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Effects of Cricket Powder on Growth Performance, Carcass Traits, Pork Quality, Physicochemical, and Sensory Analyses of Finishing Swine

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Abstract

Feeding pigs, a balanced diet is an important factor to promote growth performance and results in higher yield and quality pork. Alternative ingredients such as cricket powder (CP) can be used as a substitution to provide high-quality protein for swine. Therefore, this experiment was investigated the effects of cricket powder on growth performance, carcass traits, pork quality, physicochemical, and sensory analyses of finishing swine. Eight finishing hogs (Hampshire cross) were allotted to two treatments: 1) control (0% CP) and 2) control + 2% CP (CP replaced SBM), for 34 days. All treatments were analyzed for growth and carcass performance (ADG, ADFI, G: F, LEA, BF, HCW, and DP), sensory evaluation (9-point hedonic scale with 14 trained panelists), physicochemical (nutrition content, pH, moisture (%), ash content, color (L*, a*, b*), lipid oxidation (TBARS)), and microbiological analysis (aerobic heterotrophs (AH), *E. coli*, *Enterobacteriaceae*). Pork loin samples coated with 2% CP were used for all treatments, except the control treatment. Each treatment was prepared and stored at 3°C for 9 days. The results showed that the control diet pigs outgained pigs fed 2% CP 1.03 kg/d vs. 0.62 kg/d. There was no difference ($p>0.05$) in ADFI or G: F regardless of treatment. Pigs fed 2% CP tended to have greater DP (80.10% vs. 78.21%). The 2% CP treatment obtained the highest scores for all sensory attributes, acceptability (85.71%), and purchase intent (71.43%). Adding 2% CP improved the crude fiber (4.44%), iron (13.60 ppm), and zinc contents (21.50 ppm). Pigs fed 2% CP had increased ($p<0.05$) a* redness (10.51), pH value (5.91), and moisture content (73.03%). No *E. coli* and *Enterobacteriaceae* were detected in this experiment. In addition, samples with 2% CP increased redness values, decreased lipid oxidation, and decreased aerobic heterotrophs counts compared to the control treatment. Thus, our results suggest that adding cricket powder in swine production can be used to promote sustainability, enhance meat color, decrease undesirable microorganism growth, and prolong the shelf-life of pork loin.

Keywords: pork loin, cricket powder, grow performance

1. Introduction

From 1960 to 2021, the total meat consumption per capita in the United States increased by 38% (Tonsor & Lusk, 2022). In particular, pork consumption rose by 24% in 2021 (Tonsor & Lusk, 2022). Most U.S. swine producers feed their pigs a conventional diet based primarily on corn and soybean meal (NRC, 2012). Corn is known for being rich in sulfur-containing amino acids (AA) while soybean meal (SBM) is rich in lysine and tryptophan, which are vital for pig development (NRC, 2012). Soybean meal has antinutritional factors which cause transient hypersensitivity in early weaned pigs (Deng et al., 2022; Boontiam et al., 2022; NRC, 2012). Therefore, alternative feed derived from insects or insect meals has been introduced to swine diets to substitute SBM (Veldkamp & Vernooij, 2021). Edible insects, such as the black soldier fly, mealworm, and cricket, can be used as alternative nutrient sources to provide high-quality proteins and energy for animal feed (Shah & Wanapat, 2021; Veldkamp & Vernooij, 2021; Mielch et al., 2017; Fuah et al., 2015; van Huis et al., 2013). Cricket powder (CP) is rich in crude protein, crude fiber, and essential amino acids (Bbosa et al., 2019; Pambo et al., 2018; Dobermann et al., 2017). Piglets fed a cricket-meal-supplemented diet had a higher body weight, an increased average daily gain, and a higher digestibility of crude protein, crude fat, and dry matter (Boontiam et al., 2022;

Mielch et al., 2017; Wan et al., 2017; Xu et al., 2014). Supplementation with cricket meal was found to significantly improve growth performance of piglets in comparison to the conventional corn-SBM diet. Therefore, the aim of this study was to evaluate the effects of cricket powder fed to finishing swine on growth performance, carcass traits, meat quality, physicochemical, and sensory analyses.

2. Method

2.1 Ethics Statement

All the experimental procedures performed in this experiment were approved by the McNeese State University Animal Care and Use Committee, Lake Charles, LA.

2.2 Experimental Diets

The experiment involved two treatments during the grower-finisher period: 1) control (0% CP) and 2) control + 2% CP (CP replaced SBM), for 34 days. The chemical composition of the diets is presented in Table 1. Cricket powder (CP) was purchased from Bud's Cricket Powder (Harrison Food Group, LLC, Everett, WA).

Table 1. Diet composition

Ingredients (%)	Control	2% CP[(1)]
Corn	85.274	85.894
Soybean Meal	12.526	9.957
Cricket	-	2.000
Dicalcium Phosphate	0.404	0.491
Limestone	0.771	0.743
Salt	0.500	0.500
Vitamin[(2)]	0.375	0.375
Trace Mineral[(2)]	0.100	0.100

[(1)] CP = Cricket powder

[(2)] Vitamin-mineral premix supplied the following nutrients per kilogram of diet:
vitamin A, 5512 IU; vitamin D3, 2200 IU; vitamin E, 30 IU; vitamin K3, 2.2 mg;
vitamin B12, 27.6 µg; riboflavin, 4 mg; pantothenic acid, 14 mg; niacin, 30 mg; choline chloride, 400 mg; folic acid, 0.7 mg; thiamine, 1.5 mg; pyridoxine, 3 mg; biotin, 44 µg; Mn (MnO), 40 mg; Fe ($FeSO_4$·H2O), 75 mg; Zn (ZnO), 75 mg; Cu ($CuSO_4 \cdot 5H_2O$), 100 mg; I (KI), 0.3 mg; Se (Na_2SeO_3), 0.3 mg.

2.3 Animals and Management

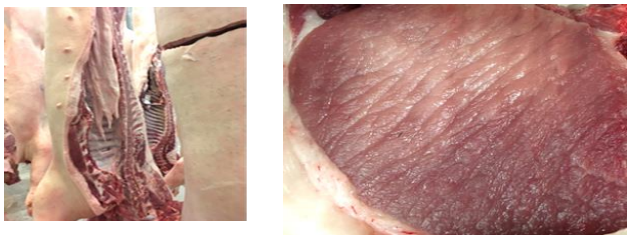
A total of eight (4 per treatment group) finishing hogs (Hampshire cross) were used in this experiment. Piglets were housed in an open-sided barn on concrete floors. Water and feed were provided *ad libitum*. After 34 days, pigs were harvested. Pigs, feed, and feeders were weighed weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and gain per feed ratio (G:F).

2.4 Carcass Composition

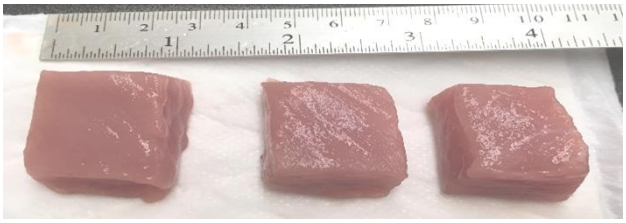
Hogs were slaughtered at the McNeese State University Center for Advancement of Meat Production and Processing (CAMPP), Lacassine, LA. Conventional carcass measurement were collected: loin eye area (LEA), 10^{th} rib back fat (BF), hot carcass weight (HCW), and dressing percent (DP).

2.5 Meat Sampling

Pork loin was removed from the right side of each carcass (Figure 1). The samples were transferred to food science laboratory, cut into 1-inch cubes, vacuum-packed, and placed in the refrigerator at 3°C until further analyzed.



a) b)



c)

Figure 1. Meat carcass: a) after slaughter b) pork loin between 10th and 11th ribs c) meat cut into 1-inch cube.

2.6 Sensory Evaluation

2.6.1 Consumer Acceptability

Using a 9-point hedonic scale, 14 trained panelists (3 males, 11 females) solicited from students and faculty in the McNeese State University School of Agricultural Sciences evaluated pork loin treatments. Each treatment was unpacked, cooked at 177°C for 20 minutes until internal temperature reached 62.8°C, and cut into 1-inch cube. The pork attributes were evaluated on appearance, color, flavor, tenderness, juiciness, and overall liking (9=like extremely, 8=like very much, 7=like moderately, 6=like slightly, 5=neither like nor dislike, 4=dislike slightly, 3=dislike moderately, 2=dislike very much, 1=dislike extremely) (Table 2). All samples were coded with three random digits. Panelists were required to cleanse their palates with water before and between tasting the samples.

Table 2. Hedonic scale

Parameter	9-point hedonic scale								
Appearance	1	2	3	4	5	6	7	8	9
Color	1	2	3	4	5	6	7	8	9
Flavor	1	2	3	4	5	6	7	8	9
Tenderness	1	2	3	4	5	6	7	8	9
Juiciness	1	2	3	4	5	6	7	8	9
Overall Liking	1	2	3	4	5	6	7	8	9

2.6.2 Acceptability and Purchase Intent

Each treatment was evaluated separately using a 2-point hedonic scale (yes/no). Using the acceptability and purchase intent questionnaire, consumers evaluated pork loin treatments for acceptability, whether they would purchase the product if commercially available, and whether they would purchase the meat if fed with cricket powder, which improves the protein content (Table 3).

Table 3. Acceptability and purchase intent questionnaire (n = 14) of pork loin treatments

	Control	2% CP
Acceptable		
Yes		
No		
Purchase		
Yes		
No		
Purchase if Fed CP		
Yes		
No		

2.7 Physicochemical Analyses

2.7.1 Crude Protein Analysis

Protein content was analyzed using the total nitrogen combustion method following the AOAC (2000). Samples were weighed (15-20 mg) and placed in a tared tin capsule. All treatments were loaded to an autosampler of NA2100 Protein Nitrogen Analyzer for combustion analysis.

2.7.2 Crude Fat Analysis

Crude fat was analyzed by following the procedure of the Soxtec Avanti 2050 Automatic System User Manual 1000 7414, Rev 3.0. Each sample was weighed (3 g) into tared thimble and placed into the condenser of extraction unit. Fifty milliliters (50 mL) of petroleum ether was added to each extraction cup. All extraction samples were analyzed with the Soxtec Avanti 2050 Auto Fat Extraction System.

2.7.3 Crude Fiber Analysis

Fiber content was determined using ANKOM^{200} Fiber Analyzer. A sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH) solution was prepared using separate 20 L carboy bottles with spigots and vacuum pumps. Samples were prepared, tared balanced, and placed in filter bags for analysis preparation. The filter bags were placed in the bag suspender tray. The H_2SO_4 solution was added to the ANKOM Fiber Analyzer vessel. The samples were agitated for 45 minutes at 100°C. Then, the filter bags were rinsed three times with hot water for 3-5 minutes each. Agitation and rinse steps were repeated with NaOH solution. Filter bags were removed from the bag suspender, placed in acetone for 2-3 minutes, and dried in the Gallenkamp prime oven at 105°C. After 2 hours, all samples were placed in a desiccant pouch bag and cooled to room temperature. The bags were weighed and recorded for crude fiber calculation.

2.7.4 Mineral Analysis

Mineral content was analyzed using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) techniques described by the Official Methods of Analysis (AOAC, 2000). For sample digestion, 0.5 g of each treatment was weighed and transferred to an acid washed volumetric flask. Twenty milliliters (20 mL) of 7:1 v/v nitric acid/perchloric acid was added to each flask and boiled until white fumes appeared. After the samples were cooled, 10 mL of deionized water was added, placed on hotplate, and heated until all samples turned into a liquid solution. All samples were filtered and analyzed by ICP-OES.

2.7.5 pH

Pork loin treatments were analyzed for pH with an electrode portable meter probe (Model 2000 VWR Scientific). Calibration of the pH meter was accomplished using pH 7 and pH 4 standardization buffers before use.

2.7.6 Moisture Content

Moisture content was determined according to the method of the Association of Official Analytical Chemists (AOAC, 2000). Each 3-5 g sample was dried in a hot air oven (Model 26 Precision Thelco) at 60°C for 24 hours. Samples were reweighed and recorded. Percent moisture was then calculated using the following formula:

$$\% \text{ Moisture content} = \left(1 - \frac{\text{dry basis}}{\text{wet basis}}\right) * 100 \quad (1)$$

2.7.7 Ash Content

Ash content was determined according to the method of the AOAC (2000). Samples were weighed (5 g) and placed into a tared crucible. Each sample was dried and ashed in a muffle furnace at 550°C for 12 hours, then transferred to a desiccator to cool. Samples were reweighed and recorded for ash content calculation.

$$\% \text{ Ash content (dry basis)} = \frac{\text{wt after ashing - wt of crucible}}{\text{original sample wt * dry matter coefficient}} * 100 \quad (2)$$

2.7.8 Color Testing

Color was measured at three different locations on each sample with a Minolta colorimeter (Model CR-10 portable) using an 8 mm aperture, 10° observer angle, D65 illuminant source in terms of L* lightness (white=100, black=0), a* redness (+40=red, -40=green), and b* yellowness (+40=yellow, -40=blue).

2.7.9 Lipid Oxidation (TBARS test)

The thiobarbituric acid-reactive substances (TBARS) method (Papastergiadis et al., 2012) was used to measure lipid oxidation. Fifteen grams (15 g) of each treatment with two replications was blended with 30 mL of trichloroacetic acid solution. The sample solution was filtered through Whatman No. 1 filter paper. Five milliliter (5 mL) aliquots of the filtrate were transferred to separate test tubes (in duplicate) and mixed with 5 mL of 0.02 M TBA. The mixture was vigorously agitated in a vortex and heated in a boiling water bath (100°C) for 45 minutes to develop a pink color. After cooling the reaction mixture under running water, the absorbance was determined at 530 nm using a Beckman Du-640 spectrophotometer against a blank containing 5 mL of distilled water and 5 mL of TBA reagent. The TBA values used to express the results were calculated from standard curves and known dilutions of tetraethoxypropane (TEP) and the results were expressed as mg malondialdehyde

(MDA)/kg sample.

2.8 Microbiological Analysis

Microorganisms were quantified using the standard of the AOAC (2000). Pork loin samples were assayed for three microorganisms: aerobic heterotrophs (AH), *Escherichia coli*, and *Enterobacteriaceae*.

2.8.1 Buffered Peptone Water

Eight hundred milliliters (800 mL) of buffered peptone water was prepared by mixing 8.0 g peptone powder, 4.0 g sodium chloride, 2.8 g dipotassium phosphate, and 1.2 g mono-potassium phosphate. All mixtures were boiled until dissolved and autoclaved at 121°C for 15 minutes. After sterilizing, buffered peptone water was cooled and stored in refrigerator at 3°C for further analyses.

2.8.2 Aerobic Heterotrophs (AH), Escherichia coli, Enterobacteriaceae Enumerations

Buffered peptone water was added as a diluent option for serial dilutions. Petrifilm™ Count Plates (3M™, U.S.) were used to enumerate (log CFU/g) aerobic heterotrophs (AH), *E. coli*, and *Enterobacteriaceae*. Samples were prepared with 1 g of sample mixed in 9 mL of peptone water. All samples were mixed with a vortex for one minute to release bacteria. Each 1 mL of sample/peptone water slurry was aseptically transferred and plated on the 3M™ Petrifilm™. All microbial enumerations were performed in duplicate. All films were incubated in a horizontal position, clear side up, and in stacks of no more than twenty at 37°C for 24 hours under aerobic condition.

2.9 Statistical Analysis

Data were analyzed by one-way analyses of variance (ANOVA) utilizing IBM Statistical Product and Service Solutions (SPSS) Statistics software to determine any significant differences with $p<0.05$. All data are presented as least squares means with standard deviation, and a significance level of $p<0.05$ was used for statistical analysis of means from two finishing pig treatments.

3. Results and Discussion

3.1 Carcass Performance

Pigs fed the control diet had greater ADG (1.03 kg/d) compared with pigs fed 2% CP (0.62 kg/d). However, there were no differences ($p>0.05$) in ADG, ADFI, G:F, LEA, BF, HCW, and DP regardless of treatments (Table 4). Both treatments had higher HCW compared to the average national 97.84 kg in 2022 (USDA ERS, 2023). Pigs fed 2% CP had lower LEA (60.84 cm^2) and greater DP (80.10%).

Table 4. Growth performance and carcass traits in finishing pigs fed cricket powder

Parameter	Control	2% CP
ADG (kg/d)	1.03 ± 0.09	0.62 ± 0.37
ADFI (kg)	3.58 ± 0.08	2.27 ± 0.07
G:F	0.13 ± 0.09	0.12 ± 0.01
LEA (cm2)	61.29 ± 0.92	60.84 ± 0.49
BF (cm)	2.29 ± 0.08	2.41 ± 0.25
HCW (kg)	124.06 ± 0.47	117.48 ± 0.74
DP (%)	78.21 ± 0.47	80.10 ± 0.88

No difference ($p>0.05$). Data represents the mean ± one standard deviation.

Means are two replications of pigs per treatment.

3.2 Sensory Evaluation

3.2.1 Consumer Acceptability

Using the 9-point hedonic scale, participants evaluated treated pork loin samples for appearance, color, flavor, tenderness, juiciness, and overall liking (Table 5). There was no difference ($p>0.05$) between treatments. The 2% CP treatment obtained the highest scores for appearance (6.04), color (6.07), flavor (6.36), tenderness (5.75), juiciness (5.71), and overall liking (6.29). Therefore, these results suggested that utilizing cricket powder in pig feed may enhance the sensory profile of cooked pork loin.

Table 5. Consumer acceptance scores for sensory attributes and overall liking (n = 14) of pork loin treatments

	Control	2% CP
Appearance	5.14 ± 2.14	6.04 ± 1.99
Color	5.21 ± 2.22	6.07 ± 2.18
Flavor	5.82 ± 2.04	6.36 ± 1.97
Tenderness	5.39 ± 2.36	5.75 ± 1.71
Juiciness	5.00 ± 1.83	5.71 ± 1.33
Overall Liking	5.71 ± 2.09	6.29 ± 1.61

No difference ($p>0.05$). Data represents the mean ± one standard deviation.

3.2.2 Acceptability and Purchase Intent

Consumers used the acceptability and purchase intent questionnaire to evaluate the pork loin treatments (Table 6). Treatments with 2% CP showed the highest scores of acceptability (85.71%) and purchase intent (71.43%).

Table 6. Acceptability and purchase intent questionnaire (n = 14) of pork loin treatments

	Control	2% CP
Acceptable	Number/Percentage	
Yes	10/71.43	12/85.71
No	4/28.57	2/14.29
Purchase	Number/percentage	
Yes	6/42.86	10/71.43
No	8/57.14	4/28.57
Purchase if Fed CP	Number/percentage	
Yes	7/50.00	7/50.00
No	7/50.00	7/50.00

3.3 Physicochemical Analyses

3.3.1 Nutrition Content

Pork loin samples were analyzed for nutritional content (Table 7). Adding 2% CP in pig feed improved the crude fiber (4.44%), iron (13.60 ppm), magnesium (0.03%), potassium (0.40%), and zinc content (21.50 ppm), which are essential in human total daily intake (Barraj et al., 2010).

Table 7. Nutrition content for pork loin treatments on "as is" basis[(1)]

Nutrition content	Control	2% CP
Protein (%)	23.90	21.40
Crude Fat (%)	2.26	1.04
Crude Fiber (%)	<0.50	4.44
Boron (ppm)	11.90	7.65
Calcium (%)	0.01	0.01
Copper (ppm)	<1.10	<1.00
Iron (ppm)	5.55	13.60
Magnesium (%)	0.02	0.03
Manganese (ppm)	<1.10	<1.00
Phosphorus (%)	0.18	0.21
Potassium (%)	0.34	0.40
Sodium (%)	0.03	0.03
Sulphur (%)	0.22	0.19
Zinc (ppm)	14.50	21.50

[(1)] Analyses completed at Louisiana State University Department of Agricultural Chemistry, Baton Rouge, LA.

3.4 Physicochemical Analysis

In this study, the physicochemical analyses were pH, moisture content, ash content, color testing and lipid oxidation. The results of physicochemical attributes are summarized in Table 8. Meat with 2% CP significantly

increased ($p<0.05$) pH (5.91), moisture content (73.03%), L* lightness (51.44), and a* redness (10.51). The pH values of both pork loin treatments were within the normal range of good quality fresh pork pH of 5.10-6.36 (Wright et al., 2005). Redness (a*) of meat is commonly used by consumers as an indicator of the freshness of the meat, the high redness values generally indicate fresher meat (AMSA, 2012). Adding 2% CP also had higher ash content (1.02%) and b* yellowness (11.19). The TBARS value is used to evaluate the lipid oxidation of meat; lower TBARS values are indicative of longer shelf-life for food. Meat with 2% CP had significantly ($p<0.05$) lower TBARS value (0.25 mg MDA/kg) compared to control treatment (0.32 mg MDA/kg). Hence, this study suggested that adding cricket powder in pig feed can extend freshness and shelf-life of meat.

Table 8. Physicochemical analysis of pork loin treatments stored at 3°C

	Control	2% CP
pH	5.87 ± 0.06^{a}	5.91 ± 0.05^{b}
Moisture (%)	68.96 ± 7.86^{a}	73.03 ± 1.95^{b}
Ash (%)	0.90 ± 0.44^{a}	1.02 ± 0.20^{a}
L*	48.63 ± 3.88^{a}	51.44 ± 5.46^{b}
a*	7.90 ± 1.84^{a}	10.51 ± 2.02^{b}
b*	10.56 ± 1.62^{a}	11.19 ± 2.22^{a}
TBARs (mg MDA/kg sample)	0.32 ± 0.07^{a}	0.25 ± 0.08^{b}

[a,b] LSMeans with different superscripts within a row are significantly different ($p<0.05$).
Data represents the mean ± one standard deviation. Means are two replications per treatment.

3.5 Microbiological Analysis

Microbial counts of pork loin treatments are shown in Table 9. No *E. coli* and *Enterobacteriaceae* were detected. Pork loin samples with 2% CP had significantly ($p<0.05$) lower aerobic heterotrophs of 2.18 log CFU/g than the control treatment of 2.72 log CFU/g. This may be due to chitin and chitosan derivatives in CP, which can kill pathogenic microorganisms by neutralizing negative charges on the microbial surface (Yan et al., 2021).

Table 9. Microbial testing (log CFU/g) of pork loin treatments stored at 3°C

	Control	2% CP
Aerobic heterotrophs	2.72 ± 1.14^{a}	2.18 ± 0.98^{b}
E. coli	*	*
Enterobacteriaceae	*	*

[a,b] LSMeans with different superscripts within a row are significantly different ($p<0.05$).
* = non-detectable. Data represents the mean ± one standard deviation. Means are two replications per treatment.

4. Conclusions

Utilizing insect products as alternative nutrient sources in feed is an effective substitution to provide high-quality protein and energy for swine production. Cricket powder (CP) is rich in protein, crude fiber, iron, magnesium, potassium, and zinc content, which are essential in human total daily intake. In this experiment, pigs fed 2% CP improved growth performance, carcass traits, pork quality and physicochemical characteristics. For sensory analysis, pork loin with added cricket provided higher sensory and acceptability scores, and lower microorganism growth.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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