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Comparative Digestibility of Nutrients, Energy and Dietary Fiber in Feed Ingredients Fed to Philippine Black Tiaong Native (*Sus scrofa domesticus*) and Hybrid Pigs

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Abstract

The study was carried out to compare the digestibility of nutrients, energy and dietary fiber in conventional feed ingredients fed to Philippine black Tiaong native pigs and hybrid pigs. A total of 18 Philippine black Tiaong native and 18 hybrid pigs (PIC L337 × C24) were randomly allotted to 1 of 3 experimental treatments arranged in a 3 × 6 (black Tiaong native pigs) and 2 × 9 (hybrid pigs) Latin square design. A corn basal diet consisting of 95% corn (as-fed basis) and vitamins and minerals was formulated. The next two diets were formulated by mixing 70% of the basal diet with 30% (as-fed basis) soybean meal and rice bran. The apparent total tract digestibility (ATTD) of nutrients, NDF, ADF and ash and the DE and ME concentration of each ingredient was calculated using the difference procedure. Results showed that ATTD of GE and ME of the diet were greater ($P<0.001$) for native pigs compared with hybrid pigs. Likewise, the DE and ME of corn, soybean meal and rice bran measured in Philippine black Tiaong native pigs were greater ($P<0.001$) compared with those measured in hybrid pigs. Philippine black Tiaong native pigs also had greater ($P<0.03$) ATTD of CP, crude fiber, NDF, ADF, and ash and tended ($P=0.08$) to have greater ATTD of fat compared with hybrid pigs. The results of this study suggest that Philippine black Tiaong native pigs are more efficient in digesting nutrients as well as their ability to ferment dietary fiber.

Key Words: Digestibility, Energy, Fiber, Nutrient, Native pig

Introduction

Nutrient and energy digestibility of feedstuffs in modern pigs are well established and form the basis of nutrient requirements expressed in digestible basis. There are some evidences that indigenous breeds such as Meishan (Kemp et al., 1991), Alentejano (Freire et al., 1998), Mong-Cai (Len et al., 2007) and Mukota (Ndindana et al., 2002) can digest and utilize feeds particularly high fiber ingredients more efficiently than modern crossbred pigs. This greater ability to digest high fiber diets may be due to a larger hindgut and probably to a more active microflora (Fevrier et al. 1988; Freire et al., 1998; Len et al., 2007). It is, therefore, possible that the type of dietary fiber as well as breed of the pig influence the degree of fermentability of dietary fiber, and consequently energy value of different feedstuffs (von Heimendahl et al., 2010). However, there is limited data in indigenous breeds in particular the Philippine black Tiaong native pigs. The ability of Philippine black Tiaong native pigs to digest different nutrients, energy and dietary fiber compared with hybrid pigs have never been fully investigated, hence, this study was carried out.

Materials and Methods

Animals and Experimental Design

A total of 18 Philippine black Tiaong native and 18 hybrid (PIC L337 × C24) pigs of similar weights were used. For each breed, each pig was randomly allotted to one (1) of four (4) dietary treatments arranged in a 3 × 6 (native pigs) and 2 × 9 (hybrid pigs) Latin square design. Pigs were individually penned in metabolism cages (0.6 × 2.2 × 1.2 m) equipped with a feeder and a drinker, fully slatted floors, a screen floor, and urine trays, which allowed for the total, but separate, collection of urine and fecal materials from each pig.

Experimental Diets

A corn-diet consisting of 95% corn (as-fed basis), vitamins and minerals was formulated (Tables 1 and 2). The next two diets were formulated by mixing 70% of the basal diet with 30% (as-fed basis) soybean meal and rice bran. All the experimental diets were in mash form.

Table 1. Analyzed chemical composition (as-fed basis) of corn, soybean meal and rice bran used in the experiment.

ITEM	INGREDIENT		
	Yellow Corn	SBM[1]	Rice Bran
Dry Matter	86.78	87.36	87.53
Gross Energy, kcal/kg	3,929.00	4,066.00	4,381.00
Crude Protein (N × 6.25)	7.97	43.68	12.01
Crude fat	4.29	1.02	13.25
Crude fiber	1.74	2.87	3.67
Ash	1.33	6.49	6.55
Neutral Detergent Fiber	8.96	8.37	11.35
Acid Detergent Fiber	2.56	6.93	4.55
Acid Detergent Lignin	6.40	1.44	6.80

[1]SBM = soybean meal

Table 2. Ingredient composition (as-fed basis) of experimental diets.

ITEM	DIET		
	Corn Basal Diet	SBM	Rice Bran
Ingredient, %			
Basal diet	--	70.00	70.00
Corn, yellow	94.89	--	--
Soybean meal	--	30.00	--
Rice bran	--	--	30.00
Copra expeller	--	--	--
Monocalcium phosphate	2.29	--	--
Limestone	1.69	--	--
Vitamin premix[1]	0.43	--	--
Mineral premix[2]	0.14	--	--
Salt	0.57	--	--
Total	**100.00**	**100.00**	**100.00**

[1]Provided the following quantities of vitamins per kg of complete diet: Vitamin A, 11,128 IU; vitamin D3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.42 mg; thiamin, 0.24 mg; riboflavin, 6.58 mg; pyridoxine, 0.24 mg; vitamin B12, 0.03 mg; D-pantothenic acid, 23.5 mg; niacin, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg.
[2]Provided the following quantities of micro minerals per kg of complete diet: Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

Sample Collection

Pigs were weighed at the beginning of the experiment. The quantity of feed provided per pig daily was calculated as three times their estimated requirement for maintenance energy (i.e., 106 kcal/kg $BW^{0.75}$; NRC, 2012) and divided into three equal meals that were provided at 0700, 1000, and 1600 h. Water was made available at all times. The experiment lasted for 30 days for native pigs and 20 days for modern crossbred pigs. The pigs were allowed a five-day adaptation period to their diet and a five-day collection period using the marker-to-marker approach (Adeola, 2001). Urine was collected over a preservative of 50 ml of 6N HCl. Fecal samples and 20% of the collected urine were stored at -20°C immediately after collection.

Chemical Analyses

At the conclusion of the experiment, fecal and urine samples were thawed then mixed within animal and diet. A sub-sample was collected and used for chemical analysis. Fecal samples were dried to a constant weight in a hot air oven (65-70°C) and ground through a 40-mesh sieve. Samples of corn, soybean meal, rice bran and copra expeller and all diets were analyzed for DM by oven drying triplicate samples at 135°C for 2 hours (AOAC, 2007), CP (AOAC, 2007), ether extract (AOAC, 2007), crude fiber (AOAC, 2007), and ash (AOAC, 2007). Feed ingredients and diet samples were analyzed in triplicate for ADF (AOAC, 2007) and NDF (Holst, 1973). Fecal, urine, feed ingredients, and diet samples were analyzed in triplicate for GE using bomb calorimeter.

Energy Calculations

The amount of energy lost in the feces and in the urine, respectively, was calculated, and the quantities of DE and ME in each of the diets were calculated (Adeola, 2001).

$$\mathbf{DE_{diet}} = \frac{\mathbf{GE_{intake} - Fecal\ energy_{output}}}{\mathbf{ADFI}}$$

$$\mathbf{ME_{diet}} = \frac{\mathbf{GE_{intake} - \left(Fecal\ energy_{output} + Urine\ energy_{output}\right)}}{\mathbf{ADFI}}$$

The DE and ME in the corn-diet were multiplied by 70% to calculate the contribution from the corn-diet to the DE and ME in diets containing soybean meal and rice bran. The DE and ME in soybean meal and rice bran were calculated by difference using the following equation (Widmer et al., 2007):

$$DE_A = \frac{DE_D - (S_B \, x \, DE_B)}{S_A}$$

Where DE_A is the digestible energy of test ingredient (kcal/kg), DE_D is digestible energy of component in the diet based on test ingredient (kcal/kg), DE_B is digestible energy of component in the diet based on reference ingredient (kcal/kg), S_B is contribution level of component from reference ingredient to the diet based on the test ingredient (%), and S_A is contribution level of component from test ingredient to the diet based on the test ingredient (%).

Digestibility Calculations

The apparent total tract digestibility (ATTD, %) of DM, GE, CP, crude fat, crude fiber, ash, NDF and ADF were calculated using the following equation:

$$\mathbf{ATTD}\ (\%) = \frac{[\mathbf{Nutrient_i} - \mathbf{Nutrient_f}]}{\mathbf{Nutrient_i}}\ \mathbf{x\ 100}$$

where ATTD is the apparent total tract digestibility, $Nutrient_i$ is the total nutrient intake (g) from d 6 to d 10; and $Nutrient_f$ is the total fecal output (g) of the nutrient originating from the diet fed from d 6 to d 10 (Almeida and Stein, 2010).

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS with pig as the experimental unit. The model included breed, diet, and breed × diet as fixed effects and pig as the random effect. If significant ($P \leq 0.05$) differences exist, the PDIFF option of SAS was used to separate means and adjusted using the Tukey-Kramer test. The α-level used to determine significance and tendencies between means were ≤0.05 and ≤0.10, respectively.

Results

Daily Energy Balance

There were no significant breed × diet interaction for DM intake, GE intake, ATTD of GE, fecal output, fecal GE output, urinary GE output, DE and ME of the diet (Table 3). This implies that the effect of breed on daily energy balance is independent of the diet. There was no main effect of diet on daily energy balance (Table 4). However, Philippine black Tiaong native pigs had greater (P<0.03) DM and GE intake and tended (P<0.10) to have greater fecal output than hybrid pigs. Fecal GE output, however, was similar between the breeds. As a result, ATTD of GE and DE of the diet were greater (P<0.001) for Philippine black Tiaong native pigs compared with hybrid pigs. Urinary output and urinary GE output was also greater (P<0.001) in Philippine black Tiaong native pigs compared with those of hybrid pigs; however, ME of the diet was also greater (P<0.001) for Philippine black Tiaong native pigs.

Energy Concentration

There were no significant breed × diet interaction for energy concentration (Table 5); therefore, only main effects of diet and breed were discussed. There was no diet effect observed for both DE and ME of corn, soybean meal, and rice bran (Table 6). However, the DE and ME of corn, soybean meal and rice bran in Philippine black Tiaong native pigs were greater (P<0.001) compared with the DE and ME of the same ingredients measured in hybrid pigs.

Apparent Total Tract Digestibility of Nutrients

There were no significant breed × diet interactions for ATTD of nutrients, except for CP (Table 7). In modern crossbred pigs, ATTD of CP of SBM was greater than both rice bran and yellow corn, and rice bran was greater than in yellow corn. In Philippine black Tiaong native pigs, ATTD of CP of SBM was also greater while rice bran and yellow corn have similar ATTD of CP.

For the main effect of diet, SBM had greater (P = 0.02) ATTD of fat than both rice bran and yellow corn, and rice bran had similar ATTD of fat with yellow corn (Table 8). There were no significant differences in ATTD of crude fiber and NDF among the ingredients, but SBM had greater (P = 0.02) ATTD of ADF than yellow corn, with rice bran being intermediate. The ATTD of ash in SBM was similar to those of rice bran but both were greater (P=0.002) than yellow corn.

For the main effect of breed, Philippine black Tiaong native pigs had greater (P<0.03) ATTD of CP, crude fiber, NDF, ADF, and ash and tended (P=0.08) to have greater ATTD of fat compared with hybrid pigs. This indicates that Philippine black Tiaong native pigs are more efficient in digesting nutrients than hybrid pigs, including their ability to ferment dietary fiber.

Table 3. Daily energy balance (DM basis) in imported hybrid and Philippine black Tiaong native pigs fed diets containing yellow corn, soybean meal, and rice bran (Interactive effects).[1,2]

ITEM	HYBRID			NATIVE			SEM	*P*-value		
	Corn	SBM	RB	Corn	SBM	RB		Breed	Diet	Breed × Diet
DM intake, g	305	398	344	739	727	764	275	0.03	0.36	0.34
GE intake, kcal	1,040	1,410	1,191	2,519	2,577	2,646	114	<0.001	0.18	0.33
Fecal output, g	77	106	96	112	117	128	18	0.09	0.55	0.77
Fecal GE output, kcal	312	441	391	460	473	496	73	0.12	0.59	0.73
ATTD[3] of GE, %	87	86	86	92	92	92	2	<0.001	0.97	0.96
Urinary output, g	117	204	135	732	597	533	54	<0.001	0.23	0.08
Urinary GE output, kcal	7	14	10	19	18	14	4	0.04	0.58	0.46
DE of diet, kcal/kg	3,422	3,506	3,408	3,608	3,731	3,641	63	<0.001	0.21	0.92
ME of diet, kcal/kg	3,411	3,488	3,393	3,596	3,719	3,632	64	<0.001	0.24	0.90

[1]Data are least square means of 6 replicates per treatment.
[2]HYBRID = progeny of PIC L337 male × C24 female (Pig Improvement Co., Hendersonville, TN, USA). NATIVE = Black Tiaong pigs sourced from National Swine and Poultry Research and Development Center, Tiaong, Quezon.
ATTD = apparent total tract digestibility; DM = dry matter; GE = gross energy; DE = digestible energy; ME = metabolizable energy

Table 4. Daily energy balance (DM basis) in imported hybrid and Philippine black tiaong native pigs fed diets containing yellow corn, soybean meal, and rice bran (Main effects).[1,2]

ITEM	DIET			SEM	BREED		SEM	*P*-value		
	Corn	SBM	RB		Hybrid	Native		Breed	Diet	Breed × Diet
DM intake, g	473	517	841	195	349	872	159	0.03	0.36	0.34
GE intake, kcal	1,780	1,994	1,918	81	1,214	2,581	66	<0.001	0.18	0.33
Fecal output, g	94	112	112	13	93	119	11	0.09	0.55	0.77
Fecal GE output, kcal	386	457	444	51	382	476	42	0.12	0.59	0.73
ATTD of GE, %	89	89	89	1	87	92	0.91	<0.001	0.97	0.96
Urinary output, g	425	401	334	38	152	621	31	<0.001	0.23	0.08
Urinary GE output, kcal	13	16	12	2	10	17	2	0.04	0.58	0.46
DE of diet, kcal/kg	3,515	3,619	3,524	46	3,445	3,660	36	<0.001	0.21	0.92
ME of diet, kcal/kg	3,503	3,604	3,513	45	3,431	3,649	37	<0.001	0.24	0.90

[1]Data are least square means of 6 replicates per treatment.

[2]HYBRID = progeny of PIC L337 male × C24 female (Pig Improvement Co., Hendersonville, TN, USA). NATIVE = Black Tiaong pigs sourced from National Swine and Poultry Research and Development Center, Tiaong, Quezon.

ATTD = apparent total tract digestibility; DM = dry matter; GE = gross energy; DE = digestible energy; ME = metabolizable energy

Table 5. Energy concentration in yellow corn, soybean meal, and rice bran fed to imported hybrid and Philippine black tiaong native pigs (Interactive effects). [1,2]

ITEM	HYBRID			NATIVE			SEM	*P*-value		
	Corn	SBM	RB	Corn	SBM	RB		Breed	Diet	Breed × Diet
As-fed basis										
GE, kcal/kg	3,960	4,066	3,956	3,960	4,066	3,956	--	--	--	--
DE, kcal/kg	3,607	3,702	3,374	3,803	4,018	3,717	160	0.04	0.15	0.87
ME, kcal/kg	3,594	3,668	3,353	3,797	4,009	3,697	163	0.03	0.15	0.85
DM basis										
GE, kcal/kg	4,550	4,673	4,554	4,550	4,673	4,554	--	--	--	--
DE, kcal/kg	4,144	4,255	3,883	4,369	4,618	4,278	184	0.04	0.16	0.87
ME, kcal/kg	4,130	4,216	3,860	4,362	4,607	4,255	187	0.03	0.16	0.87

[1]Data are least square means of 6 replicates per treatment.
[2]HYBRID = progeny of PIC L337 male × C24 female (Pig Improvement Co., Hendersonville, TN, USA). NATIVE = Black Tiaong pigs sourced from National Swine and Poultry Research and Development Center, Tiaong, Quezon.
DM = dry matter; GE = gross energy; DE = digestible energy; ME = metabolizable energy

Table 6. Energy concentration in yellow corn, soybean meal, and rice bran fed to imported hybrid and Philippine black tiaong native pigs (Main effects).[1,2]

ITEM	INGREDIENT			SEM	BREED		SEM	*P*-value		
	Corn	SBM	RB		Hybrid	Native		Breed	Diet	Breed × Diet
As-fed basis										
GE, kcal/kg	3,960	4,066	3,956	--	3,994	3,994	--	--	--	--
DE, kcal/kg	3,705	3,860	3,545	113	3,561	3,846	92	0.04	0.16	0.89
ME, kcal/kg	3,692	3,838	3,535	115	3,539	3,838	94	0.03	0.19	0.86
DM basis										
GE, kcal/kg	4,550	4,673	4,554	--	4,592	4,592	--	--	--	--
DE, kcal/kg	4,256	4,436	4,080	130	4,094	4,421	106	0.04	0.17	0.89
ME, kcal/kg	4,242	4,411	4,069	132	4,068	4,412	108	0.03	0.21	0.86

[1]Data are least square means of 6 replicates per treatment.

[2]HYBRID = progeny of PIC L337 male × C24 female (Pig Improvement Co., Hendersonville, TN, USA). NATIVE = Black Tiaong pigs sourced from National Swine and Poultry Research and Development Center, Tiaong, Quezon.

DM = dry matter; GE = gross energy; DE = digestible energy; ME = metabolizable energy

Table 7. Apparent total tract digestibility (ATTD, %) of nutrients and dietary fiber in yellow corn, soybean meal, and rice bran fed to imported hybrid and Philippine black tiaong native pigs (Interactive effects). [1,2]

ITEM	HYBRID			NATIVE			SEM	*P*-value		
	Corn	SBM	RB	Corn	SBM	RB		Breed	Diet	Breed × Diet
ATTD, %										
Crude Protein	68.10^{d}	93.50^{ab}	77.19^{c}	91.88^{ab}	98.03^{a}	90.31^{b}	2.02	0.0002	0.0006	0.009
Crude fat	70.23	22.09	78.83	92.53	54.12	92.80	13.00	0.08	0.02	0.79
Crude fiber	48.47	61.58	71.18	76.88	87.64	78.40	6.81	0.01	0.21	0.30
Neutral Detergent Fiber	61.18	58.00	66.69	79.08	81.14	79.63	7.44	0.03	0.88	0.80
Acid Detergent Fiber	54.67	76.74	68.17	78.39	93.06	81.48	4.65	0.003	0.02	0.55
Ash	10.73	60.73	50.82	30.96	82.93	76.03	8.36	0.02	0.002	0.96

[1]Data are least square means of 6 replicates per treatment.
[2]HYBRID = progeny of PIC L337 male × C24 female (Pig Improvement Co., Hendersonville, TN, USA). NATIVE = Black Tiaong pigs sourced from National Swine and Poultry Research and Development Center, Tiaong, Quezon.
[3]ATTD = apparent total tract digestibility.
[a-c]Values within a row lacking a common superscript letter are different ($P \leq 0.05$).

Table 8. Apparent total tract digestibility (ATTD, %) of nutrients and dietary fiber in yellow corn, soybean meal, and rice bran fed to imported hybrid and Philippine black tiaong native pigs (Main effects).[1,2]

ITEM	DIET			SEM	BREED		SEM	*P*-value		
	Corn	SBM	RB		Hybrid	Native		Breed	Diet	Breed × Diet
ATTD, %										
Crude Protein	79.99	95.77	83.76	1.42	79.60	93.41	1.16	0.0002	0.0006	0.009
Crude fat	81.38^{a}	38.11^{b}	85.82^{a}	9.19	57.05	79.82	7.50	0.08	0.02	0.79
Crude fiber	62.68	74.61	74.79	4.81	60.41	80.97	3.93	0.01	0.21	0.30
Neutral Detergent Fiber	70.14	69.57	73.16	5.26	61.96	79.95	4.29	0.03	0.88	0.80
Acid Detergent Fiber	66.53^{b}	84.90^{a}	74.83^{ab}	3.28	66.52	84.31	2.68	0.003	0.02	0.55
Ash	20.85^{b}	71.83^{a}	63.42^{a}	5.91	40.76	63.31	4.82	0.02	0.002	0.96

[1]Data are least square means of 6 replicates per treatment.

[2]HYBRID = progeny of PIC L337 male × C24 female (Pig Improvement Co., Hendersonville, TN, USA). NATIVE = Black Tiaong pigs sourced from National Swine and Poultry Research and Development Center, Tiaong, Quezon.

[a-c]Values within a row lacking a common superscript letter are different ($P \leq 0.05$)

Discussion

Differences in nutrient digestibility, particularly with dietary fiber, may be a result of both population and variety of microflora residing in the gut of native pigs. The swine microflora contains highly active ruminal cellulolytic and hemicellulolytic bacterial species. These microorganisms are known to increase in response to the ingestion of diets high in plant material (Varel and Yen, 1997). Varel (1987) reported that the cellulolytic organisms in the pig, like *Bacteroides succinogenes* and *Ruminococcus flavefaciens*, are similar to those in the rumen and this explains why pigs can maintain themselves by merely grazing on forage. A larger number of cellulolytic bacteria were found in the fecal samples from pigs fed the high fiber diet. These significantly affect the intestinal bacterial metabolism and number, and activity of the cellulolytic population (Varel et al., 1984; Varel et al., 1988). Wenk et al. (2001) also revealed that increases in the microbial growth in the GIT can lead to an increased excretion of nutrients in feces and DF beneficially influences the well-being and health of the pigs. The most dominant bacteria are: *Prevotella ruminicola*, Selenomonas ruminantium, *Butyrivibrio fibrisolvens*, *Lactobacillus acidophilus*, *Peptostreptococcus productus*, and six *Eubacterium aerofaciens*. These bacteria and microorganisms ferment undigested feed components and endogenous secretions in the LI (Mosenthin, 1998).

The results of the present study confirm that Philippine black Tiaong native pigs have the same ability as other indigenous swine breeds in digesting nutrients, energy and dietary fiber compared with modern crossbred pigs. Urriola and Stein (2012) also observed that Meishan pigs have greater ATTD of DM, GE, and some nutrients in corn-soybean meal diets than Yorkshire pigs. Likewise, Len et al. (2009) also reported that Mong Cai pigs had higher ATTD of OM, GE, crude fiber, NDF, EE, and CP than Landrace × Yorkshire pigs, but had significantly lower ADG and poorer F/G. As was observed in the present study, the ATTD of fat was also better in Mong Cai pigs (Samkol and Ly, 2008). Len et al. (2009) showed that Mong Cai pigs had longer intestines fed on fibrous diets than Landrace × Yorkshire pigs. These indicate that the gastrointestinal tract of Mong Cai pigs developed more rapidly than Landrace × Yorkshire pigs, which may partly explain the observed differences in digestibility.

In contrast, Yen et al. (2004) observed no differences between Duroc × White composite crossbred and Meishan pigs in total viable bacteria and cellulolytic bacteria from fecal samples, in vitro digestibility of alfalfa NDF fractions by fecal inocula, whole-body oxygen consumption, net portal absorption of VFA, total energy of absorbed VFA, and the potential of absorbed VFA for meeting the energy needs for whole-body heat production. These results indicate that, in contrast to other studies, the ability of Meishan growing pigs to utilize a high-fiber diet is not superior to that of Duroc × White composite crossbred growing pigs. Furthermore, Ly et al. (1998) also observed that the crude fiber and NDF contents of the diet was higher in improved pigs (CC21) than in Cuban Creole pigs and daily fecal output of water and SCFA was significantly greater in Creole pigs than in CC21 pigs. These imply that digestion of a diet very high in fiber does not appear to be greater in Creole pigs and that improved pigs digested most of the diet components better than the Creole pigs.

Conclusion

In conclusion, Philippine black Tiaong native pigs have greater ability to digest energy, CP, fat, fiber and minerals compared with hybrid pigs. Therefore, energy and nutrient digestibility values for feed ingredients determined in modern hybrid pigs are underestimated, and may not be used to formulate diets for Philippine black Tiaong native pigs. Nutritional value of feed ingredients must be determined for Philippine black Tiaong native pigs to develop effective and sustainable feeding programs.

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