主論文の要約

Study on novel feeding systems using coconut co-products in swine in the Philippines

（フィリピンにおけるココナツ由来副産物を用いたブタの新たな飼養体系に関する研究）

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The swine and coconut productions are two important agricultural industries in the Philippines. Pig is the top commodity among the livestock and poultry industries, which 65% of the pigs are kept by smallhold pig raisers. It is the second most important commodity next to rice because plays a major role in ensuring the country's food security by providing about 60% of the total animal meat consumption of Filipinos. On the other hand, Philippines is known to be the top producers of coconut and coconut based products and co-products in the world. The total area planted with coconut, in 2015 was 3.52 million hectares, which is about 26% of the total agricultural land covering 68 out of 81 provinces of the Philippines. Coconut is one of the top 5 commodities in the crop sector and coconut oil remained as the top agricultural export commodity in the Philippines, which accounts to 25% of the total agriculture exports. Together, the pig and coconut farming provide food and livelihood to many Filipinos and greatly contribute to the country's agricultural economy. Clearly, the importance of both pig and coconut industries, not only due to its economic contribution, but also to the Filipinos cannot be ignored.

However, despite of being dynamic and technologically advance, the pig production in the Philippines is still confronted with problems on low sow productivity and inefficiency of production brought by high cost of feed. The cost of feed accounts to about 70% of the total cost in animal production. Currently, because of the increasing cost of traditional ingredients (e.g. corn, soybean meal [SBM], wheat, fish meal etc.), the importance and use agricultural co-products as feedstuff for swine has increased. Thus, co-products of the coconut industry become more important to be used in animal feed. Philippines, as the top producer of coconut, alongside produced large volume of coconut co-products (CCP) which is being used as feed for pigs. Majority of these CCP include copra meal (CM) or copra expellers and white copra (WC), which are traditionally and mainly used as ingredient in making animal feeds. In 2015, Philippines topped the production of CM with 720 thousand metric tons of which about 44% were exported mainly to South Korea, Vietnam and India. The CM is considered as the largest locally available protein feed material in many tropical countries including Philippines. It is believed to contain high energy value because of its residual oil content. Thus, it is considered as an economical and valuable local feed for pigs that can be used to partially replace costly imported feed ingredients such as SBM. The WC is a co-product in the manufacture of virgin coconut oil (VCO). WC is also called coconut residue from VCO. The VCO is the natural oil obtained from fresh, mature kernel of the coconut by mechanical extraction. In the Philippines, the meal or residue were reported to contain a lot of oil about 35-48% fat content. The residue or WC are used as feeds or processed in high-value products. The use of WC as feed for pigs are becoming more popular. The protein enriched copra meal (PECM) is another co-product of the coconut industry. PECM is produced by subjecting raw CM in a solid-state fermentation process, using *Aspergillus niger* to increase the protein content. The crude protein (CP) of PECM ranges from 35 to 38% on a dry matter (DM) basis. Because PECM is a relatively new feedstuff, its feeding value needs to be established.

The CCP despite being available in the Philippines, data on nutrient compositions and feeding values of locally produced CCP in swine are very limited. This lack of data may lead to use of inaccurate nutrient values for CCP. Such situation will lead to inaccurate feed formulation if CCP is used in the mixed feed. This may affect the production efficiency of pigs. Feeding experiments and laboratory analysis, and use of highly specialized equipment are needed to generate data, but expensive.

This study aims to determine the nutritive value of CCP to effectively utilize in swine diets, and to develop novel tools to accurately predict the nutrient value of CCP. In this study, the physical characteristic such as color was used to develop tools such as prediction models to estimate the nutrient value in CCP. Special equipment called colorimeter was used to quantify the color. The principle in measuring instrumental color in CCP lies behind the fact that varying degree of heat treatment is applied to CCP during its production and this process results to differences in the physical color and nutrient composition in CCP. However, report showed that excessive heat treatment may lead to the Maillard reactions, a process that results to the destruction of amino acids and formation of the Maillard reaction products that are biologically unavailable.

In Chapter 2, samples were collected from different sources to establish the nutrient composition and physical characteristics (including instrumental color) of CCP and to develop equations to estimate nutrient composition in CCP. The result showed that wide variation in the chemical compositions was observed in 28 CCP, particularly the ether extract (EE), CP, and crude fiber (CF) content. Moreover, wide variation was observed in particle size and color values in CCP. This suggests that the differences in processing methods and source influenced the chemical composition and physical characteristics in CCP. There is a great possibility of using inaccurate nutrient values of CCP in making feeds, which may affect the growth of pigs. Prediction models were successfully developed to estimate the gross energy (GE) and CP using EE and ash, respectively. Moreover, essential amino acids (isoleucine, leucine, methionine, phenylalanine, threonine and valine) can be predicted using CP in CCP. The instrumental color was found useful to estimate the content of selected essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, tryptophan, threonine and valine) and other chemical compositions (GE, CP, EE, neutral detergent fiber [NDF]) in CCP.

In Chapter 3, an energy balance experiment using 22 growing pigs placed in a metabolism cage was conducted to determine the concentration of digestible energy (DE), metabolizable energy (ME) and net energy (NE), and to develop prediction equations for DE and ME in CCP fed to growing pigs. The CCP used were CM, PECM and WC, which were obtained from different sources in the Philippines. A total collection of feces and urine method using marker to marker approach as described by Adeola (2001) was used in the experiment. The samples of CCP, diets, feces and urine were collected and analyzed in the laboratory. The DE and ME concentrations of CCP diets and ingredients were calculated. The NE of diets and ingredients were estimated using published prediction equation. The DE, ME and NE concentrations differed among CCP and ranged from 1,843 to 3,284, 1,666 to 3,211, and 1,008 to 2,352 kcal/kg DM, respectively. This may be due to differences in the residual oil and fiber content observed in CCP samples. Moreover, the differences in the processing method and source may influenced the digestibility of energy in CCP. A positive correlation was observed between the DE and ME and acid detergent fiber (ADF) using 8 CCP samples (excluding WC samples). The DE and ME, NE concentrations differ among CCP sources fed to growing pigs. Moreover, DE and ME values in CCP can be predicted using ADF as independent variable. Lastly, instrumental color cannot be used to estimate the digestibility of DE and ME in CCP fed to growing pigs.

In Chapter 4, a feeding experiment using 22 growing pigs was conducted to determine the apparent total tract digestibility (ATTD) and standardized total tract digestibility (STTD) of phosphorus (P) and calcium (Ca) in CCP fed to growing pigs, and to develop prediction equations to estimate ATTD and STTD of P and Ca. The CCP used were CM, PECM and WC, which were obtained from different sources in the Philippines. The samples of CCP, diets and feces were collected and analyzed in the laboratory. The digestibility of P and Ca in CCP were calculated. The ATTD and STTD of P and Ca among CCP sources were not significantly different when fed to growing pigs. This suggests that the digestibility of P and Ca values in CCP are not influenced by the source and processing method used in the production of CCP. The STTD P and ATTD Ca in CCP may be best predicted using total P and Ca as independent variables, respectively. However, it was found that instrumental color cannot be used to estimate the digestibility of P and Ca in CCP fed to growing pigs.

In Chapter 5, a feeding experiment using 6 pigs (surgically equipped with T-cannula in the distal ileum) was conducted to determine the apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of amino acids in CCP and SBM fed to growing pigs, and to develop equations to estimate SID of amino acids in CCP. The CCP used were: 1) CM, 2) WC, 3) oven-dried CM (ODCM, oven-dried at 150°C for 30 min) and 4) PECM which were obtained from different sources in the Philippines. The ileal digesta of pigs were collected, freeze dried and analyzed for CP and amino acid contents. The AID and SID of most amino acids were not significantly different among pigs fed diets with different CCP sources. The concentration of standardized ileal digestible CP and amino acids in CCP were less than SBM. This suggest that the variation in CP and amino acids among CCP sources were not enough to make significant differences. The standardized ileal digestible arginine, glutamic acid, and tyrosine in CCP were negatively correlated with CP. The standardized ileal digestible lysine and proline were negatively correlated with a* value. The lower standardized ileal digestible lysine in ODCM is most likely due to heat damage (oven-drying at 150°C for 30 min) as a result of the Maillard reaction. Moreover, CP and a* value can be used as independent variable to estimate standardized ileal digestible arginine and lysine, respectively, in CCP fed to growing pigs. Lastly, instrumental color can be used to estimate the standardized ileal digestible lysine in CCP fed to growing pigs.

In conclusion, the present study has successfully established the chemical composition and physical characteristics, determined the digestibility values of energy (DE, ME, NE), P and Ca (STTD of P and ATTD of Ca), and the digestibility of amino acids (SID of amino acids) in locally produced CCP. Moreover, this study has developed prediction equations to estimate nutrient composition and feeding values in CCP. Lastly, instrumental color was found useful to estimate the GE, CP, EE and NDF contents, the total arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, tryptophan, threonine and valine, and the standardized ileal digestible lysine in CCP fed to growing pigs, using the prediction models developed. The established nutrient values and the novel tools developed for CCP in this study are expected to maximize the utilization of CCP as an alternative feedstuff in swine diets.