

**Effect of Tapioca Levels on Production of Swine****ABSTRACT**

There is little definitive information available regarding tapioca's effect on the swine performance and meat quality. Thus, this study was carried out. Thirty-six cross-bred [(Landrace × Yorkshire) × Duroc] growing-finishing swine with their average initial BW of 26.5±2.1 kg was used in this study. The animals were fed with control (no addition of tapioca), treatment 1 (T1 – 10% tapioca) and treatment 2 (T2 – 20% tapioca) for different periods (tapioca as-fed basis). The experimental period lasted for 98d. Carcass characteristics, physicochemical properties, meat composition and sensory test were not significantly different among treatments except for the carcass weight which was increased ( $p<0.05$ ) in the tapioca diet groups. Swine fed with tapioca-replaced diet has no detrimental effects on growth performance or meat quality. Instead, it significantly increased the carcass weight. Therefore, we conclude that tapioca replacement of 20% can aid as alternative feed ingredient of energy source in improving carcass weight for growing-finishing swine.

**Keywords:** Swine production; growth performance; swine diet; tapioca.

**1. INTRODUCTION**

Livestock producers are continually looking for new ingredients to include in diets to fulfill specific consumers' demands. Although conventional grains are the most widely used high energy feedstuff, unconventional carbohydrates often provide an alternative. Moreover, a concentrated carbohydrate source provided in a diet with high starch composition may improve the growth rate and carcass traits of pigs [1]. One of these is tapioca, which is a source of starch (62.0%) and has a nutritional value that allows for the partial replacement of cereal grain; this might maximize efficiency for the expected characteristics [2]. Tsudir *et al.* [3] reported that tapioca has dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), nitrogen free extract (NFE) and total ash (TA) of 94.20, 3.30, 0.60, 2.70, 91.10 and 2.30 percentages, respectively. Also, the energy content (ME) of tapioca root in pig was somewhat similar to maize [4, 5, 6]. Tapioca has been used as a livestock feed in some of the countries. It has been included at large scale (multi-millions of tons of feed, annually) without causing (health, production, or meat-quality) problems. However, there is little definitive information available regarding its effect on swine meat characteristics. Zinn and DePeters [7] previously reported that tapioca pellets can be used to replace up to 30% of dry matter intake

35 in growing to finishing diets without adversely affecting the average daily gains of feedlot  
36 cattle. Moreover, a 10-25% inclusion level of tapioca feed ingredient in the swine diet was  
37 recommended by Moehn *et al.* [2]. However, there is little definitive information available  
38 regarding its effect on swine meat characteristics. Thus, the objective of this study was to  
39 determine the effect of tapioca as feed ingredient in the diet of growing-finishing swine for growth  
40 performance and carcass quality in swine.

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## 42 2. MATERIALS AND METHODS

### 43 2.1 Animals, diets and study design

44 A total of 36 male swine [(Landrace × Yorkshire) × Duroc] with average live weight of  
45 26.53±2.10 kg at the beginning of the experiment and 114.13±3.16 kg at the time of slaughter  
46 were used in this experiment. Twelve swine were used in each treatment and control group  
47 which was represented by three pens with four swine in each pen. The swine were provided  
48 balanced diet at 5.5% of BW/d and supplied fresh water throughout the experiment. The  
49 feeding was done in phases; grower (20-50kg), early finisher (50-80kg) and late finisher (80-  
50 120kg), and tapioca levels were provided at 0% (Control), 10% (T1) and 20% (T2) (Table 1).  
51 The composition of the diets and their calculated chemical compositions were prepared in  
52 accordance with the National Research Council (NRC) guideline [8]. The animals used in this  
53 experiment were cared for in accordance with the guidelines established by National Institute  
54 of Animal Science (NIAS), Korea. The research protocol including the procedures for the care  
55 and treatment of the animals was reviewed and approved by the Animal Care Committee at  
56 the NIAS, Korea.

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68 **Table 1. Ingredient composition** and nutrient content of the experimental diets for  
 69 **growing-finishing swine** at different stages (as fed-basis)

Live weight (kg)	Grower (20 ~ 50)			Early finisher (50 ~ 80)			Late finisher (80 ~ 120)		
	Control	Tapioca	Tapioca	Control	Tapioca	Tapioca	Control	Tapioca	Tapioca
		10%	20%		10%	20%		10%	20%
<b>Ingredients, %</b>									
Soybean meal	19.07	22.73	25.66	11.99	16.54	19.18	3.94	9.84	12.49
Corn	68.76	50.73	45.91	76.23	54.65	49.98	68.31	56.28	50.19
Palm meal	-	-	-	-	-	-	-	2.50	5.00
Tapioca	-	10.00	20.00	-	10.00	20.00	-	10.00	20.00
Lupine seed	6.48	-	-	6.36	-	-	8.06	-	-
Wheat grain	-	8.85	1.91	3.3	11.82	5.04	11.63	13.67	5.34
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Methionine	-	-	0.02	-	-	-	-	0.03	0.06
Lysine	0.19	0.17	0.13	0.14	0.10	0.07	0.17	0.11	0.11
Limestone	0.84	0.84	0.60	0.82	0.77	0.54	0.86	0.86	0.44
Molasses	2.47	2.96	3.00	0.32	3.00	3.00	4.00	3.68	4.00
Dicalcium phosphate	0.77	0.57	0.81	0.54	0.33	0.57	0.23	0.11	0.52
Soybean oil	1.12	3.00	1.81	-	2.49	1.32	2.50	2.62	1.55
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
<b>Nutrient Content*</b>									
DM, %	89.64	89.65	89.64	89.67	89.66	89.68	89.68	89.68	89.69
CP, %	16.16	15.90	16.00	13.80	13.80	13.80	11.50	11.70	11.50
DE, kcal/kg	3,450	3,450	3,450	3,400	3,400	3,400	3,400	3,400	3,400
CF, %	4.00	4.00	4.00	4.00	4.00	4.00	4.30	4.30	4.30
Ca, %	0.60	0.60	0.60	0.50	0.50	0.50	0.45	0.45	0.45
P, %	0.50	0.50	0.50	0.45	0.45	0.45	0.40	0.40	0.40
Lysine, %	0.95	0.95	0.95	0.75	0.75	0.75	0.60	0.60	0.60
Methionine, %	0.25	0.25	0.25	0.23	0.22	0.22	0.19	0.21	0.21

70 \* Calculated values

71 Vit.-Min. premix provided 3.5g per kg of diet containing 1,600,000 IU of vit. A, 300,000 IU

72 of vit D<sub>3</sub>, 800 IU of vit E, 132mg of vit K<sub>3</sub>, 1,000mg of vit B<sub>2</sub>, 1,200 mg of vit. B<sub>12</sub>, 2,000mg of  
73 niacin, 60mg of folic acid, 35,000mg of choline chloride, 800mg of pantothenic calcium,  
74 9,000mg of Zn, 12,000mg of Mn, 4,000mg of Fe, 500mg of Cu, 6,000mg of I, and 100mg of Co.

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76 The experiment was conducted at the Animal Environment Division research farm, NIAS,  
77 Suwon, South Korea. According to protocol and management, the swine house had a fully slatted  
78 floor pens and an automatic temperature and humidity controller. The average temperature  
79 and relative humidity of the house during the experimental period were  $20.0 \pm 0.59^{\circ}\text{C}$  and  
80  $60.0 \pm 2.8\%$  (mean  $\pm$  SD), respectively. The slurry was removed from the pit using a typical  
81 gravity drain waste system during experimental periods. The swine were provided with *ad*  
82 *libitum* access (5.5% of BW/d) to un-pelleted (except tapioca as pellet) balanced growing  
83 swine feed (mash) in 3 daily meals of equal amounts, administered at 0800, 1600, and 2400 h,  
84 with a stainless-steel feeder and fresh water supplied by a nipple waterer throughout the  
85 experiment. The study was conducted for 14 weeks of experimental period with 7d dietary  
86 adaptation. Growth performance such as body weight changes, feed intake and feed  
87 conversion ratio were also measured. In addition, carcass characteristics, physicochemical  
88 properties, meat composition, color properties and sensory test of pork *longissimus dorsi*  
89 muscle at 14<sup>th</sup> weeks of age were also determined. Three replicates for each of the parameters  
90 were used and their averaged data were considered the representative value.

## 91 2.2 Measurements for growth performance

92 The body weights of the swine were recorded every two weeks from the initial day to the final  
93 day of the experiment to calculate the body weight gain (BWG). The feed intake of the swine  
94 was recorded every two weeks by offering a weighed quantity of feed and weighing the  
95 residual. The feed conversion ratio (FCR) was expressed as gain (G): feed intake (F) of swine.

## 96 2.3 Meat quality evaluation

97 When the swine reached the average live weight of  $114.13 \pm 3.16$  kg, three swine per pen  
98 were randomly selected and transported to a commercial abattoir. They were slaughtered after  
99 electrical stunning on the following day and hot carcass weight was measured so that the  
100 dressing percentage could be calculated. The dressing percentage for an individual animal was  
101 defined as the hot carcass weight divided by the live weight. The carcass and meat quality  
102 measurements (obtained from the left side of the carcass) included *longissimus* muscle area,  
103 rib eye area, and meat quality grade [9]. Approximately 24 h after slaughter, pH and

104 temperature were determined from the right side of the carcass in the center of the *longissimus*  
105 muscle between the 3<sup>rd</sup> and 4<sup>th</sup> ribs. A 2.54-cm section of the 9th-rib chop was then removed,  
106 and cooking loss and shearing force values were determined as described previously by  
107 Kauffman *et al.* [10] and Bee *et al.* [11], respectively. The carcasses were stored in a deep  
108 freezer (-18°C) for chemical body analyses. Laboratory analyses of the pork samples were  
109 conducted two months after sampling. The samples were thawed at room temperature (20°C),  
110 ground, homogenized, and analyzed in triplicate. The preparation of the carcasses for  
111 chemical body analyses was conducted by the method developed by Kotarbińska [12]. Meat  
112 moisture and ash contents were determined according to AOAC guidelines [13]. Crude  
113 protein content in the samples was obtained via the Kjeldahl method [13]. Crude fats were  
114 extracted by the Bligh and Dyer method [14] with a chloroform/methanol mixture. Color  
115 measurements were taken using a colorimeter (Minolta CM 3500m, Japan). The color  
116 readings including lightness (L), redness (a) and yellowness (b) were taken from a  
117 *longissimus* section (from the 8th to 10th ribs). The equipment was standardized using a white  
118 color standard.

#### 119 **2.4 Sensory evaluation**

120 For the sensory evaluation, meat samples were cooked in an electric grill with double pans  
121 (Nova EMG-533, 1,400 W, Evergreen, Korea) to an internal temperature of 75°C. The meat  
122 samples (2 × 4 × 1.5 cm) were placed in randomly coded white dishes and served with  
123 drinking water. Fifty panel members from the NIAS did the sensory evaluation on the meat. A  
124 5-point hedonic scale ranging from 1 (dislike very much) to 5 (like very much) was used to  
125 evaluate product attributes (juiciness, tenderness and flavor) in accordance with the guidelines  
126 established by Arambawela *et al.* [15].

#### 127 **2.5 Statistical analysis**

128 All the data collected were subjected to one-way ANOVA procedures in a completely  
129 randomized design using the general linear model (GLM) procedures (SAS Inst. Inc., Cary,  
130 NC) [16]. The growth performance, carcass traits, and pork quality data were compared and  
131 significant differences among means of treatment and control groups were separated using  
132 Duncan's multiple range (comparison) tests. Variability in the data was expressed as the  
133 pooled mean values and standard error (SE) or standard error of the mean (SEM) via the  
134 MEANS procedure. The threshold for significance was  $p < 0.05$  for all measured variables.

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### 139 3. RESULTS AND DISCUSSIONS

#### 140 3.1 Growth performance

141 Several grain sources for swine are available in the market. In spite of that, livestock  
142 producers are mostly concerned with choosing carbohydrate-source products are the energy  
143 value and cost of the grains. Tapioca is one of these alternative carbohydrate-sources which  
144 are more economical. Having somewhat similar energy content (ME) of tapioca root and  
145 maize [4, 5, 6] explains unaffected digestible energy (DE) with 3,450 kcal/kg and 3,400  
146 kcal/kg in grower and finisher feed formulation as well as other parameters available when we  
147 replaced with tapioca in the feed (Table 1).

148 The effects of the experimental dietary treatments on the growth performance, including  
149 weight gain, feed intake and feed conversion ratio of the swine are provided in Table 2. The  
150 animals remained healthy throughout the duration of the experimental periods and no  
151 differences in feed and water intakes were observed between the control and the tapioca-  
152 replaced groups. Growth performance was not significantly affected by the treatments. This  
153 indicates that replacing corn with tapioca will not affect the growth performance but rather  
154 will help the livestock producer in reducing feed cost.

155 **Table 2. Effects of dietary tapioca on the growth performance at 14<sup>th</sup> weeks of swine<sup>1</sup>**

Parameters	Control	Tapioca		SEM <sup>4</sup>
		10%	20%	
Body weight, kg				
IBW <sup>2</sup>	26.5	26.3	26.8	2.10
FBW <sup>3</sup>	112.5	115.0	116.9	3.16
Average Daily Gain, kg	0.84	0.87	0.88	0.02
Average Feed Intake, kg/d	2.61	2.73	2.74	0.54
Average Daily Water Intake, L/pig/d <sup>5</sup>	5.48	5.53	5.59	5.53
Feed conversion ratio	3.11	3.14	3.11	0.09

156 Values presented as Mean; <sup>1</sup> Individual pig was the experimental unit (n = 12); <sup>2</sup> IBW - initial  
157 body weight; <sup>3</sup> FBW - final body weight; <sup>4</sup> SEM – standard error mean; <sup>5</sup> Average daily water  
158 intakes during the entire experiment including adaptation and collection periods.

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160 Although there was not significant difference; between the treatments, swine receiving diets  
161 with tapioca tended to show a higher growth performance compared to the control. There was  
162 a trend of decreasing final body weight (116.9, 115.0 and 112.5 kg), average daily gain (0.88,  
163 0.87 and 0.84 kg), and average feed intake (2.74, 2.73, and 2.61 kg/d) for T2, T1 and control  
164 respectively. However, in the study reported by Tsudir *et al.* [3], significantly higher ADG  
165 was observed in 50% level of tapioca replacement in feed. The result of our study was  
166 different with the result obtained by Tsudir *et al.* [3] due to higher tapioca level was replaced.  
167 On the other hand, there was an increase in the intake of feed during the whole experimental  
168 period when the grain was replaced with tapioca at different levels which was comparable to  
169 the result obtained by Tsudir *et al.* [3]. This indicates that the diet containing tapioca has a  
170 high palatability which made it readily accepted by the swine and thus increases in feed intake.

### 171 3.2 Carcass characteristics and meat quality

172 Indices of carcass quality including carcass characteristics, physicochemical properties, and  
173 meat composition are shown in Table 3. The carcass characteristics, (rib eye area, dressing  
174 percentage, and meat quality grade), physical properties (shear force, cooking loss, pH,  
175 temperature and water holding capacity (WHC)), and meat composition (moisture, fat, protein  
176 and ash) were not significantly different except for the carcass weight ( $p<0.05$ ). Moreover,  
177 carcass weight showed increasing trend from lowest to highest level of tapioca  
178 supplementation ( $p<0.05$ ) with the Control, T1 and T2 recording 85.08, 88.17 and 88.75,  
179 respectively. The reason for the increase in carcass weight is unclear. However, Schumacher  
180 *et al.* [17] stated that carbohydrates (sucrose) improved carcass weights. Although they  
181 employed different carbohydrate ingredients in that study, our results on tapioca replacement  
182 were generally consistent with theirs. Even though it was not significant, the increased feed  
183 intake and final body weight might be the reason for the significant increase in carcass weight  
184 of tapioca-based treatments.

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195 **Table 3. Effects of dietary tapioca on carcass characteristics, physicochemical properties,**  
 196 **and meat composition of pork *longissimus dorsi* muscle at 14<sup>th</sup> weeks of age**

Parameters	Control	Tapioca		SEM <sup>1</sup>
		10%	20%	
<b>Carcass characteristics</b>				
Rib eye area, cm <sup>2</sup>	49.62	50.34	49.53	1.57
Carcass weight, kg	85.08 <sup>b</sup>	88.17 <sup>a</sup>	88.75 <sup>a</sup>	1.54
Dressing percentage, 24-h	73.11	73.95	73.98	0.11
Meat quality grade	1.17	1.17	1.08	0.10
<b>Physicochemical properties of the sirloin</b>				
Shearing force, kg/0.5inch <sup>2</sup>	3.89	4.00	3.84	0.08
Oven dry or cooking loss, %	33.44	33.21	32.88	0.40
pH, 24-h	5.58	5.60	5.58	0.02
Temperature, °C, 24-h	3.99	4.01	4.04	0.03
Water holding- capacity, %	53.91	53.27	53.59	0.41
<b>Meat composition, %</b>				
Moisture	72.72	73.22	72.77	0.33
Fat	3.37	3.34	3.38	0.40
Protein	22.32	22.53	22.29	0.15
Ash	0.96	0.99	0.98	0.01

197 <sup>a,b</sup> Mean; Means in the same row with different superscripts are significantly different

198 ( $p < 0.05$ ); <sup>1</sup>SEM – standard error of the mean.

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200 Comparable results were also obtained in physicochemical properties of sirloin and meat  
 201 composition of tapioca-replaced and non-replaced treatments (Table 3). The result was in  
 202 concordance with Wang *et al.* [18] research wherein meat quality was also not affected by the  
 203 treatments of tapioca. The results might be due to comparable CP and DE content of the feed  
 204 formulations. As Goerl *et al.* [19] and Witte *et al.* [20] stated, formulating diets based on CP  
 205 and energy had no effects on physicochemical properties of muscle such as pH and WBC.  
 206 Thus, tapioca-supplementation did not significantly affect the physicochemical properties and  
 207 meat composition.



208 **Table 4. Effects of dietary tapioca on organoleptic test of pork *longissimus dorsi* muscle**  
 209 **at 14<sup>th</sup> weeks of age**

Parameters	Control	Tapioca		SEM <sup>1</sup>
		10%	20%	
<b>Color properties of the sirloin</b>				
L	55.17	55.39	55.10	0.76
CIE	a	7.93	7.71	0.26
	b	2.70	2.88	0.31
Hunter	L	48.08	48.30	0.77
	a	6.70	6.52	0.23
	b	2.17	2.32	0.25
<b>Sensory test of pork</b>				
Juiciness	4.53	4.53	4.53	0.15
Tenderness	4.51	4.67	4.53	0.18
Flavor	4.78	4.68	4.68	0.11

210 CIE= International Commission on Illumination; L= lightness; a= Redness; b= Yellowness;  
 211 <sup>1</sup>SEM – standard error mean.

212 The color properties (L=lightness, a=redness and b=yellowness) and sensory test (juiciness,  
 213 tenderness, flavor) of pork *longissimus dorsi* muscle at 14<sup>th</sup> week of age are shown in Table 4.  
 214 Results were unaffected by the different dietary treatments ( $p>0.05$ ) which is similar to the  
 215 results of Goerl *et al.* [19] and Witte *et al.* [20] where the color and sensory properties were  
 216 also not affected by their dietary treatments. The results of the present study were also in  
 217 concordant with the results of Beech *et al.* [21] and Fernandez *et al.* [22] where no effect was  
 218 detected on pork quality when carbohydrate (sugar) was added to the diet. This may be due to  
 219 the fact that tapioca, which is a type of starch has no strange smell or high fat levels that can  
 220 influence carcass characteristics. McKean [23] stated that the desired effect of the tapioca was to  
 221 improve weight gain and feed efficiency by improving gut digestion and reducing pathogenic  
 222 organism loads.

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#### 224 4. CONCLUSION

225 The uses of 20% tapioca as feed ingredient improved carcass weight of swine. Thus, tapioca  
 226 can be an alternative feed ingredient in growing-finishing swine without any detrimental  
 227 effects on growth performance and meat quality.

228 **Ethical disclaimer:**

229 Animal Ethics committee Reference Number is not available with me, but ethical committee's suggestions for  
230 management is included. If you suggest, then I may omit. The institute mainly followed EU Ethics.

231 Korea also followed Welfare Quality Assessment Protocol for Pigs (Sows and Piglets, Growing and Finishing  
232 Pigs) from

233 [\[https://www.google.co.kr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBsQFjAA&url=http%3A%2F%2Fwww.welfarequalitynetwork.net%2Fdownloadattachment%2F45627%2F21651%2FPig%2520Protocol.pdf&ei=XyXzU6LMFcG48gXyjYC4Dg&usg=AFQjCNG5G\\_tOnriEP5ZLdOhmEFnXoQ8g5Q\]](https://www.google.co.kr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBsQFjAA&url=http%3A%2F%2Fwww.welfarequalitynetwork.net%2Fdownloadattachment%2F45627%2F21651%2FPig%2520Protocol.pdf&ei=XyXzU6LMFcG48gXyjYC4Dg&usg=AFQjCNG5G_tOnriEP5ZLdOhmEFnXoQ8g5Q)

235  
236 Consent: NA

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