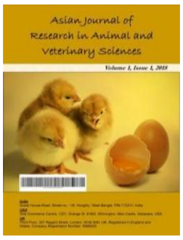


*Asian Journal of Research in Animal and Veterinary Sciences*

*1(4): 280-287, 2018; Article no.AJRAVS.45429*

# Effect of Tapioca Levels on Production of Swine

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors MJA and SSL designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SBC and KCN managed the analyses of the study. Author KCN managed the literature searches. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/AJRAVS/2018/45429
*Editor(s):*
(1) Dr. Jean-Marie Exbrayat, Professor, Lyon Catholic University (UCLy), France and Ecole Pratique des Hautes Etudes (EPHE), France.
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*Reviewers:*
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(3) Michael Boateng, Kwame Nkrumah University of Science and Technology, Ghana.
Complete Peer review History: http://www.sdiarticle3.com/review-history/45429

***Original Research Article***

***Received 23 September 2018***
***Accepted 12 December 2018***
***Published 12 January 2019***

## 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

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

## 2. MATERIALS AND METHODS

### 2.1 Animals, Diets and Study Design

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

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

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

| Live weight (kg) | Grower (20 ~ 50) | | | Early finisher (50 ~ 80) | | | Late finisher (80 ~ 120) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Item/ Diets** | **Control** | **Tapioca 10%** | **Tapioca 20%** | **Control** | **Tapioca 10%** | **Tapioca 20%** | **Control** | **Tapioca 10%** | **Tapioca 20%** |
| **Ingredients, %** | | | | | | | | | |
| 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 |
| **Nutrient Content*** | | | | | | | | | |
| 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 |

**Calculated values,*

*Vit.-Min. premix provided 3.5g per kg of diet containing 1,600,000 IU of vit. A, 300,000 IU of vit $D_3$, 800 IU of vit E, 132mg of vit $K_3$, 1,000㎎ of vit $B_2$, 1,200 mg of vit. $B_{12}$, 2,000㎎ of niacin, 60㎎ of folic acid, 35,000㎎ of choline chloride, 800㎎ of pantothenic calcium, 9,000㎎ of Zn, 12,000㎎ of Mn, 4,000mg of Fe, 500㎎ of Cu, 6,000㎎ of I, and 100㎎ of Co.*

were also determined. Three replicates for each of the parameters were used and their averaged data were considered the representative value.

## 2.2 Measurements for Growth Performance

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

## 2.3 Meat Quality Evaluation

When the swine reached the average live weight of 114.13 ± 3.16 kg, three swine per pen were randomly selected and transported to a commercial abattoir. They were slaughtered after electrical stunning on the following day and hot carcass weight was measured so that the dressing percentage could be calculated. The dressing percentage for an individual animal was defined as the hot carcass weight divided by the live weight. The carcass and meat quality measurements (obtained from the left side of the carcass) included *longissimus* muscle area, rib eye area, and meat quality grade [9]. Approximately 24 h after slaughter, pH and temperature were determined from the right side of the carcass in the center of the *longissimus* muscle between the 3rd and 4th ribs. A 2.54-cm section of the 9th-rib chop was then removed, and cooking loss and shearing force values were determined as described previously by Kauffman et al. [10] and Bee et al. [11], respectively. The carcasses were stored in a deep freezer (-18°C) for chemical body analyses. Laboratory analyses of the pork samples were conducted two months after sampling. The samples were thawed at room temperature (20°C), ground, homogenized, and analyzed in triplicate. The preparation of the carcasses for chemical body analyses was conducted by the method developed by Kotarbińska [12]. Meat moisture and ash contents were determined according to AOAC guidelines [13]. Crude protein content in the samples was obtained via the Kjeldahl method [13]. Crude fats were extracted by the Bligh and Dyer method [14] with a chloroform/methanol mixture. Color measurements were taken using a colorimeter (Minolta CM 3500m, Japan). The color readings including lightness (L), redness (a) and yellowness (b) were taken from a *longissimus* section (from the 8th to 10th ribs). The equipment was standardized using a white color standard.

## 2.4 Sensory Evaluation

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

## 2.5 Statistical Analysis

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

# 3. RESULTS AND DISCUSSION

## 3.1 Growth Performance

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

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

Although there was not significant difference; between the treatments, swine receiving diets with tapioca tended to show a higher growth performance compared to the control. There was a trend of decreasing final body weight (116.9, 115.0 and 112.5 kg), average daily gain (0.88, 0.87 and 0.84 kg), and average feed intake (2.74, 2.73, and 2.61 kg/d) for T2, T1 and control respectively. However, in the study reported by Tsudir et al. [3], significantly higher ADG was observed in 50% level of tapioca replacement in feed. The result of our study was different with the result obtained by Tsudir et al. [3] due to higher tapioca level was replaced. On the other

**Table 2. Effects of dietary tapioca on the growth performance at 14th weeks of swine[1]**

| Parameters | Control | Tapioca | | SEM[4] |
|---|---|---|---|---|
| | | 10% | 20% | |
| Body weight, kg | | | | |
| IBW[2] | 26.5 | 26.3 | 26.8 | 2.10 |
| FBW[3] | 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[5] | 5.48 | 5.53 | 5.59 | 5.53 |
| Feed conversion ratio | 3.11 | 3.14 | 3.11 | 0.09 |

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

hand, there was an increase in the intake of feed during the whole experimental period when the grain was replaced with tapioca at different levels which was comparable to the result obtained by Tsudir et al. [3]. This indicates that the diet containing tapioca has a high palatability which made it readily accepted by the swine and thus increases in feed intake.

## 3.2 Carcass Characteristics and Meat Quality

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

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

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

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

| Parameters | Control | Tapioca | | SEM[1] |
|---|---|---|---|---|
| | | 10% | 20% | |
| **Carcass characteristics** | | | | |
| Rib eye area, $cm^2$ | 49.62 | 50.34 | 49.53 | 1.57 |
| Carcass weight, kg | $85.08^b$ | $88.17^a$ | $88.75^a$ | 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 |
| **Physicochemical properties of the sirloin** | | | | |
| Shearing force, $kg/0.5inch^2$ | 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 |
| **Meat composition, %** | | | | |
| 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 |

*a,b Mean; Means in the same row with different superscripts are significantly different ($p<0.05$); [1]SEM – standard error of the mean.*

**Table 4. Effects of dietary tapioca on organoleptic test of pork *longissimus dorsi* muscle at 14th weeks of age**

| Parameters | | Control | Tapioca | | SEM[1] |
|---|---|---|---|---|---|
| | | | 10% | 20% | |
| **Color properties of the sirloin** | | | | | |
| **CIE** | L | 55.17 | 55.39 | 55.10 | 0.76 |
| | a | 7.93 | 7.71 | 8.24 | 0.26 |
| | b | 2.70 | 2.88 | 3.01 | 0.31 |
| **Hunter** | L | 48.08 | 48.30 | 48.03 | 0.77 |
| | a | 6.70 | 6.52 | 6.97 | 0.23 |
| | b | 2.17 | 2.32 | 2.43 | 0.25 |
| **Sensory test of pork** | | | | | |
| 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 |

*CIE= International Commission on Illumination; L= lightness; a= Redness; b= Yellowness; [1]SEM – standard error mean.*

## 4. CONCLUSION

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

## ETHICAL DISCLAIMER

Animal Ethics committee Reference Number is not available, but respective ethical committee's suggestions for management is included. The institute mainly followed EU Ethics.

Korea also followed Welfare Quality Assessment Protocol for Pigs (Sows and Piglets, Growing and Finishing Pigs) from [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=XyXzU6LMEcG48gXyjYC4Dg&u

sg=AFQjCNG5G_tOnriEP5ZLdOhmEFnXoQ8g5Q]

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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*The peer review history for this paper can be accessed here:*
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