18	0.935
N retention (g d^{-1})	16.52±2.34	18.21±4.10	0.400
N absorbed /N intake (%)	73.86±10.38	70.50±7.13	1.212
Over all			
N intake (g d^{-1})	22.54±5.11	24.30±5.62	0.206
N fecal out put (g d^{-1})	2.72±0.90[a]	4.61±1.34[b]	0.000
N absorbed (g d^{-1})	19.82±4.40	19.70±4.85	0.918
N urine output (g d^{-1})	3.62±1.87	4.11±1.92	0.3101
N retention (g d^{-1})	16.21±4.07	15.59±4.81	0.5896
N absorbed /N intake (%)	71.92±7.78[b]	63.55±10.37[a]	0.001

[a,b] Means in the same rows with different superscripts differ significantly ($p<0.05$)

Table 7: Effects of carbohydrate source on carcass in growing Kadon pigs

Item	BR	CC	p value
Number of pigs	8	8	-
Initial BW (kg)	14.51±1.09	14.55±2.26	0.972
Slaughter BW (kg)	32.56±3.50	30.39±3.05	0.206
Percentage of carcass (%)	68.74±5.75	65.45±4.17	0.213
Loin weight (kg)	2.47±0.51	2.18±0.37	0.223
Percentage of loin/carcass weight	10.98±1.40	11.08±1.16	0.878
Back Fat (cm)	1.83±0.42[a]	1.04±0.42[b]	0.002
Head (kg)	2.89±0.33	2.53±0.36	0.056
Heart (g)	164.38±30.52[a]	120.63±15.22[b]	0.004
Liver (g)	675.00±115.05	691.88±148.80	0.804
Lungs (g)	658.13±187.08	558.13±158.92	0.269
Spleen (g)	78.13±23.29	71.25±13.82	0.487
Kidneys (g)	178.13±18.31	165.63±25.13	0.276
Stomach (g)	587.50±313.68	666.88±434.34	0.682
Small intestine	726.25±195.59	765.00±160.00	0.671
Large intestine	990.00±231.52	874.00±274.75	0.377

[a,b] Means in the same rows with different superscripts differ significantly ($p<0.05$)

Table 8: Chemical composition of loin from Kadon pigs fed either the BR or CC diet

Item	BR	CC	P value
Dry matter,%	30.2±2.9	28.0±4.6	0.260
Crude protein, (% of DM)	67.6±3.9	69.7±4.91	0.351
Ash, (% of DM)	5.5±0.5	5.4±0.5	0.755
Total fat, (% of DM)	24.7±7.1	23.2±7.8	0.692
pH_1	6.18±0.10	6.25±0.32	0.578
pH_U	5.98±0.28	6.14±0.29	0.256

[a, b] Means in the same rows with different superscripts differ significantly ($p<0.05$). There were 8 pigs per dietary treatment

The higher digestibility of CP in the pigs fed the BR diet is reflected in the data for the nitrogen balance (Table 6). As would be expected the faecal N output was significantly smaller for the pigs fed the BR diet. N retention in the 2 groups of pigs was similar. This can be explained by the intake of N not limiting growth and N retention. The higher group mean ADG in the pigs fed the BR diet was not associated with a tendency towards more N retention. This might point at a difference in body composition or gut fill between the 2 groups of pigs.

Table 7 shows the results of carcass analysis. There were significant differences between the 2 dietary groups. The CC diet had induced less back fat and a lower weight of heart. The lower back fat content in pigs fed the CC diet implies a change in body composition, which is difficult to explain in the light of unchanged nitrogen retention and tendency towards a decrease in final body weight. The lower heart weight in the pigs on the CC diet cannot be easily explained. The loin weight of the pigs fed either the BR or CC diet was not different (Table 7) and the proximate composition was not different either (Table 8).

This study with growing Kadon pigs clearly shows that the nutritional quality of BR is better than that of CC when looking at the digestibilities of macronutrients. However, as noted earlier, BR is more expensive than CC, but is also contains more protein. Thus, the higher amount of protein and the higher digestible carbohydrate content of BR, in combination with the actual prices and availability of BR and CC, will determine which carbohydrate source will be used in pig production, including on small-holder farms.

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