creative commons
COMMONS DEED

저작자표시-비영리-변경금지 2.0 대한민국

이용자는 아래의 조건을 따르는 경우에 한하여 자유롭게

- 이 저작물을 복제, 배포, 전송, 전시, 공연 및 방송할 수 있습니다.

다음과 같은 조건을 따라야 합니다:

저작자표시. 귀하는 원저작자를 표시하여야 합니다.

비영리. 귀하는 이 저작물을 영리 목적으로 이용할 수 없습니다.

변경금지. 귀하는 이 저작물을 개작, 변형 또는 가공할 수 없습니다.

- 귀하는, 이 저작물의 재이용이나 배포의 경우, 이 저작물에 적용된 이용허락조건을 명확하게 나타내어야 합니다.
- 저작권자로부터 별도의 허가를 받으면 이러한 조건들은 적용되지 않습니다.

저작권법에 따른 이용자의 권리는 위의 내용에 의하여 영향을 받지 않습니다.

이것은 이용허락규약(Legal Code)을 이해하기 쉽게 요약한 것입니다.

Disclaimer

dCollection

A Dissertation
for the Degree of Doctor of Philosophy

Effects of Dietary Cashew Nut Testa as an Alternative to Wheat Bran in Swine Diet

양돈사료 내 소맥피 대체원료로서의 캐쉬넛피의 첨가효과

February, 2017

By
Hong, Young Gi

School of Agriculture Biotechnology
Graduate School, Seoul National University

Effects of Dietary Cashew Nut Testa as an Alternative to Wheat Bran in Swine Diet

양돈사료 내 소맥피 대체원료로서의 캐쉬넛피의 첨가효과

지도교수 김 유 용

이 논문을 농학박사 학위논문으로 제출함
2017년 2월

서울대학교 대학원 농생명공학부
홍 영 기

홍영기의 농학박사 학위논문을 인준함
2017년 2월

위 원 장 ______________________ (인)

부위원장 ______________________ (인)

위　　원 ______________________ (인)

위　　원 ______________________ (인)

위　　원 ______________________ (인)

Overall Summary

Effects of Dietary Cashew Nut Testa as an Alternative to Wheat Bran in Swine Diet

These experiments were conducted to evaluate the 1) effects of dietary cashew nut testa (CNT) as an alternative ingredient on growth performance and carcass quality of growing-finishing pigs, 2) effects of dietary CNT levels as an alternative of wheat bran in gestating sow and 3) effect of dietary CNT supplementation levels on nutrient digestibility in gestating sows.

Experiments I. Effects of dietary cashew nut testa as an alternative ingredient on growth performance and carcass quality of growing-finishing pigs.

This experiment was performed to assess the effect of different level of CNT in growing-finishing pig diets on growth performance, blood profile and carcass characteristics. A total of 160 crossbred pigs ([Landrace X Yorkshire] X Duroc) with an average body weight of 28.05 ± 8.47kg were used for 12 weeks feeding trial for grower and finisher in Seoul National University Experimental Farm. Pigs were allotted to one of four treatments with 4 replicates and 10 pigs per pen in randomized completely block (RCB) design based on sex and initial body weight. Treatments were: 1] CON: corn and SBM based diets which met requirements of NRC (1998) + 0% CNT, 2] C2: CON + 2% CNT, 3] C4: CON + 4% CNT, and 4] C6: CON + 6% CNT. There was no significant difference in average daily gain (ADG) among treatments, but ADFI showed linear response in growing Ⅰ (P=0.02) and finishing Ⅰ phase (P=0.04), respectively. Feed efficiency in growing Ⅰ phase showed significant linear difference and quadratic response as the amount of CNT increased (linear, P<0.01; quadratic, P=0.02). Total cholesterol concentration was decreased by addition of CNT during the whole experimental period. There were no significant differences in BUN, creatinine, insulin and glucose concentration during 12 weeks of experiment. No significant differences were observed in WHC, cooking loss and shear force of pork as the level of CNT supplementation. In economic efficiency, feed costs per gain during whole experiment (0-12 week) were lower in the order of C6, C2, CON and C4. Consequently, this experiment demonstrated that addition of 6% CNT can be supplemented in growing-finishing pig diet without any negative effects on growth performance, pork quality and feed cost.

Experiments II. Effects of dietary cashew nut testa levels as an alternative of wheat bran in gestating sow

This experiment was performed to determine the effects of dietary cashew nut testa (CNT) instead of wheat bran as an ingredient on reproductive performance, litter performance, milk composition, and blood profiles of sows in gestation. The experiment was started when sows were on their 35 days of pregnancy with an initial average body weight (BW) of 211.53 ± 3.52 kg. 40 multiparous sows (Yorkshire × Landrace) were allotted to one of four treatments based on BW, backfat thickness and parity in 10 replicates. Treatments were as followed: 1] C0: corn-SBM based diet, 2] C2: basal diet with 2% CNT, 3] C4: basal diet with 4% CNT, and 4] C6: basal diet with 6% CNT. Experimental diet (gestating diet) contained 3,265 kcal of ME/kg, 12.90% crude protein, 0.74% lysine, 0.20% methionine, 0.90% calcium, and 0.70% total phosphorus, respectively. Other nutrients were met or exceeded NRC requirement (1998). There were no significant differences in body weight, body weight change, backfat thickness, and backfat thickness changes of gestating sows at 35 day, 70 day, and 110 day, 24 hour after parturition and 21day of lactation among treatments. But the body weight change of lactating sows tended to decrease linearly (P=0.09) and the daily feed intake of

sows tended to increase (P=0.09) during lactation. The quadratic response was observed in weaning to estrus interval (WEI) after weaning (P=0.02), and the treatment added 2% of CNT (C2) showed the shortest WEI among treatments. Total born alive piglets were 10% higher in C2 and 12.5% higher in C4 treatment, respectively compared to control treatment. Litter birth weight (P = 0.04) and piglet weight (P = 0.01) after cross-fostering were reduced by addition of CNT in diet. However, litter weight gain and piglet weight gain had no significant differences in 21 day of lactation. In milk composition, the percentage of fat (p = 0.03), lactose (p = 0.02) and total solid (p = 0.03) in 24 h postpartum showed a quadratic correlation with the increasing CNT level during gestation while lactation progressed showed no correlation. Along with the increasing CNT level in diets, insulin concentration at 70 d of gestation was reduced linearly (p = 0.03). Consequently, there were no negative effects of addition of 4% CNT instead of wheat bran in gestating sow. Consequently, 4% of CNT supplementation instead of wheat bran in gestating sows diet could be acceptable as an alternative ingredient.

Experiments III. Effect of dietary cashew nut testa supplementation levels on nutrient digestibility in gestating sows

This experiment was conducted to evaluate the effect of cashew nut testa (CNT) supplementation levels on nutrient digestibility and its availability in gestating sows. A total of 20 gestating sows (Yorkshire × Landrace, at d 90 of gestation) with initial BW of 252.61 ± 24.69 kg, BF thickness (P_2 position) of 23.4 mm and average parity 6.5 was used in a digestibility trial. Sows were allotted to one of four treatments in a completely randomized design (CRD) by their body weight, backfat thickness and their parity. Treatments were: 1] C0: corn-SBM based diet, 2] C2: basal diet with 2% CNT, 3] C4: basal diet with 4% CNT, and 4] C6: basal diet with 6% CNT. Experimental diet (gestating diet) contained 3,265 kcal of ME/kg, 12.90% crude protein, 0.74% lysine, 0.20% methionine, 0.90% calcium, and 0.70% total phosphorus, respectively. Other nutrients were met or exceeded

NRC requirement (1998). There were no significant differences in BW and BF thickness at initial and final days of trial by dietary CNT level. Increasing the supplementation of CNT level decreased digestibility of dry matter (linear, P=0.03), crude protein (linear, P=0.04), ether extract (linear, P=0.05) in gestating sows. Also, crude fiber, ADF and NDF digestibility tended to decease linearly by increase of dietary CNT level (linear, P=0.07; linear, P=0.06, linear, P=0.02, respectively). These results indicated that nutrients digestibility was lowered as dietary CNT level was increased, but body weight and backfat thickness of sows were not affected by dietary CNT during gestation.

Contents

List of Tables

Chapter II

Chapter III

Chapter IV

Chapter Ⅴ

List of Figures

Chapter II

List of Abbreviation

ADG	average daily gain
ADFI	average daily feed intake
BUN	blood urea nitrogen
BW	body weight
CNT	cashew nut testa
CRD	completely randomized design
DDGS	Distiller's dried grains with solubles
DE	digestible energy
DM	dried matter
G:F	gain to feed ratio
GLM	general linear model
Ig	immunoglobulin
IU	international unit
Lin	linear response
LSD	least significance difference
MCP	mono-calcium phosphate
ME	metabolizable energy
MUFA	monounsaturated fatty acid
NE	net energy
NSP	non starch polysaccharide
PUFA	polyunsaturated fatty acid
Quad	quadratic response
RCBD	randomized completely block design
RCN	raw cashew nut
SBM	soybean meal
SEM	standard error of mean
VFA	volatile fatty acid
WHC	water holding capacity

Chapter I. General Introduction

Since the early 2000s, when biodiesel production increased in the United States, the price formation in international grain market has become unstable. The price of major source of animal feed such as corn, soybean, and wheat surged to double. Although now it may be stabilized, the price tends to rise significantly again.

Corn and soybean meal are the most important raw materials for swine feed, and these two raw materials have a significant impact on the prices of other raw materials. The request for these two raw materials has increased sharply with the rapid growth of developing country such as China, India, and other south east countries. However, fluctuations of world grain prices are very short term in nature.

Korea has highly industrialized after some decades of rapid growth, however its agriculture industry is hampered by a lack of cultivated land. Instead of encouraging agriculture, the Korean government has imported various agricultural products, while they focused on developing manufacturing industry for fast development. Therefore, Korea has been heavily dependent on imported food and feed grains. According to the 2016 report of Korea feed association, about 97% of feed grain that Korean feed companies used was imported grain in first quarter of 2016. Moreover, main ingredients are corn and soy bean meal in swine diets. That`s why Korean feed and livestock market could get serious damages from instable international feed grain market. Even Koran feed industry is inevitably susceptible to exchange rate and freight rate.

According to the report from Dutch swine association, the feed prices are too high in Korea. Feed cost reaches at least 70% of the pig production. Since the proportion of feed cost is too high among total cost in swine farm, it is vital to find new ingredient in Korean swine feed sector. The most important interest of swine farmers in Korea is the way reducing feed cost. Many alternative feed sources have been introduced, but the successful incorporation of these non-conventional nutrients source into animal diets is limited because of insufficient information on nutritional quality of these resources. These ingredients should meet the need of cost and quality both.

Wheat bran, gluten feed, and rice bran are commonly used in swine feed diets as fiber source in Korea. However these materials are quiet limited in use due to their high contents of fiber. But it is growing interest in high fiber swine feed recently. Inclusion of high-fiber source in sow feed may influence on reproductive performance and welfare of gestating sows by reducing stereotypic behavior (Meunier-Salaun et al., 2001). Also, as the technique of enzyme developed, more interests of these materials have been increased.

There have been many researches about alternative ingredients for main raw materials such as corn and soybean meal to reduce feed price, but it is hard to find the study of alternatives for by-products such as wheat bran and gluten feed in swine feed. It is important developing alternative raw materials which can replace by-products include brans, because prices of bran is also linked to that of the main raw material.

Cashew has been cultivated essentially for food and medicine purposes by using the whole cashew fruit, the apple and the kernel (Dendena, 2015). Cashew nuts are abundant sources of essential minerals and rich in “heart-friendly” monounsaturated-fatty acids like oleic and palmitoleic acids. Increasing demand for cashews and government effort to promote cashew cultivation have led to increase in cashew nut area and production. It has grown at a rate of 4.97%/year since 2001.

Cashew nut testa (CNT) is a by-product obtained during the process of cashew nut. It has not been considered as an ingredient in swine feed due to its high contents of fiber and difficulty of collecting. However, as the processing plant has been modernized and enlarged, it became easier to use CNT in various ways (Armstrong, 2011). This ingredient contains high level of hydrolysable tannins and polyphenols (Dendena, 2015), so it has been used as a vegetable tanning material.

As the industry of cashew nut developed gradually and supply of cashew nut testa increased, cashew nut and byproducts are interested in as an alternative ingredient in feed industry. As the price of international grain raised, the supply and price of bran became unstable (Armstrong, 2011). Therefore, it was necessary to study new ingredients that can replace conventional ingredient like bran, especially wheat bran in swine diet.

Consequently, three experiments were conducted to evaluate CNT that one of the byproduct of cashew nut as an alternative ingredient in swine feed. 1) to investigate effects for different levels of CNT supplementation on reproductive performance in gestating sows, 2) to determine cashew nut bran as an alternative of wheat bran in grow and finishing rations for swine, and 3) to investigate digestibility of cashew nut bran in gestating sows.

Chapter II. Literature Review

1. Alternative feed sources in swine diet

Because feed costs comprise about 65% of the pork production, feeding is the highest costly item on pig farm (Armstrong, et al., 2012) and feed costs play a major role in determining the profitability of a swine farm (Stein and Lange, 2007).

While corn and soybean meal have been used as a major ingredient for supplying nutrients in swine feedstuff, there are a lot of optimal alternatives that may meet nutritional requirements (Stein and Lange, 2007). These alternatives may reduce the cost of the feed. Also, these can replace corn and soybean meals cost effectively when their price rise due to shortage (DiCostanzo, 2003). The major nutrient components are protein and energy in the swine feed. Traditionally grains included corn, wheat and barley are the source of energy, while byproducts from oilseeds such as soybeans supply protein (Lardy and Anderson, 2009).

Seasonal variability seriously affects the price of these feed ingredients in global and local markets (Kamalzadeh et al., 2008). It is needed to evaluate the nutritional value and cost effectiveness of diverse feed ingredients to produce a nutritionally well balanced diet at a least cost (Allen et al., 2006)

Various alternative ingredients have potential of cost effectiveness and balanced nutrients (Stein, 2007) and these ingredients are produced by the food industries include grain milling, baking, distilling, packing and rendering, fruit and vegetable, vegetable oil, milk, egg and meat processing (DiCostanzo A., 2007). These by-products are able to be used in feed to meet the nutrient requirement with reduced cost (Bogges et al., 2007). The by-products from these industries can gradually replace many parts of the energy and protein supply in swine diets (Stein, 2007). The proper amount to use in swine diet depends on the cost, quality and volume of supply. The quality included amino acid profile, digestibility, palatability, contents of anti-nutritional factors, and condition of storage (Bogges et al., 2007).

1.1 Anti-Nutritional Factor

Anti-nutritional factors are substances that when present in animal feed or water reduce the availability of one or more nutrients (Yacout, 2016). Paul R. (1987) demonstrated that one of the important criteria in selecting feed ingredients for manufacturing complete and supplemental feeds relate to the presence of anti-nutritional factors, which can significantly reduce the nutritional value of feeds. These factors interfere with the utilization of dietary nutrients in a variety of ways, including reducing protein digestibility, binding to various nutrients of damaging the gut wall and thereby reducing digestive efficiency (Dublecz, 2011). These anti-nutritional factors include trypsin inhibitors, tannins, lectins, gossypol, saponins, polyphenolic compounds, phytate, alkaloids, or glucosinolates. Anti-nutritional factors can be divided into four groups (Francis et al., 2001)

Ⅰ. Factors affecting protein utilization and digestion (e.g., protease inhibitors, tannins and glucosinolates)

Ⅱ. Factors affecting mineral utilization (e.g., phytate, gossypol pigments, oxalates and glucosinolates)

Ⅲ. Antivitamins

Ⅳ Miscellaneous (e.g., mycotoxins, mimosin, cyanogens, nitrate, alkaloids, photosensitizing agents, phytoestrogens and saponins).

Therefore anti-nutritional factors should be considered prior to decide to use new ingredient in swine diets.

1.2 Palatability

Palatability of feed, including taste and texture, refers to the acceptability by the pig and is often quantified by relative responses of feed consumption compared to other diets (Frendrick and Heughten, 2003). The palatability of feed ingredient is strongly related to the experience of animal in taste and the determinants of palatability is not only associated with eating but also the senses of smell (Atwood et al., 2016). Therefore many factors may affect the palatability of feed ingredient and it should be a factor to consider when using alternative feed ingredients to formulate swine diets (Bellaver and Easter, 1998).

1.3 Nutrient Variability

Feed ingredients vary considerably in their nutrient content not only across ingredients but also potentially within a single feed ingredient (Lackey, 2004). Due to the variability of nutrient it is more difficult to use and guarantee that the feed is properly balanced (Lackey, 2004). Managing nutrient variability among by-product sources is the primary challenge to obtaining accurate nutrient loading values for use in feed formulation (Shurson, 2007). Repeated testing of samples should be conducted prior to assess nutrient variability in an alternative feed ingredient (Shurson, 2007).

2. The fibrous source as an alternative ingredient

2.1 Introduction

Using alternative ingredient in swine diet can be an economical choice, however the nutritional value of the raw material should be evaluated (Thaler and Holden, 2001). Before using alternatives, an examination on the nutritive value in terms of their metabolizable energy, nutrient content and palpability needs to be examined (Alimon, 2009). Especially, many grain byproducts contain high level of fiber that known as the factor decrease digestibility of nutrient in mono-gastric animals (Thaler and Holden, 2001). Fiber is an important component for animal but it is resistant to digestion by endogenous enzymes in the small intestine, thereby becoming the main substrate for bacterial fermentation in the large intestine and caecum (Knudsen, 2001).

The Agricultural Research Council (1967) demonstrated that increasing the percentage of crude fiber in the swine diet depressed the growth of pig: for every 1% additional crude fiber in the diet, a 2% decrease in growth could be expected. Also, it is well known that adding fiber in diets can increase voluntary feed intake of pigs and the soluble NSP of fiber sources increase luminal viscosity that is considered as a major determinant of delayed absorption (Kyriazkkis and Emmas, 1995). That`s why fibrous ingredient was avoided in the swine feed industry even though its economic benefit in the past (Woyengo, Beltranena and Zijlstra, 2014).

However, the shortage of main raw materials such as corn and soybean meal led to consider using alternative ingredient, and many researchers have conducted to evaluate the nutritive value of dietary fiber (Stein, 2007). Trowell (1976) defined the dietary fiber as ‘the sum of lignin and the polysaccharides that are not digested by the endogenous secretions of the digestive tract’. This dietary fiber have a profound effect on gut size and development especially in the large intestine (Hong, 2009) Also, the Agricultural Research Council (1967) showed

14~17% of the VFA in the large intestine arose from the fermentation of dietary fiber source and these VFAs play a part energy supply in the large intestine. Some research has demonstrated that fibrous sources may have a positive impact on manure nitrogen retention, odor production, aerial pit emissions, and volatile fatty acid production (DeCamp et al., 2001). These fibrous ingredients are therefore a tremendous potential of swine diet (Stein, 2007).

2.2 Wheat bran

As a by-product of the dry milling of wheat into flour, wheat bran is one of the major alternative ingredients used in animal feed industry. Like many other byproducts of the food industries, wheat bran contains more fiber than corn and soybean meal, which may adversely affect digestibility of nutrient (Huang et al., 2015). Wheat bran is a fluffy, low-density feed that is similar in nutrient content to oats and it has one-half the density of corn or wheat and about four times the phosphorous content of most grains (Thomas, 2015). It contains relatively high level of vitamins such as niacin, thiamin, and riboflavin (Stevensen, 2012).

Wheat bran generally contains about 15% protein, 0.6% lysine, 0.18% tryptophan, and 1.15% phosphorus (Thaler and Holden, 2001). However, they recommended wheat bran in sow diets around farrowing as a laxative agent due to its low ME value. Increasing the inclusion of wheat bran in a corn-soybean meal based diet reduced energy and nutrient digestibility and heat production as well as DE, ME, and NE of diets, but values for DE, ME, and NE for wheat bran determined using the difference procedure were not different from values determined using linear regression (Jaworski et al., 2016).

Darith (2011) stated 35 percent of wheat bran could be utilized effectively as basal diet for growing finish-pig which started from 50kg to 100kg. Pigs fed added wheat bran (5-10-15-20%) and those fed the basal diet gained similarly, but 40% wheat bran (5.8% crude fiber) signigicant1y reduced rate of gain (Hines, 1980).

Inclusion of wheat bran into piglet diet might decrease the number of pathogenic E. coli and reduce the outbreak of post-weaning diarrhea (Francisco, 2010). Inclusion of what bran, either fine or coarse, significantly ($P<0.05$) decreased E. coli numbers in the ileal digesta (Molist et al., 2010). Using of wheat bran has an additional benefit because the SCFA in ileal digesta would be higher (Francisco, 2010). Furthermore, the treatment can increase the availability of wheat bran (Kraler et al. 2014). For example, fermentation as well as extrusion improves the nutritional value of wheat bran. However, fermentation of wheat bran seems to be the more potent than extrusion (Kraler et al. 2014).

2.3 Soy Hull

Soy Hull is consisted of the external part of the kernel and obtained by residue during oil extraction when the soybeans are heated and crushed (Butolo, 2002). It has about 75% of non-starch polysaccharides (NSP) and over 60% of them are insoluble in nature (Lo, 1989). Some studies have shown that soy hull has an important tool to reduce total N and ammonia in mature, reducing the environmental pollution, that is increasing current social problem (Decamp et al., 2001, Keys and Wood, 2001)

Gentilini et al. (1997) found values of 2,233 kcal of DE/kg and 2,188 kcal/kg of ME for raw soy hull, and 2,248 kcal of DE/kg and 2,164 kcal of ME/kg, for toasted soy hull. Many studies have demonstrated the possibility of soy hull use in swine diets, even though it has some limitations (Bowers et al., 2000; DeCamp et al., 2001). Levels up to 10% have not caused impairment in the swine performance (Keys and Wood, 2001), although it may reduce the digestibility of some nutrients (Dilger et al., 2002; Moeser and Kempen, 2002).

There was no negative impact when pigs were fed on 6% soy hull diets in finishing and on 12% soy hull diets in growing and finishing pigs (Lima et al., 1997). Also, their results showed that the economic use of soy hull in growing and finishing pig diets reached up to 6 % since this alternative ingredients cost up to 20% of soybean meal (Lima et al., 1997)

Soy hull`s high contents of fiber has also been shown to have some drastic effects on nutrient digestibility like that of protein and energy (Jacela, 2007). Thus, its recognized potential use in pigs has been mainly in sow diets to increase gut-fill in sows during gestation (Jacela, 2007). However, according to Stewart (2013), carcass yield was reduced as the level of soy hulls increased in fishing diets. This result is similar to previous research that increasing levels of dietary fiber leads to greater gut fill and an increase in digestive tract tissue weights, thus causing a reduction in carcass yield and hot carcass weight (Jacela, 2007). So, their suggestion is removing or reducing the level prior to marketing should be practiced, similar to feeding practices with other fibers ingredients (Stewart, 2013)

2.4 Rice Bran

As the staple food in Asian country, the global production of rice exceeds 700 million tons per year and it is the main source of carbohydrates for humans worldwide (USDA, 2016). After milling of rice, around 65~72% of the grain is recovered as polished rice, which is used for human consumption and then 28~35% of the remaining may be used in animal feeding (Singh et al., 2013). The remaining includes rice hulls, rice bran, and broken rice (Singh et al., 2013).

Rice bran primarily consists of the outer layers of the grain (Campabadal et al., 1976). This ingredient usually includes the pericarp, seed coat and aleurone, as well as most of the germ (Kaufmann et al., 2005). Rice bran is categorized as full fat rice bran or defatted rice bran that contains approximately140g/kg and 35g/kg ether extract, respectively (NRC, 2012). It is known that the available energy of rice bran is high and its concentration of crude protein ranges from 150g/kg in full fat rice bran to 173g/kg in defatted rice bran (NRC, 2012).

It is generally used in animal ration in the East and South East of Asia where the rice is consumed as the staple food (USDA, 2016). Due to its high content of energy, rice bran had received attention as a source of oil for human consumption (Calvert et al., 1985). There have been many efforts to evaluate the chemical composition of rice bran, however, this ingredient originated from many different rice cultivars and grown in diverse conditions may differ in chemical composition (Majun and Payne, 1977). Different milling process also can affect the composition of rice bran (Kaufmann et al., 2005).

Rice bran contains a high level of non-starch polysaccharides (NSP), primarily arabinoxylan and cellulose (Singh et al., 2013). NSP`s can hold a large amount of water, together with dissolved nutrients and reduce not only nutrient availability, but also voluntary feed intake (Goodyear et al., 2015). NSP is known that it may decrease nutrient digestibility and thus limit the inclusion of rice bran in swine diets (Bogges, 2007).

Inclusion of 20% of full fat rice bran substantially reduce the digestibility of both crude protein and dry matter in the small intestine by around 9% in a corn-soybean meal based diet, however adding NSP enzyme may enhance the availability of rice bran (Jin 2002). Yin et al. (2000) showed adding a xylanase based enzyme product to ration gave substantial improvement in digestibility of rice bran.

Calvert (1985) suggested that limit the rice bran in the growing-finishing ration to 25 percent or less. Both full fat rice bran and defatted rice bran might be included in diets fed to weanling pigs from 2weeks post weaning by at least 20% without compromising growth performance (Calvert 1985). It is suggested extrusion to improve stability of rice bran because it is easily oxidized due to its high level of fat contents (Chae and Lee, 2002).

2.5 Distiller`s Dried Grains with Solubles

Distiller`s dried grains with solubles (DDGS) is produced from the fuel ethanol industry and is available for inclusion in diets fed to swine (Stein, 2007).

This ingredient has become the most famous and economical alternative feed raw material for use in animal diets not only for swine but also poultry and ruminant diet (Stein 2007). Production of U. S. ethanol has been stimulated by higher oil prices and the influence of the Energy Policy of 2005 and the Energy Independence and Security Act of 2007 (Government Printing Office, 2006 and 2007). With an increase in the number of new ethanol plants, which produce DDGS as a co-product, the availability and attractiveness for use of DDGS swine diets also has increased (Hastad., et al, 2005).

Corn is two thirds starch, and during the fermentation and distillation processes, the starch is converted to ethanol and One bushel of corn produces approximately 2.6 gallons of ethanol, 17 lbs. of CO_2, and a wet spent-mash (Thaler, 2002). Its high energy, moderate protein and lysine content, along with its relatively high concentration of phosphorus and digestibility (50 to 68%), make it an excellent partial replacement for corn, soybean meal, and inorganic phosphate in swine diets (Shurson 2007).

DDGS has shown low lysine relative to its lever of crude protein and tryptophan is the second limiting amino acid after lysine, so should be monitored when using more than 10% corn DDGS in swine diets (Shurson, 2007). The apparent ileal digestibility coefficient for lysine was 53.6% for golden colored corn DDGS and the lysine digestibility coefficient for a dark colored corn DDGS source was 0% (Whitney et al., 2000). These results demonstrate that golden colored DDGS sources have much higher digestibility of lysine and other amino acids compared to darker colored and heat damaged DDGS sources (Whitney, 2000).

DDGS can be added to swine diets without adverse effects on performance or carcass quality, but these recommendations assume that high quality DDGS is free from mycotoxins and diets are formulated on a digestible amino acid and available phosphorus basis (Shurson, 2007). Whitney and Shurson (2004) showed that if diets are formulated in a digestible amino acid basis, using up to 25% DDGS in piglet diets will result in equivalent growth performance compared to feeding a diet containing no DDGS as long as the pigs weigh at least 7 kg when DDGS diets are initially fed. But, growth rate and feed intake may be reduced if DDGS is added to diet of pigs weighing less than 7 kg (Whitney and Shurson, 2004).

Wilson et al. (2003) showed that DDGS can be fed to gestating sows at an inclusion rate of up to 50% without negative effects on the pigs. In their experiment, inclusion of DDGS in the diets of gestating sows did not show any adverse effect in lactation feed intake, litter weight gain, and reproductive cycle (Wilson, 2003). Also, Stein (2008) reported that feeding DDGS to lactating sows at diet inclusion rates from 15% to 30% showed no negative effects. Thus, DDGS can be included in diets of gestating sows at inclusion rates of up to 50% and in diets of lactating sows at inclusion rates of up to 30% if diets are formulated based on concentrations of digestible energy, amino acids, and phosphorus (Stein, 2008).

Adding DDGS to grower-finisher diets does not affect muscle quality, eating characteristics, and shelf life of pork, but can negatively affect belly and pork fat quality, especially if inclusion rates over 20% (Xu et al., 2010a). Corn DDGS contains over 10% of vegetable oil, and this oil composed of about 60% of linoleic acid which is long-chain fatty acid (Shurson, 2010). Feeding diets containing high contents of unsaturated fatty acids such as linoleic acid can reduce fat firmness and increase the amount of unsaturated fatty acids in pork fat (Xu, 2010). Results from two studies where DDGS was fed to grower-finisher pigs showed that belly thickness was linearly reduced when increasing levels of corn DDGS were added to the diet (Stein 2007).

2.6 Palm Kennel Meal

Palm kennels are the seeds of the oil palm tree, which can be obtained by cracking the nuts that remain after the palm oil has been extracted from the fruits (Hartley, 1988). The palm kernel co-products such as palm kernel expellers and meals are co-products from the kernels of oil palm fruits after oil removal by chemical or mechanical extraction (Sulabo et al., 2013). This contains low energy density, poor amino acids profiles, and high fiber containing relatively high soluble fiber, such as β-mannans and glucomannans that may affect animal gut health compared with conventional feed ingredients (Pluske et al., 2002). However, it contains considerable amounts of oil.

Palm kernel meal has become a famous feed raw material, with its world production figure in 1993 put at 3.63 million tons (Dutch Commodities Board for Animal Feeding stuffs, 1993). This is abundant in tropical region and there have been many attempts to use it for livestock (Onwudike, 1986). However, due to its high fiber content and low palatability it had been usually only in ruminant animal feed rather than non-ruminant until early in 2000 (Pluske et al., 2002).

There are two processes in the extraction of palm kernel oil; expeller press and an indigenous local technique that employs hydrothermal techniques to extract the oil (Boateng et al., 2008). These two different methods of extraction lead to variation of nutritional value of palm kennel meal (Boateng, 2008). The chemical analyses have showed huge variations in chemical composition attributed to, and among others, the source, the extent and method of oil removal (Rhule, 1996; Carvalho et al., 2005).

Nwokolo (1977) indicated that up to 30% level of Palm kennel meal could be incorporated into broiler starter ration without any adverse effects on growth rate, while Yeong et al, (1981) compared levels from 0 to 30% and recommended 15% level in broiler feed.

Palm kennel meal has been reported to contain anti-nutritional factor β-mannan that hinders the full utilization of nutrients by monogastric animals (Pluske et al., 2002). To address this problem, many studies on the effect of enzyme supplementation of palm kennel meal in monogastric animal feeding has been carried out (Oluwafemi, 2008).

The degradation of β-mannans in palm kennel meal by a sufficient enzyme to mannose would release the sugars that could be absorbed and metabolized by monogastric animals (David, 1997). The supplementation of β- mannanase to pigs tended to show the better growth performance (Hong, 2009). No any negative effects on nutrient digestibility when weaned pigs were fed palm kennel meal (Seo, 2015).

2.7 Copra meal

The coconut palm is one of the most useful tropical trees and is used for food, beverage, shelter, and animal feed and it is grown industrially for the edible and highly saturated oil contained in the flesh of its fruits (Elias et al., 2005). The main coconut by-product is the copra meal. Depending on the oil extraction method, the oil residue in the marketed product ranges from 1 to 22% (Göhl, 1982).

This by-products can be a good candidate for alternative feedstuffs because of the relatively low price and good nutrient composition compared with corn and SBM (Agunbiade et al., 1999). But, its high concentration of non-starch polysaccharides (NSP) such as mannan may limit the use in swine diets and the protein in copra meal is low in lysine and histidine (Kwon, 2015). Copra meal contains between 12 and 16% crude fiber and about 45% total dietary fiber (Göhl, 1982). Concentrations of β-mannans, galactomannans, arabinoxylogalactans, and cellulose are relatively high and its water binding capacity is much greater compare to palm kernel meal (Balasubramaniam, 1976).

Previous studies demonstrated that supplemental NSP-degrading enzymes could improve the nutrient digestibility in swine and poultry diets (Yin et al., 2000; 2001). Increase in the ME content and a nutrient digestibility improvement of copra meal treated by β-mannanase in broiler diets (Khanongnuch et al., 2006). 20% of copra meal can be used in the diet of grower-finisher pigs, however its performance might depend on the formulation (O`Doherty, 2000).

This ingredient may be included in growing and finishing diets by up to 30% without affecting growth performance (Grieve et al., 1966). Moreover, copra meal can be used by up to 50% in growing-finishing diets if diets are supplemented with synthetic AA or proteins with higher quality (Thorne et al., 1988). In weaning piglet diets from 2 weeks post-weaning, the growth performance was linearly reduced when copra meal was included in the diet and pigs fed diets containing 15% copra meal gained approximately 1 kg less over a 3-wk period than pigs fed a control diet without copra meal (Jaworski et al., 2014).

3. General information of Cashew

3.1 Cashew nut

The cashew, botanically known as *Anarcadium Occidentale* is native to northeast Brazil in the 16th Century and it is known that Portuguese traders introduced it to Mozambique and coastal India, however just a soil retainer to stop erosion on the coasts (Encyclopedia Britannica, 2016). The cashew tree is evergreen and it grows up to 12 meters high and has a spread of 25 meters and it has extensive root system which can allow it to tolerate a wide range of moisture levels and soil types (Africa Agro Service, 2016). This is a multipurpose tree crop with great economic importance to third world countries such as Brazil, Vietnam, Nigeria, Philippines, Sri Lank and etc. (Adeigbe O.O., 2015). However, only about 60-65% of the total African cashew production is utilized in food and feed industry according to Fetuga et al. (1974).

According to Training Manual on Cashew Production & Management (Agribusiness System Assistance Program), cashew is a drought resistant crop. It can grow successfully in areas with a very distinct dry season or where the annual rainfall is as low as 50 and it can likewise grow well in areas with high levels of rainfall (as much as 350 cm annually) provided the soil is well-drained

(Encyclopedia Britannica, 2016).

The two major producers of cashew nut are Brazil and India and they produce 200,000 ton and 120,000 ton per year respectively (Fetuga et al., 1974). The third largest global source is Africa producing about 100,000 ton while the raw cashew nuts are processed in many of the producing countries (Spore, 1997; Olunloyo, 1996), only about 60-65% are useful for edible purposes and the rest are discarded as broken or scorched kernels (Fetuga et al., 1974).

The nut (kennel) is a major commercial product of the cashew tree and it is used for a cocktail delicacy or in the food industry for the ingredient of biscuits, ice creams and chocolates (Adenikinju et al., 1989). Its pulped fruit can be used for juice, alcohol, jams and pies, however due to its unfamiliar taste, 95% or more of the apple crop is not eaten in the main producing areas of East Africa and India (Mitchell and Mori, 1987).

3.2 Global perspective

Though Brazil is the native country of cashew, it gained greater popularity in India, Vietnam and other African countries than Brazil itself (Mole 2000). CASHEW HANDBOOK 2014 stated that Africa produces 42% of the estimated 2.6 million tons of raw cashews every year and it exports 90% to the rest of the world, retaining the rest for domestic produce. And Vietnam had become the largest cashew kernel exporter in 2006 and has been successfully holding on to its position until now. They export over 250,000 tons of cashew kernels per year (CASHEW HANDBOOK 2014).

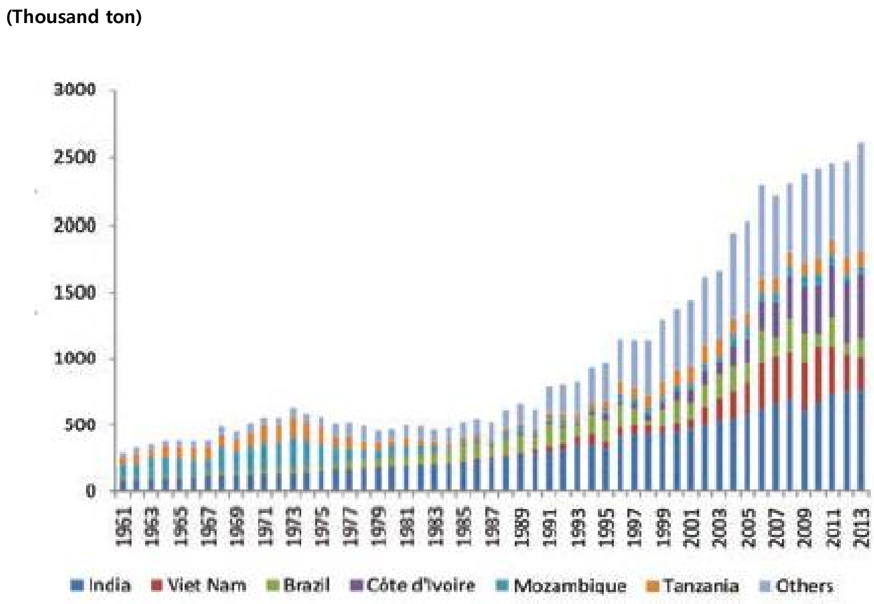

Figure 1. Trend in RCN production over the years in major cashew growing regions (adapted from CASHEW HANDBOOK 2014)

Global cashew nut production has grown at a rate of 4.97 per cent since 2001 but the area is growing by only 2.56 % (cashewinfor.com, 2014). Increasing demand for cashews and government effort to promote cashew cultivation have led to increase in cashew nut area and production. However, Brazil, native country of cashew, has shown negative growth rate due to drought periods during last decade (Mole 2000).

The global area and production during last decade recorded lower growth rate compared to 1991-2000 (FAO, 2013). Global raw cashew area is likely to be 4,509 thousand ha from the current 4,588 thousand ha, a 1.73% decrease according to forecast (FAO, 2013). However, global RCN production is projected at 3,049 thousand tons by 2017 from the current levels of 2,600 thousand tons with an increase of 17.25% (Cashew Handbook 2014).

3.3 Cashew products and by-products: uses and processing

Cashew has been cultivated essentially for food and medicine purposes by using the whole cashew fruit, the apple and the kernel (Dendena, 2015). Since the World War II, further values have added to cashew due to the exploitation of a major by-product, the cashew nut shell liquid, which has then been extensively used for industrial applications (Azam-Ali and Judge, 2001).

Table 1. Projected RCN area and production till 2017 (CASHEW HANDBOOK 2014)

Year	Area (ha)	Production (thousand ton)
2000	3,241	1,359
2001	3,209	1,423
2002	3,501	1,598
2003	3,502	1,652
2004	3,761	1,929
2005	4,086	2,014
2006	4,312	2,292
2007	4,147	2,335
2008	4,114	2,311
2009	4,155	2,454
2010	4,218	2,481
2011	4,403	2,515
2012	4,464	2,572
2013	4,588	2,600
2014	4,485	2,795
2015	4,513	2,879
2016	4,529	2,964
2017	4,509	3,049

3.3.1 Cashew nut processing

Cashew processing techniques have developed over the years, with the improvement of automation at some levels of the processing chain, as well as the diversification of facilities across countries to meet environmental conditions and production capacities (Dendena, 2015). The main purpose of processing is the extraction of the kernel from the shell and the most difficult problems in shelling cashew nuts are due to the irregular shape of the nut, the harsh leathery shell, and the cashew nut shell liquid within the shell (Asogwa, 2008). These things should not be allowed to pollute the nut during processing nor compromise the safety of the worker. There are many processing systems available now but, all systems follow the five major steps (Fitzpatrick 2011).

1. Preparation

In the raw nuts, there are many kinds of foreign matter including sand, stones, and dried apple etc. These foreign matter in the roasting operation can be avoided by cleaning the nuts. The raw nuts can be sieved by hand using mesh sieve. To avoid burn out them during the roasting process, soak the nuts in water and then their moisture may increase up to 15 to 25%.

2. Removal of the shell

This process can be performed either by cracking or manual or machinery cutting. Manual cutting coupled with steam cooking has been found to give the highest percentage of complete cut (up to 99%). Removing the shell by using a knife has long been the traditional method as a manual cutting and it is still used in many small size processing sites. Automatic cutting is performed in highly automated plants by using a shelling machine (Dendena, 2015).

3. Peeling

This step is to remove the testa that is made brittle. This is the step required to remove the testa that is made fragile and easy to peel by heating or roasting the nuts. The oven air drying is followed by a steam thermal shock performed in steam chambers. Peeling is then done with compressors, often coupled with manual finishing in order increasing the rate of fully peeled nuts (Fitzpatrick, 2011).

4. Grading

After peeling kernels are graded as their size and color. It is conducted manually or automatically by machines. In this process, drum or roller grader is used for selecting whole nuts.

5. Packing

Kernels are cleaned with aspirators and packed by vacuum packing and gas flushing in order to extend the shelf life of the processed nuts (Fitzpatrick, 2011).

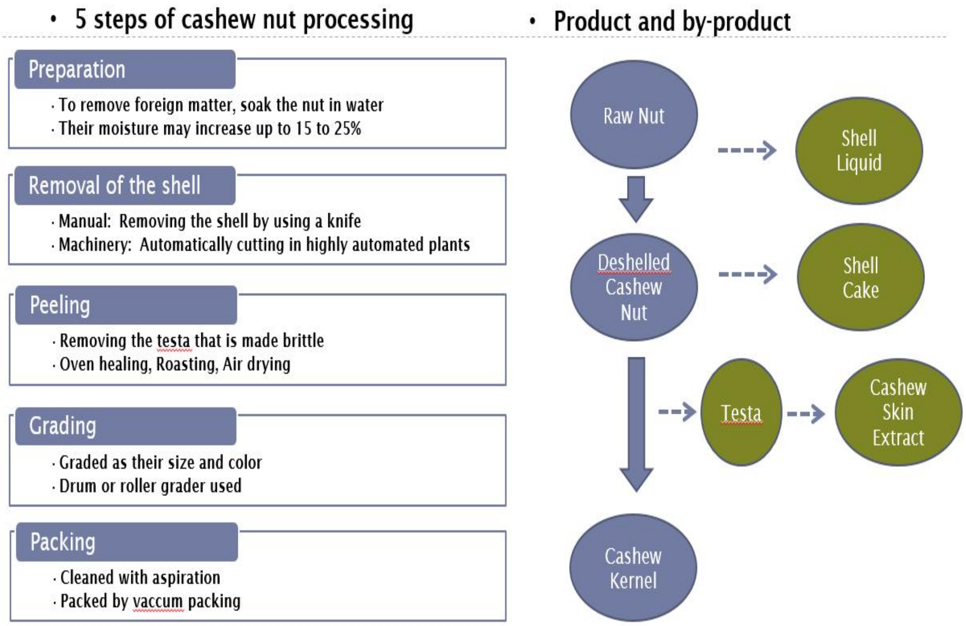

Figure 3. Snapshot of cashew nut processing reporting: phases of the processing flow (left column), processing options reported in literature (mid column), and products and by-products resulting from processing steps (right column) (adapted from Asogwa et al. (2008) and Fitzpatrick (2011))

3.3.2 Cashew kennel

The main product of cashew is kennel. It has been estimated that about 60% of cashew nut is consumed in the form of snacks, mostly roasted and salted (Dendena, 2015). The remaining 40% is instead used in snacks and bakery products, often as a substitute for peanut and almond (Azam-Ali and Judge, 2001).

Cashews are not only one of the good-tasting and most versatile nuts, but they also come loaded with health benefits (Johnson, 1973). Cashews nutrition benefits include the ability to improve heart health, support healthy brain functioning, and improve digestion and nutrient absorption. And it might be able to help losing weight (Pribis, 2014).

Cashew consumption has increased in recent years in most Western countries. Generally, nuts are repeatedly ranked as some of the healthiest foods due to an important addition to human diet in order to prevent a wide range of chronic diseases (Pribis, 2014). One of the best things about cashews is that they taste great in both sweet and savory recipes (Panda, 2013).

Cashew nut and its byproducts supply a complex food rich in macro and micronutrients, as well as small quantities of antioxidants and bioactive compounds that are relevant to many health beneficial attributes (Alasalvar and Shahidi, 2008). In these bioactive compounds there are MUFA, PUFA, phenols, phytosterols, phytostanols, tocopherols, and phytates (Armstrong et al., 2012).

One of the key factors of cashews nutrition is its healthy fat content (Ryan et al., 2006). Cashews are primarily made up of unsaturated fats in the form of monounsaturated fatty acids and a smaller proportion of polyunsaturated fatty acids (Nandi, 1998). About 62% of the cashew's fats are monounsaturated fat, 18% polyunsaturated fats and the rest a mix of saturated fats (Nandi, 1998). Frequent cashew consumption can decrease risks associated with heart disease, including high cholesterol, high blood pressure and obesity (Alasalvar and Shahidi, 2008). Cashews are believed to have beneficial effects on oxidative stress levels, inflammation and vascular/arterial activity that promotes a healthy heart (Lim, 2012).

Table 2. Nutritive Value in 100 g of Cashew Nut (FAO Document Repositor)

Item	Contents
Moisture, %	5.9
Total Minerals, %	2.4
Total Fiber, %	1.3
Energy. %	785
Protein, %	24
Total Fat, %	64
Saturated, %	12.9
Unsaturated (Oleic), %	36.8
Unsaturated (Linoleic), %	10.2
Carbohydrate, %	41
Ca, %	53
P, %	52.2
Fe, %	5.3
Thiamin, %	0.63
Riboflavin, %	0.19
Niacin, %	2.5
Beta-carotene, %	60
Retinol Equivalent	33 IU; 10mg
Vitamin K	650 IU

3.3.3 Cashew apple

The cashew apple has various uses and applications. It is used as processed as far more widespread than as a raw fruit, which is restricted to South America (Dendena, 2015). Its high level of vitamin C has diffused its use and its juice is fivefold richer than citrus and fourfold richer than sweet orange (203.5 mg/100 ml of juice versus 33.7 and 54.7, respectively) (Akinwale, 2000). Its sugar content was observed to vary between 10 and 30% (Azam-Ali and Judge, 2001). It contains high level of minerals, mainly calcium and phosphorus and it also contains small proportions of tannins (up to 0.35 %) that confer an astringent flavor to the fruit (Nair, 2010).

The residues of cashew apple juice extraction are nitrous because they contain 9% protein, 4% fat, 8% crude fiber, and almost 10% pectin and they are used to various products such as candies, jam, and drinks (Akinwale, 2000). Also, cashew vinegar, candy and jam, canned apple, cashew apple chutney, cashew pickles, and a wide variety of soft drinks are obtained from cashew apple (Nair, 2010). Since it is thought to heal diarrhea and prevent cholera, cashew apple has also been traditionally used for its medicinal properties (Azam-Ali and Judge, 2001).

Since cashew apple contains high sugar, its juice has been found to be suitable as a source of reducing sugars for fermentative and enzymatic processes aimed at producing lactic acid, dextran, and oligosaccharides (Silveira et al. 2012), as well as for ethanol production (Pinheiro et al. 2008).

3.3.4 Cashew nut shell liquid

The outer shell waste represents around 70% of the raw nut weight and contains up to 30–35% of shell liquid (Das et al., 2004). Cashew nut shell liquid is very important by-product derived from cashew processing, due to its distinctive chemical characteristics that make it a worthy source for unsaturated long chain phenols (Quirino et al., 2014). The chief applications of the cashew nut shell liquid are in the polymer industry, where it is used as a chemical compound in brake linings, varnishes, paints and surface coatings (Kumar et al., 2002). Cashew nut shell liquid-derived polymers supply more flexibility resulting in products easier to process compared to usual phenolic resins (Kumar et al., 2002).

Cashew nut shell liquid has other characteristics such as termite and insect resistance (Lubi and Thachil, 2000). This characteristics makes these resins suitable for use in agriculture (Kumar et al., 2002), and its antimicrobial properties extend their uses to the medical area (Himejima and Kubo, 1991). The extensive applicability of cashew nut shell liquid proposes that this material is a prominent bio-based compound that could possibly reduce the environmental effects of the plastic and composite industry, while it is maintaining economic advantage (Quirino et al., 2014).

Table 3. Physiochemical characteristics of cashew nut shell liquid (Akinhanmi et al., 2008)

Parameter	Value
Refractive index	1.686 ~ 1.693
Specific gravity	0.924 ~ 0.941
Viscosity (30℃)	41 ~ 56
Moisture (%)	3.9 ~ 6.7
Ash (%)	1.2 ~ 1.3
Saponification value (mg KOH/g)	47.6 ~ 58.1
Iodine value (mg/100g)	215 ~ 235
Acid value (mg/KOH/g)	12.1 ~ 15.4
Free fatty acid (mg KOH/g)	6.1 ~ 7.8

3.3.5 Cashew nut testa (skin extract)

Cashew kernel is covered by a skin which is color of a reddish-brown. This skin was reported to be rich in hydrolysable tannins, as well as in polyphenols, for which the content can be as high as 243 mg/g of cashew skin extract (Dendena, 2015). Among these compounds, especially epicatechin were found to have outstanding antioxidant properties, as proved by the scavenging activity of the cashew skin extract in antioxidant assay test (Kamath and Rajini, 2007).

The other studies that aimed to test this ingredient treatment against dimethoate exposure showed same findings. This prevalent organophosphorus pesticide has been stated that cause hyperglycemia and pancreatitis, the latter likely due to oxidative stress (Banerjee et al. 2001).

Cashew skin extract was proved to ameliorate and restore tissue antioxidant status in rat pancreases and confer normal glucose tolerance, therefore this ingredient can be a promising source for natural antioxidants (Kamath et al. 2008). It is because ethanolic extract of cashew nut skin has substantial antioxidant activity in various antioxidant assay systems (Banerjee et al. 2001).

3.3.6 Cashew shell cake

After the removal of nut shell liquid, there remain shell cake which is now used as fuel in cashew processing factories and in shell liquid extraction plants (Nair 2010). Its calorific value is higher than sawdust and cow dung, it was found to be about 17.8 MJ/kg (Mohod et al, 2008). However, it is used with limitation because of its loose form, which fumes out acidic gases while it burn down, therefore, cashew shell cake was tested as a mixture with other waste materials and it was proven to be effective with sawdust, cow dung and wheat flour (Fitzpatrick, 2001).

Mohod et al. (2008) stated this mixtures provide fuel with excellent energy density ratio, low water absorption properties, and better durability. It means it has good resistance to shock and so increasing the ease of management and carrying (Mohod et al, 2008) Therefore, the using of cashew shell cake as fuel is an additional opportunity for improving the energetic self-reliance of cashew processing plants because of its extensive availability and low cost (Nair, 2010).

3.3.7 Cashew bark

As it have been widely reported in many literature, the bark of cashew tree has been traditionally used medical use (Freitas and Paxton, 1996). It has astringent characteristics and rich in tannins, which makes it extensively applicable for relieving hypertension, gastric disorders, and inflammations (Mota et al., 1985). Also, it has bactericidal ability (Akinpelu, 2001) and hypoglycemic activity that gives the possibility of using bark extract to treat diabetes mellitus (Alexander-Lindo et al., 2004). In recent years, the methanolic extract of cashew stem bark was known to have anti-mutagenic effects, then it may prevent DNA damage against possible mutagenic compounds. However, it is needed to study further to make clear the potential use of cashew bark extract in medicine (Barcelos et al., 2007)

3.4 Inclusion of cashew products in animal diet

3.4.1 Introduction

Due to the high cost of production in developing countries, there is an absolute need to find the possibility of using agro-industrial by products and wastes such as discarded cashew nut-waste (Marcel, 2011). While the raw cashew nuts being processed in many of the producing countries (Olunloyo, 1996), only around 60-65% of products are suitable for human food and the rest are discarded as broken or burned kernels (Fetuga et al., 1974).

Several researches have been conducted in many countries to show the nutritional value of cashew nut meal, cashew apple and its by-products in animal industry (Agbede, 2003). They found out the chemical compositions of these agricultural products and establish their nutritional value (Mohod et al., 2008).

3.4.2 Evaluation of nutritional quality of dried cashew products

Several studies have determined the chemical composition of cashew nut and its by-products (USDA, 2004). These studies have shown that cashew nut meal extracted from whole kernels contains about 42% crude protein, about 1% fat, 1.3% crude fiber and 0.5 and 0.2% calcium and phosphorus, respectively. It has excellent quality protein containing 4.6% lysine, 1.3% tryptophan, 2% cysteine and 1.6% methionine (Stamford et al., 1988). Given the chemical composition of the dried flour of cashew waste, this product can be used for animal consumption (Stamford et al., 1988). Roasted cashew nuts contain less toxicant including chelators of bone minerals (Edet, 2007).

Other analytical data shows that the rejected cashew nut could be important alternative protein (whole cashew nut meal: 34%; defatting rejected cashew nut: 45.5%) (Aletor et al., 2007). Also, it can be used as an energy contributors to compound non ruminant animal feed (Aletor et al., 2007). Cashew apple is rich source of vitamin C, organic acids, antioxidants, minerals and carbohydrates (Sivagurunathan et al., 2010).

3.4.3 Cashew by-products in ruminant diet

Even though its high oil content, discarded cashew nuts, usually called cashew nut meal can be used at relatively high levels in ruminant diets (Pimentel et al., 2007). Pimentel et al. (2007) demonstrated that the amount of RCN up to 24% (7 kg/day) could be included in the concentrate to supplement sugarcane-based daily rations. This could be included up to 50% dietary level in a total mixed ration based on corn silage (Pimentel et al., 2007). In these two experiments, cashew nut inclusion did not change milk yield in comparison to the control diet (Pimentel et al., 2007). The use of cashew nuts in the ration did not affect rumen fermentation parameters and cashew nut included at 20% in dairy cow diets in the north-eastern Brazilian semi-arid conditions decreased the interval between post-partum and first ovulation (Brasil, 2003).

Cashew bagasse has a low *in vitro* DM digestibility, probably due to its high fiber and lignin content (Pereira et al., 2016). Ensiling up to 36% cashew bagasse with elephant grass silage enhanced the nutritive value (Ferreira et al., 2004) and treating cashew bagasse with urea improved its nutritive value (Dendena, 2015).

Cashew nut shells used about 20% in West African dwarf goats fed on elephant grass-based diet resulted in lower feed intake, lower nutrient digestibility coefficients, and lower daily weight gain and degraded feed conversion ratio. There was no impact on blood parameters, even at 30% dietary level, and could reduce feed costs (Ocheja et al., 2014).

It has been known that cashew nut shell liquid can decrease methane emissions from ruminants (Kobayashi, 2012). *In vitro* experiment demonstrated that it could favorably alter rumen microbes and inhibit methane production (Kobayashi, 2012).

It is known that cashew tree leaves are not a good supplement because they contain a high level of tannins and lignin, which explains the low values observed for DM intake and DM digestibility in goats (Reddy and Elanchezhian, 2008).

3.4.4 Cashew by-products in swine diet

Cashew nut meal could be fed at up to 6% level to post-weaning pigs (6 to 12 week-old) without harmful effect on growth performance (Yao et al., 2013). In growing pigs (12 to 24 week-old), including more than 5% cashew nut meal in the diet resulted in lower feed intake, lower daily gain and lower final live weight though it had no harmful effect on health parameters (Yao et al., 2013). It was suggested that cashew nut meal could partly replace maize in the ration (Yao et al., 2013). An experiment concluded that cashew nut meal could be included in the diets of weaner pigs to replace soybean meal at up to 10% level without harmful effect on growth performance (Fanimo et al., 2004). Up to 30% of inclusion rate of cashew nut meal had no harmful effect on animal performance and reduced feed costs (Oddoye et al., 2011). Diets including cashew nut meal produced better performance than groundnut meal diets in fattening pigs (Fetuga et al., 1974).

In Nigeria, cashew nut oil meal could be included to diets if growing pigs up to 28% dietary level and these pigs show better feed intake and better N retention than those fed on ground meal (Fetuga et al., 1974).

Fattening pigs might be fed on 20% cashew apples or dried cashew apples when it used as a supplement to a mixed ration made of rice bran, maize meal and fish meal (Acero et al., 2013). Growth performance was not significantly different from those obtained with the control diet, so feed costs could be significantly reduced (Acero et al., 2013). Cashew bagasse might be fed to growing pigs at up to 20% dietary level (Farias et al., 2008). Compared to soybean meal or sorghum, cashew bagasse had low protein digestibility and low energy digestibility which resulted in low metabolizable energy (1051 kcal/kg) and reduced metabolizable energy of the diet (3225 kcal/kg vs. 4125 kcal/kg) (Farias et al., 2008).

Armstong demonstrated (2011) that CNT could be fed at up to 15% dietary level in rats used as a model for pig feeding. However, increasing CNT in the diet resulted in decreased feed intake, water intake, lower live weight gain and lower efficiency of feed utilization, and it was suggested that optimal level would be only 5% inclusion (Donkoh et al., 2012). In Nigeria, CNT is used as a protein source and substitute ingredient for ground nut meal (Adesehinwa et al., 2004). This included at 25% dietary level each in the diet of growing pigs (19 kg LW) and it showed no deleterious effect on growth performance (Adesehinwa et al., 2004). However, the inclusion of CNT in finishing pig diet resulted in degraded feed conversion ratio, reduced carcass yield, bacon thickness and fat: meat ratio. By contraries, it increased feed costs therefore it was subsequently not recommended (Pinheiro et al., 2000).

3.4.5 Tannin effects in animal diet

It is known that tannins are very complex and water-soluble polyphenolic compounds (Koleman, 2008). Tannins are defined as water soluble polymeric phenolics that precipitate proteins (Haslam, 1989). They are usually subdivided into four groups: hydrolyzable tannins, condensed tannins, phloro tannins and proanthocyanidins (Koleman, 2008). Hydrolyzable tannins are gallic acid and ellagic acid esters of core molecules that consist of polyols such as sugars and phenolics such as catechin (Lei et al., 2001). Tannic acid works as antibacterial properties reduce gastrointestinal parasites and diarrhea (Songer, 2005). Multiple reports demonstrated the efficacy of tannins or plant extracts in the control of zoonotic pathogens like campylobacter and salmonella (Niezen et al., 1995).

Tannin has several beneficial effects such as antioxidant effect and improving animal performance (Koleman, 2008). However, they also have anti-nutritional substances that reduce the digestibility of nutrients and performance in livestock animals (Smulikowska et al., 2001). High concentration of ta nnins may reduce feed intake due to its astringent taste, but tannins at optimal level in diets can improve digestive utilization of feed (Frutos, 2004).

Excessive use of tannins in livestock animals can bring negative effect (Waghorn, 1994). Addition of less than 5% of tannin in swine feed can lead to decreasing growth rate because it can damage mucosal lining of the GI tract, alter excretion of certain cations and inhibit protein digestion (Reed, J. D., 1995). More than 5% of tannins can often cause mortality (Reed, J. D., 1995).

4. Literature Cited

Acero L. H., C. G. Lagan and M. A. C. Padul. 2013. Growth performance of fattening hogs fed with freshe and dried cashew apple. Int. Pro. Chem., Biol. Enc. Eng. (IPCBEE). 51: 23-27.

Adenikinju S. A., E. B Esan and A. A. Adeyemi. 1989. Nursery techniques, propagation and management of cacao, kola, coffee, cashew and tea. In: Progress in tree crop research in Nigeria, 2nd edn. CRIN, Ibadan. 224.

Adesehinwa A. O. K and B. K. Ogunmodede. 2004. Performance and serum metabolites of growing pigs fed diets containing 'dusa' and cashew nut testa as protein source. Indian J. Animal Sci. 74: 1136-116.

Africa agro service. 2016. *http://www.africagro.com/products.htm.* (2016.10.11).

Agbede J. and V. A. Aletor. 2003. Evaluation of fishmeal replaced with protein concentrate from Glyricidia in diets for broiler-chicks. Int. J. Poult. Sci. 2: 242-252.

Agbo, N. W. 2008. Oilseed meals as dietary protein sources for juvenile Nile Tilapia (*oreochromis niloticus L.*). Ph.D. Dissertation. University of Stirling, Scotland, UK.

AGRICUTURAL RESEARCH COUNCIL, 1967. In the Nutrient requirement of farm livestock No. 3: Pigs, pp. 56-63. Agricultural Research Council; London.

Agunbiade, J., et al. 1999. Energy and nutrient use of palm kernels, palm kernel meal and palm kernel oil in diets for growing pigs. Anim. Feed Sci. Technol. 80: 165-181.

Akinpelu D. A., 2001. Antimicrobial activity of Anacardium occidentale bark. Fitoter 72: 286–287.

Akinwale T. O., 2000. Cashew apple juice: its use in fortifying the nutritional quality of some tropical fruits. Eur Food Res Technol. 211: 205–207.

Alasalvar C. and F. Shahidi. 2008. Tree Nuts. Nutraceutical Science and Technology 9: 166:2-8.

Aletor O., J. O. Agbede, S. A. Adeyeye and V. A. Aletor. 2007. Chemical and physio-chemical characterization of the flours and oils from whole and rejected cashew nuts cultivated in southwest Nigeria. PJN. 6: 89-93.

Alexander–Lindo R. L., E. S. A. Morrison and M. G. Nair. 2004. Hypoglycaemic effect of stigmast–4–en–3–one and its corresponding alcohol from the bark of Anacardium occidentale (cashew). Phytother Res. 18: 403–407.

Alimon A.R. 2009. Alternative raw materials for animal feed. Makalah diterima. Faculty of Agriculture Universiti Putra Malaysia.

Allen L., B. Benoist, O. Dary and R. Hurrell. 2006. Guidelines on food fortification with micronutrients. WHO and FAO. 197.

Armstrong D., V. Attoh-Kotoku, R.O. Kwame and R. Gascar. 2012. Evaluation of nutritional quality of dried cashew nut testa using laboratory rat as a model for pigs. The Scientific World J.10: 1100-5.

Asogwa E. U., L. A. Hammed and T. C. N Ndubuaku. 2008. Integrated production and protection practices of cashew (Anacardium occidentale) in Nigeria. Afr J Biotechnol 7: 25.

Atwood S. B, F. D. Provenza, R. D. Wiedmeier and R. E. Banner. 2016. Influence of free-choice vs mixed-ration diets on food intake and performance of fattening calves. J. Animal Sci. 12: 3034-3040.

Azam-Ali S.H. and E. C. Judge. 2001. Small-scale cashew nut processing. Rugby, UK: Food and Agriculture organization – FAO.

Balasubramaniam K. 1976. Polysaccharides of the kernel of maturing and matured coconuts. J Food Sci. 41:1370–1373.

Banerjee B. D., V. Set and R. S Ahme. 2001. Pesticide-induced oxidative stress: perspective and trends. Rev Environ Health. 16: 1–40.

Barcelos G. R. M., F. Shimabukuro, M. P. Mori, M. A. M. Maciel and I. M. D. S. Cólus. 2007. Evaluation of mutagenicity and antimutagenicity of cashew stem bark methanolic extract *in vitro*. J Ethnopharmacol. 114: 268–273.

Barnes, J. A., M. D. Tokach, J. M. DeRouchey, R. D. Goodband, S. S. Dritz and J. L. Nelssen. 2013. Effects of standardized ileal digestible tryptophan: lysine ratio in diets containing 30% dried distillers grains with solubles (DDGS) on finishing pig performance and carcass traits. J. Anim. Sci. 91:3244-3252.

Bellaver C. and R. A. Easter., 1998. Evaluation of swine diet formulation based on amino acid digestibility estimates. Pesquisa Agropecuaria Brasileira.

Boateng M, D. B. Okai and A. Donkoh. 2008. Palm kernel cake extraction and utilisation in pig and poultry diets in Ghana. Livestock research for rural development 20.

Boggess M., H. Stein and J. DeRouchey. 2007. Alternative feed ingredients for swine rations. National Pork Board.

Bowers K. A., C. T. Herr, T. E. Weber, D. Smith and B. T. Richert. 2000. Evaluating inclusion levels of soybean hulls in finishing pig diets. Swine day. Purdue Unv.

Butolo, J. E. 2002. Quality of ingredients in animal feed. First Edition. Campinas, SP.

Calvert C., K. Parker, J. Parker, R. N. Sayre, and R. M. Saunders. 1985. Rice bran in swine rations. California Agriculture 5-6:19-20

Campabadal C., D. Creswell, H. D. Wallace and G. E. Combs. 1976. Nutritional value of rice bran for pigs. Trop. Agri. 53:141-149.

Casas G. and H. Stein. 2016. Effects of full fat or defatted rice bran on growth performance and blood characteristics of weanling pigs. J. Anim. Sci. 94

Cashew Handbook 2014. – Global perspective. http://www.3fg.co/products.htm#cashewnut. (2016.08.13)

Cashewinfo.com http://www.cashewinfo.com/. (2016. 08.15)

Chae B. J. and S. K. Lee. 2001. Rancid rice bran affects growth performance and pork quality in finishing pigs. Asian-Aust. J. Anim. Sci. 1: 94-101.

Darith. 2011. Effect of wheat bran utilization on the performance of finishing pig at Tang Hang Ly Farm. IJERD. 2-2.

Das P., T. Sreelatha and A. Ganesh. 2004. Bio oil from pyrolysis of cashew nut shell-characterization and related properties. Biomass Bioenergy 273: 265–275.

David M. J., N. Samad and S. Rasool. 1997. Proceedings of 19th MSAP Conference, 8-10 sept. Johor Baru pp 137-138.

DeCamp S., et al. 2001. Effects of soybeans hulls on pig performance, manure composition, and air quality. Purdue Swine Research Reports.

Dendena B. and S. Corsi. 2015. "Cashew, from seed to market: a review." ASD 34: 753-772.

DiCostanzo A. 2003. Use of byproducts to meet the nutritional needs of the cowherd. Minnesota Beef Cow/Calf Days. 14-27.

Dilger, R. N., D. Rangland and O. Adeola. 2002. Evaluating the effect of soybean hulls on amino acid digestibility in swine. Purdue swine research reports.

Dublecz K. 2011. Animal Nutrition: chapter 4. The significance of antinutritional factors. Pannon Egyetem.

Dutch Commodities Board for Animal Feeding stuffs. 1993. Informative Bulletin Diervoeder mart. Jaargan 5:3.

Edet E. A., 2007. Chemical evaluation of the nutritional value of raw and roasted cashew nut. MSc thesis, university of Calabar, Nigeria, 120-130.

Elias C., Y. Agustin, E. Moro, E. Pedrosa and M. Bendano. 2005. Bailey`s industrial oil and fat products. Wiley online library.

Encyclopedia Britannica. 2016. https://global.britannica.com/plant/cashew. (2016.08.15)

Etuk E. B., N. J. Okeudo, B. O. Esonu and A. B. I. Udedibie. 2012. Antiuntritional factors in Sorghum: Chemistry, mode of action and effects on livestock and poultry. J Anim Feed Res. 2:113–119.

Fanimo A. O., T. E. Oduguwa, T. E. Adewunmi and A. I. Lawal. 2004. Utilization of diets containing cashew-nut reject meal by weaner pigs. Nigerian J. Anim. Prod. 31: 22-26.

Farias L. A., J. B. Lopez, A. V. Figueriredo, D. M. Albuquerque, A. A. Araujo and L. Ramos. 2008. Xashew pulp meals (Anacardium occidentale L.) for growing: nutrient metabolism and performance. Ciena Anim. Bra. 9: 100-109.

Ferreira A. C. H., J. N. M. Neiva, N. M. Rodriguez, R. N. B. Lobo and V. R. Vasconcelos. 2004. Nutritive value of elephantgrass silage added by-products from the cashew juice industry. Rev. Bras. Zoot. 33: 1380-1385.

Fetuga, B. L., G. M. Babatunde and V. A. Oyenuga. 1974. The feeding stuff potential of cashewnut scrap kernel meal. Tropical products Institute, London, (UK). 208-214.

Fitzpatrick J., 2011. Cashew nut processing equipment study—summary. African Cashew initiative. http://www.africancashewalliance.com/

Food and Agriculture Organization – FAO. 2013. Dietary protein quality evaluation in human nutrition—report of an FAO Expert Consultation.

Francisco H. 2010. Wheat bran modifies the microbial population and enhances gut fermentation in the gastrointestinal tract of post-weaning piglets. University of Barcelona.

http://www.tdx.cat/bitstream/handle/10803/5717/fmg1de1.pdf?sequence=1. (2016.10.18)

Francis, G., P. S. Harinder, H. P. S. Makkar and B. Klaus. 2001. Antinutritional factors present in plant derived alternate fish feed ingredients and their effects in fish. Acuaculture. 197:197-227.

Frederick B. and E. Heugten, 2013. Palatability and Flavors in Swine Nutrition. Animal Science Facts. North Carolina State University.

Freitas B. M. and R. J. Paxton. 1996. The role of wind and insects in cashew (Anacardium occidentale L.) pollination in North Eastern Brazil. J Agric Sci 126:319–326.

Frutos P., G. Hervás, F. J. Giráldez and A. R. Mantecón. 2004. Review: Tannins and ruminant nutrition. Spanish J Agr Res. 2:191–202.

Gentilini, F. P., G. J. Lima and F. Rutz. 1997. Energy values of raw and toasted soybean hulls obtained with swine. Proceedings of VIII Brazilian Congress of Swine Specialists. Brazil. 375-376.

Göhl, B., 1982. Feed in the tropics. FAO, Division de Production et Santé Animale, Roma, Italy

Goodyear A., A. Kumar and E. P. Ryan. 2015. Dietary rice bran supplementation prevents salmonella colonization differentially across varieties and by priming intestinal immunity. J Funct Foods. 18: 653–664

Grieve G. C., D. F. Osbourn and F. O. Gonzales. 1966. Coconut oil meal in growing and finishing rations for swine. Trop Agri Trinidad. 43:257–261.

Hartley C. W. S., 1988. The origin and development of the oil palm industry in the oil palm. Elaeis guineensis Jacq 3rd Edition. 1-43.

Haslam E. 1989. Plant polyphenols. Cambridge University Press, Cambridge, UK.

Hastad C. W., J. L. Nelssen, R. D. Goodband, M. D. Tokach, S. S. Dritz1 and J. M. DeRouchey. 2005. Adding dried distillers grains to swine diets affects feed preference. Swine Research.

Himejima M. and I. Kubo. 1991. Antibacterial agents from the cashew Anacardium occidentale (Anacardiaceae) nut shell oil. J Agric Food Chem 39: 418–421.

Hines R. H. 1980. Utilization of wheat bran in finishing swine diets. Swine Day. Kansas University. November 13.

Hong. 2009. Different levels of copra meal supplementation with mannanase on growth performance, pork quality and nutrient digestibility in growing-finishing pigs. Seoul national university.

Huang Q., Y. B. Su, D. F. Li, L. Liu, C. F. Huang, Z. P. Zhu and C. H. Lai. 2015. Effects of inclusion levels of wheat bran and body weight on ileal and fecal digestibility in growing pigs. AJAS. 28: 847–854.

Jacela, J. Y., R. C. Sulabo, J. M. DeRouchey, M. D. Tokach, J. L. Nelssen, R. D. Goodband and S. S Dritz. 2007. Amino acid digestibility and energy content of two different soy hull sources for swine. Swine Day. Kansas State University. 142-149.

Jaworski N.W., J. Shoulders, J.C. González-Vega and H.H. Stein. 2014. Effects of using copra meal, palm kernel expellers, or palm kernel meal in diets for weanling pigs. PAS. 30:243-251.

Jaworski, N., et al. 2016. Wheat bran reduces concentrations of digestible, metabolizable, and net energy in diets fed to pigs, but energy values in wheat bran determined by the difference procedure are not different from values estimated from a linear regression procedure. J. Anim. Sci 94: 3012-3021.

Jin G. 2002. Enzymes improve economics of rice bran based diets. Asian pork magazine.

Johnson D. 1973. The botany, origin, and spread of the cashew Anacardium occidentale L. J Plant Crops 1: 1–7.

Kamalzadeh, A. et al. 2008. Livestock production systems and trends in livestock industry in Iran. J Agri Soc Sci 4: 183-188.

Kamath V. and P. S. Rajini. 2007. The efficacy of cashew nut (Anacardium occidentale L.) skin extract as a free radical scavenger. Food Chem 103: 428–433.

Kamath V., A. K. R. Joshi and P. S. Rajini. 2008. Dimethoate induced biochemical perturbations in rat pancreas and its attenuation by cashew nut skin extract. Pestic Biochem Physiol 90: 58–65.

Kaufmann, C., W. C. Sauer, M. Cervantes, Y. Zhang, J. He, M. Rademacher and J. K. Htoo. 2005. Amino acid and energy digestibility in different sources of rice bran for growing pigs. Can. J. Anim. Sci. 85: 355-363.

Keys, A. and C. M. Wood. 2001. Use of Soybean Hulls to Mitigate Swine Lagoon Odors. Livestock Update.

Khanongnuch C., C. Sa-nguansook and S. Lumyong. 2006. Nutritive quality of β-mannanase treated copra meal in broiler diets and effectiveness on some fecal bacteria. Int. J. Poult. Sci. 5:1087-1091.

Knudsen B., 2001. The nutritional significance of “dietary fiber” analysis. Anim. Feed Sci. Technol. 90: 3–20.

Koleman E. 2008. Sweet chestnut tannins in animal diets. Available from: http://www.allaboutfeed.net/Home/General/2010/7/Sweet-chsstnut-tannins-in-animal-diets-AAF01162W/

Kobayashi. Y., 2012. Cashew nut shell is turning into functional feed. Hokkaide Univ., Res. Fac. Agri., News & Topics.

Kraler, M; K. Schedle, K. J. Domig, D. Heine, H. Michlmayr and W. Kneifel. 2014. Effects of fermented and extruded wheat bran on total tract apparent digestibility of nutrients, minerals and energy in growing pigs. Animal Feed SCI. TECH. 197: 121-129.

Kumar P., R. Paramashivappa, P. J. Vithayathil, P. V. Subba Rao and A. Rao. 2002. Process for isolation of cardanol from technical cashew (Anacardium occidentale L.) nut shell liquid. J Agric Food Chem 50: 4705–4708.

Kwon W. and B. Kim. 2015. Effects of supplemental beta-mannanase on digestible energy and metabolizable energy contents of copra expellers and palm kernel expellers fed to pigs. Asian-Australas J Anim Sci. 28: 1014-1019.

Kyriazakis. I and G. C. Emmans. 1995. The voluntary feed intake of pigs given feeds based on wheat bran, dried citrus pulp and grass meal, in relation to measurements of feed bulk. Brit J Nutr. 73: 191-207.

Lackey R. 2004. Variability of nutrient content in feed ingredients. Factsheet, Queens printer for Ontario.

Lardy G. and V. Anderson. 2009. General concepts and recommendations for using alternative feeds. AS. 1182.

Lei Z., J. Jervis, R. F. Helm. 2001. Use of methanolysis for the determination of total ellagic acid and gallic acid contents of wood and food products. J. Agric. Food Chem. 49: 1165-1168.

Lima G. J., F. P. Gentilini, A. L. Guidoni, F. Rutz and D. L. Zanotto. 1997. Use of soybean hulls in growing pig diets. Proceedings of VIII Brazilian Congress of Swine Specialists. Foz do Iguaçu. Foz do Iguaçu, Brazil. 377-378.

Lim T. K., 2012. Anacardium occidentale. Edible medicinal and non-medicinal plants, Springer, Netherlands. 45–68.

Lo, G. S., 1989. Nutritional and physical properties of dietary fiber from soybeans. Cereal Foods World. 34: 530-534.

Lubi M. C. and E. T. Thachil. 2000. Cashew nut shell liquid (CNSL)—a versatile monomer for polymer synthesis. Des Monomers Polym. 3:123–153.

Majun, G. K. and C. G. Payne. 1977. Autoclaved rice bran in layers' diets. Br. Poult. Sci. 18:201-203.

Marcel B. K. G., K. B. Andre, Z. T. Viviane and K. C. Seraphin. 2011. Cashew in breeding: Research synthesis. Int. J. Agr. & Agri. R. 1: 1-8.

Mitchell J. D. and S. A. Mori. 1987. The cashew and its relatives (Anacardium: Anacardiaceae). Mem N Y Bot Gard 42: 1–76.

Mohod A. G., Y. P. Khandetod and A. G. Powar. 2008. Processed cashew shell waste as fuel supplement for heat generation. Energy Sustain Dev. 12:73–76.

Meunier-Salaün M. C., S. A. Edwards and S. Robert. 2001. Effect of dietary fibre on the behaviour and health of the restricted fed sow. Anim. Feed. Sci. Technol. 90: 53-69.

Moeser A. J. and T. V. Kempen. 2002. Dietary fiber level and xylanase affect nutrient digestibility and excreta characteristics in grower pigs. Annual swine report.

Mota M. L. R., G. Thomas and J. M. Barbosa. 1985. Anti-inflammatory actions of tannins isolated from the bark of Anacardium occidentale L. J Ethnopharmacol 13: 289–300.

Mole P. N., 2000. An economic analysis of smallholder cashew development opportunities and linkages to food security in Mozambique's northern province of Nampula. Doctoral dissertation, Michigan State University

Molist, F., et al. 2010. Effect of wheat bran on the health and performance of weaned pigs challenged with Escherichia coli K88+. Livestock Science. 133: 214-217.

Nair K. P., 2010. The agronomy and economy of important tree crops of the developing world. Access Online via Elsevier.

Nandi B. K., 1998. Cashew nut nutritional aspects. FAO Document Repository.

Niezen J. H., T. S. Waghorn, W. A. G. Charlston and G. C. Waghorn. 1995. Growth and gastrointestinal nematode parasitism in lambs grazing either lucerne (Medicago sativa) or sulla (Hedysarum coronarium) with contains condensed tannins. J Agr Sci. 125: 281-289.

NRC. 2012. Nutrient requirements of swine, 11th ed. Natl. Acad. Press, Washington, DC.

Nwokolo, E. N., D. B. Bragg and S. S. Saben. 1977. A nutritive evaluation of palm kernel meal for use in poultry rations. Trop. Sci. 19: 147-154.

O'Brien M., 2006. Fatty acid profile, tocopherol, squalene and phytosterol content of brazil, pecan, pine, pistachio and cashew nuts. Int J Food Sci Nutr 57: 219–

228.

Ocheja J. O., D. O. Alex, S. Onoja, G. O. Usman, J. Ocheni and B. C. Lalabe. 2014. Performance, haematological and serum biochemical profiles of weaner west african dwarf goats fed with diets containing graded levels of cashew nut shell. Int. J. Res. Forest. 1: 27-33.

Oddoye E. O. K., K. Agyente, V. Anchirina and V. Johnson. 2011. Effects on performance of growing pigs fed diets containing different levels of cashew nut reject meal. Bull. Anim. Health Prod. Afric. 59: 81-86.

O`Doherty J., 2000. The use of expeller copra meal in grower and finisher pig diets. Livest Prod Sci. 67: 55–65.

Olunloyo, O. A., 1996. Marketing outlets for cashew nuts. Proc. of the National workshop on cashew production technology. Cocoa Research Institute of Nigeria, Ibadan.

Oluwafemi R., 2008. Palm kernel Cake (PKC) utilization in monogastric animal feeding - Implications for sustainable livestock development. The internet journal of veterinary medicine. Volume 6 Number 2.

Onwudike, O. C. 1986. Palm kennel meal as a feed for poultry. Anim Feed Sci Tech. 16: 179-186.

Quirino R. L., Garrison T. F and Kessler M. R. 2014. Matrices from vegetable oils, cashew nut shell liquid, and other relevant systems for bio composite applications. Green Chem.

Panda H., 2013. The complete book on cashew (cultivation, processing & by-products). Asia pacific business press Inc.

Pereira E. S., I. Y. Mizubuti, R. L. Oliveria, A. P. Pinto, E. L. Ribeiro, C. R. Gadelha, A. C. Campos, M. F. Pereira, M.S. Carneiro, P. C. Arrunda and L. P. Silva.

2016. Supplementation with cashew nut and cottonseed meal to modify fatty acid content in lamb meat. J Food Sci. 81:2143-8.

Pimentel P. G., R. B. Reis, L. A. Leite and W. E. Campos. 2012 Ruminal fermentative parameters and concentration of purine derivates in lactating dairy cows fed cashew nut. Arq. Bras. Med. Vet. Zootec. 64: 4.

Pinheiro Á. D. T., M. V. P. Rocha, G. R. Macedo and L. R. Gonçalves. 2008. Evaluation of cashew apple juice for the production of fuel ethanol. Cashew, from seed to market 771. Appl Biochem Biotechnol. 148: 227–234.

Pluske, J. R., D. W. Pethick, D. E. Hopwood and D. J. Hampson. 2002. Nutritional influences on some major enteric bacterial diseases of pig. Nutr. Res. Rev. 15: 333-371.

Pribis P. and B. Shukitt-Hale. 2014. Cognition: the new frontier for nuts and berries. Am J Clin Nutr. 1: 347-52.

Rhule S. W. A. 1996. Growth rate and carcass characteristics of pigs fed diet containing palm kernel cake. Animal Feed Sci. Technol. 61:167-172.

Paul R. 1987. Anti-nutritional factors in feed ingredients and their effects in finfish. Central Marine Fisheries Research Institute.

Reddy D. V. and N. Elanchezhian. 2008. Evaluation of tropical tree leaves as ruminant feedstuff based on cell contents, cell wall fractions and polyphenolic compounds. Livest. Res. Rural Dev. 20: 77.

Reed J. D. 1995. Nutritional toxicology of tannins and related polyphenols in forage legumes. J. Anim. Sci. 73:1516-1528.

SEO et al., 2015. Effects of palm kernel expellers on growth performance, nutrient digestibility, and blood profiles of weaned pigs. Asian Australias. J. Anim. Sci. 28: 987-992.

Shurson, G. 2007. New technologies to aid in evaluation of alternative feedstuffs. 72nd Minnesota Nutrition Conference. Owatonna, MN.

Silveira M. S., C. P. Fontes, A. A. Guilherme, F. A. Fernandes and S. Rodrigues. 2012. Cashew apple juice as substrate for lactic acid production. Food Bioprocess Technol 5: 947 – 953.

Singh A., M. Das, S. Bal and R. Boinejee. 2013. Engineering aspects of cereals and cereal based products. Boca Raton, FL, USA: CRC Press.71-97.

Sivagurunathan P. and S. M. Muthukkaruppan. 2010. Characterization of cashew apple (Anarcadium occidentale L.) fruits collected from Ariyalur District. J Bioscience. 1: 101-107.

Smulikowska S., B. Pastuszewska, E. Świech, A. Ochtabinska, A. Mieczkowska, V. C. guyen and L. Buraczewska. 2001. Tannin content affects negatively nutritive value of pea for monogastrics. J Anim Feed Sci. 10: 511–523.

Songer J. G. and F. A. Uzal. 2005. Clostridial enteric infections in pigs. J Vet Diagno Invest. 17: 528–536

Spore. 1997. More cash returns from cashews. CTA, Wagenigen. 70: 4.

Stamford T. L. M., R Vieria, N. B. Guerra, R. B. Mederious and M. L. Cavalcante. 1988. Protein enrichment of cashew wastes for animal feeds. Food Nutr Bull. 10: 86.

Stein, H. H. 2008. Use of distillers co-products in diets fed to swine. Midwest agribusiness trade research and information center at the center for agricultural and rural development, Iowa State University. 79-97.

Stein, H. H. 2007. Distillers dried grains with solubles (DDGS) in diets fed to swine.

Stein, H.H., Pedersen, and M.G. Boersma. 2005. Energy and nutrient digestibility in dried distillers grain with solubles by growing pigs. J. Anim. Sci. 83:49.

Stein, H.H. and De Lange, 2007. Alternative feed ingredients for pigs. London swine conference London, Ontario, Canada.

Stevenson L, F. Phillips, K. O'sullivan, and J. Walton. 2012. Wheat bran: its composition and benefits to health, a European perspective. Int J Food Sci Nutr. 63: 1001–1013.

Stewart L. 2013. Effects of dietary soybean hulls and wheat middlings on body composition, nutrient and energy retention, and the net energy of diets and ingredients fed to growing and finishing pigs. J Anim Sci. 91: 2756-65.

Sulabo, R. C., W. S. Ju, and H. H. Stein. 2013. Amino acid digestibility and concentration of digestible and metabolizable energy in copra meal, palm kernel expellers, and palm kernel meal fed to growing pigs. J. Anim. Sci. 91:1391-1399.

Thaler B., 2002. Use of distillers dried grains with solubles (DDGS) in swine diets. Ex 2035 Animal & Range Sciences

Thaler B. and P. J. Holden. 2001. By-products in swine diets. Pork industry handbook PIH-108. Purdue Extension.

Thomas R. L., 2016. Horse health. AAEP. http://www.aaep.org/info/horse-health?publication=2313. (2016.10.15)

Thorne P. J., J. Wiseman, D. J. A. Cole and D. H. Machin. 1988. Use of diets containing high levels of copra meal for growing/finishing pigs and their supplementation to improve animal performance. Trop Agric. 65: 197–201.

Trowell, H., et al. 1976. Dietary fibre redefined. The Lancet 307: 967.

USDA. 2016, USDA Agricultural Projection to 2025. United States department of

Agriculture.

Waghorn G.C., I. D. Shelton, W. C. McNabb, S. N. McCutcheon. 1994. Effects of condensed tannins in Lotus pedunculatus on its nutritive value for sheep. 2. Nitrogenous aspects. J Agr Sci. 123: 109-119.

Whitney M. H., M. J. Spiehs, G. C. Shurson, and S. K. Baidoo. 2000. Apparent ileal digestibilities of corn distiller's dried grains with solubles produced by new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 78:185.

Whitney M. H. and G. C. Shurson. 2004. Growth performance of nursery pigs fed diets containing increasing levels of corn distiller's dried grains with solubles originating from a modern Midwestern ethanol plant. J. Anim Sci. 82: 122-128.

Wilson J. A., M. H. Whitney, G. C. Shurson and S. K. Baidoo. 2003. Effects of feeding distillers dried grains with solubles (DDGS) to gestation and lactation diets on reproductive performance and nutrient balance in sows. J. Anim. Sci. 81.

Woyengo T. A., E. Beltranena and R. T. Zijlstra. 2014. Controlling feed cost by including alternative ingredients into pig diets: A review. 92: 1293-1305.

Xu G., S. K. Baidoo, L. J. Johnston, J. E. Cannon, D. Bibus and G. C. Shurson. 2010. Effects of feeding diets containing corn dried distillers grains with soluble, and withdrawal period of distillers dried grains with soluble, on pig growth performance and pork quality in grower-finisher pigs. J. Anim. Sci. 88: 1388-1397.

Yacout M. 2016. Anti-Nutritional factors & its roles in animal nutrition. J Dairy Vet Anim Res. 4: 107.

Yao K. S. A., M. Kimse, D. Soro and A. Fantodji, 2013. Effect of incorporation of cashews in food rations on growth performance of pigs: phases and post-weaning growth. Int J. Bio. Chem. Sci. 7: 479-488.

Yeong, S. W., T. K. Mukherjec and R. I. Hutorgalung. 1981. The nutritive value of palm kernel cake as feed stuff for poultry. Proceedings of a National workshop on oil palm by-product utilization. Malaysia. 100-107.

Yin, Y. L., J. D. G. McEvoy, H. Schulze, U. Henning, W. B. Souffrant, and K. J. McCracken. 2000. Apparent digestibility (ileal and overall) of nutrients and endogenous nitrogen losses in growing pigs fed wheat (var. Soissons) or its by-products without or with xylanase supplementation. Livest. Prod. Sci. 62:119-132.

Yin, Y. L., S. K. Baidoo, L. Z. Jin, Y. G. Liu, H. Schulze and P. H. Simmins. 2001. The effect of different carbohydrase and protease supplementation on apparent (ileal and overall) digestibility of nutrients of five hulless barley varieties in young pigs. Livest. Prod. Sci. 71: 109-120.

Chapter III: Effects of dietary cashew nut testa as an alternative ingredient on growth performance and carcass quality of growing-finishing pigs.

ABSTRACT: The objective of this experiment was to evaluate the effect of different level of CNT in growing-finishing pig diets on growth performance, blood profile and carcass characteristics. A total of 160 crossbred pigs ([Landrace X Yorkshire] X Duroc) with an average body weight of 28.05 ± 8.47kg were used for 12 weeks feeding trial for grower and finisher in Seoul National University Experimental Farm. Pigs were allotted into 4 treatments with 4 replicates and 10 pigs per pen in randomized completely block design (RCBD) based on sex and initial body weight. Treatments were: 1] CON: corn and SBM based diets which met the requirements of NRC (1998) + CNT 0%, 2] C2: CON + CNT 2%, 3] C4: CON + CNT 4%, and 4] C6: CON + CNT 6%. There was no significant difference in average daily gain (ADG) among all treatment, but ADFI showed linear response in growing Ⅰ (P=0.02) and finishing Ⅰ phase (P= 0.04), respectively. Feed efficiency among all treatments in growing Ⅰ phase showed significant linear differences and quadratic increase as the amount of CNT increased (linear, P<0.01; quadratic, P=0.02). Total cholesterol concentration was decreased by addition of CNT during whole experimentation. There were no significant differences in BUN, creatinine, insulin and glucose concentration during a total of 12 weeks experimentation. There were no significant differences in WHC, cooking loss and shear force of pork as the level of CNT supplementation. In economic efficiency, feed cost per gain during whole experiment (0-12 week) were lower in the order of C6, C2, CON and C4. Consequently, this experiment demonstrated that addition of 6% of CNT can be supplemented in growing-finishing pig diet without any negative effect on growth performance, pork quality and feed cost.

Key words: Cashew nut testa, growing – finishing pig, growth performance, pork quality

INTRODUCTION

The increase in world fuel prices in the last decade have affected the global animal feedstuffs supply and subsequently, prices (Alimon, 2009). In Korea, most of feed ingredients are not produced locally. Particularly, swine diets are dependent on imported ingredients such as corn and soybean meal. Even it depends highly on byproduct such as bran and other oilseed meal. For this reason, feed costs comprise over 65% of the pork production in Korea. According to US Grain (2014), Korean swine feed industry depend on imported ingredients close to the average of 97% since 2010. Based on this fact, serious problems are expected to arise in many areas related to domestic animal industry due to the increase of feed cost when the price of imported ingredients sharply rises.

Not only Korea but many countries of the world are trying to look for various solutions to these problems, and one of them is developing alternative ingredient.

Especially, major imported ingredient such as corn and soybean meal is largely used in growing-finishing pig diet, and imports of these two ingredients account for the largest portion (US Grain, 2014), therefore very high interest in the alternatives that may replace these raw materials. It is needed to find an appropriate alternative ingredient which can replace major ingredients (Sogunle, 2009)

Alternative ingredients that are currently being studied are concerned not only about price but also nutritional value and volume of production. Cashew nut testa (CNT) is one of the alternative ingredients can meet these various conditions. The cashew tree (*Anarcardium Occidentale*) is a native of Brazil and it is now widely distributed throughout the tropical areas, particularly in many countries of Africa and Asia (Akinhanmi, 2008). Because CNT contains more protein, fiber, calcium, and magnesium than corn and wheat bran (Armstrong, 2011), it has become more interested as an alternative ingredient these days. Other byproducts of of cashew nut such as cashew nut shell, apple, and rejected nut have been studied in in many case and used in various ways. However, there have not been many studies on CNT (Armstrong, 2011).

In this study, therefore, consider using CNT as an ingredient substitute for wheat bran in growing-finishing pig diet and conduct to investigate how the growth performance, blood profile, carcass characteristics, and economic value response to the different CNT level.

MATERIALS AND METHODS

Experimental animals and housing environment

A total of 160 crossbred pigs ([Landrace X Yorkshire] X Duroc) with an average body weight of 28.05 ± 8.47 kg were used for 12 weeks feeding trial for grower and finisher in Seoul National University Experimental Farm. Pigs were allotted into 4 treatments with 4 replicates and 10 pigs per pen in randomized completely block design (RCBD) based on sex and initial body weight. Pigs were reared in growing and finishing facilities and fed *ad libitium* through feeder and nipple water during whole experimental periods. The room temperature was kept at 24~25℃ during the experiment. Body weight and feed intake were recorded at 3, 6, 9 and 12 weeks to calculate average daily gains (ADG), average daily feed intakes (ADFI) and gain to feed ratio (G:F ratio).

Experimental Diet

The treatments were set up by the level of CNT and 4 different types of experimental diet were formulated and provided to growing and finishing pigs following 4 phases (growing Ⅰ, growing Ⅱ, finishing Ⅰ and finishing Ⅱ): 1]

CON: corn and SBM based diets which meet requirements of NRC (1998) + CNT 0 %, 2] C2: CON + CNT 2 %, 3] C4: CON + CNT 4%, 4] C6: CON + CNT 6 %. All the experimental diets were formulated to meet or exceed nutrient of NRC (1998).

Experimental diet was added and formulated based on corn-soybean meal, which contains 3,265 kcal of ME/kg for whole experimental periods. And during growth phases, growing Ⅰ, growing Ⅱ, finishing Ⅰ and finishing Ⅱ, diet contained 18%, 16.3%, 15.5% and 13.2% of crude protein, respectively. The formula and chemical composition of experimental diets were presented in Table 1, 2, 3 and 4.

Blood profiles

Blood was collected from the jugular vein of randomly selected 5 pigs at the start of the experiment. After the initiation of the experiment, blood was collected from a total of 20 pigs, 5 pigs from each treatment for each growth phase when measuring body weight (3 weeks, 6 weeks, 9 weeks, 12 weeks). After samples were collected in disposable culture tube, they were centrifuged for 15 min at 3,000 rpm on 4℃. Then, pure sera samples were separated by pipette and stored at -20℃. Total blood urea nitrogen (BUN) concentration in blood samples were analyzed by using automatic biochemical analyzer (ADVIA 1650, Japan) and glucose concentration were analyzed by using a blood analyzer (Modular analytics, PE, Roche, Germany) with enzymatic kinetic assay. Insulin in serum was assayed using ECLIA (electro chemi luminescence immuno assay). Total cholesterol was analyzed by enzymatic colorimetric assay and creatinine by kinetic colorimetry assay.

Pork quality

A total of 16 pigs, 4 pigs per each treatment, were selected randomly after 12 weeks of experiment. After slaughtered, longissimus muscle was collected from between caudal vertebra and 5th rib. Muscle pH was measured using a pH meter (Model 720, Thermo Orion, USA) at 0, 3, 6, 12, and 24 hours after slaughter. Water holding capacity (WHC) was measured by Laakkionen method (1970). Longissimus muscle was grinded and sampled in 2 ml filter tube, then heated in water bath (80℃) in 20 min and centrifuged for 10 min at 2,000 rpm on 10℃. After that, drip-loss was measured for calculating water holding capacity and it was used following equation.

$$\text{Water holding capacity} = \frac{\text{Moisture (\%)} - \text{Free moisture}}{\text{Moisture (\%)}} \times 100$$

The collected samples were cut into 3 cm thick stakes shape and then the samples were heated to an internal temperature of 70° C and allowed to cool for 30 minutes in running water. The samples were cored (0.5 inch in diameter) parallel to muscle fiber and the cores were used to measure the shear force using a Instron Univeral Testing Machine (Model 4465, UK). To calculate cooking loss, samples were cut into 3 cm thick stakes shape and packed with polyethylene bag. They were heated in water bath until core temperature reached 70℃ and weighed before and after cooking. The cooking loss was calculated as following equation (Honikel, 1998).

$$\text{Cooking loss (\%)} = \frac{\text{Sample weight before heating} - \text{Sample weight after heating}}{\text{Sample weight before heating}} \times 100$$

Statistical analysis

Statistical analysis was carried out according to LSD (least significance difference) multiple test, using general linear model (GLM) and a procedure of SAS (2009) package program. Each pen was set as an experimental unit for analysis of the growth performance data and the individual pig was set for blood profile and pork quality. Orthogonal polynomial contrast was used to determine the linear quadratic effects of dietary CNT. It was considered that there was a significant differences if $P<0.05$ for all statistical analyzes.

RESULTS AND DISCUSSION

Growth Performance

The effects of supplementation of dietary CNT on growth performance in growing-finishing pigs were in Table 5. There were no significant differences in average daily gain (ADG) among all treatment, but ADFI showed linear response (linear, P=0.02; P= 0.04) in growing Ⅰ and finishing Ⅰ phase. G:F ratio showed linear response(linear, P<0.01) and quadratic response(quadratic, P=0.02) in growing Ⅰ phase.

ADFI in growing Ⅰ phase decreased as the amount of CNT increased (linear, P=0.02). However, ADFI in finishing Ⅰ phase showed linear increase as as the amount of CNT increased (linear, P=0.04).

Feed efficiency among all treatments in growing Ⅰ phase showed significant linear differences and quadratic increase as the amount of CNT increased (linear, P<0.01; quadratic, P=0.02). There was no differences in feed efficiency in other phases.

The results of this experiment were similar to those of Poommarin et al. (2015) in that the feed efficiency was positively influenced by the addition of CNT. Their study also showed that the increase in the level of CNT did not significantly change the body weight and ADG but had a positive effect on the feed efficiency. The reason for this results may be the effect of fat content in the experimental diets. Cisneros (1997) demonstrated that the feed efficiency could be improved as the fat content in the feed increased. As the deficient energy content due to the increase of CNT was adjusted using tallow in this experiment, the amount of tallow increased as the level of CNT increased. Therefore, it is suggested that the feed efficiency increased linearly with increasing level of CNT. This is because the digestible energy differs depending on the difference in energy source (Cole et al., 1971). Based on the Giles`s report (1998) that ADFI may change depending on the level of digestible energy, the linear decrease of ADFI in growing Ⅰ phase can be explained with same reason. But, it is thought that the linear increase of ADFI in finishing phase was not due to the content of tallow but the influence of CNT because the content of tallow in finishing phase was lower than growing phase. Madsen (1985) concluded that the feed intake could be increased as the fiber content in feed increase.

Dietary fiber in growing pigs has not been widely used because of its adverse effects on digestibility of nutrients (Johnston, 2003). However, many studies have shown that dietary fiber did not have detrimental effect in growing pigs when it was added in optimal level (Shriver, 2003; Komegay, 1981; Galassi et al., 2003). Shriver et al. (2003) showed that a low-protein growing diet with 10% soybean hulls did not affect adversely on growth performance. Also, Kornegay (1981) demonstrated that soybean hulls did not show detrimental effects on growth performance when they were added up to 15% in growing and finishing pig diets. Galassi et al. (2003) showed wheat bran could be added up to 24% without adverse effects. These studies suggested that optimal levels of fermentable dietary fiber can replace grain ingredients in growing pigs.

Tannin in feed has an adverse effect on ADFI in growing pig due to its astringent taste (Krueger et al., 2010). In this study, ADFI decreased only in growing Ⅰ phase of C6. However, there was no significant difference in ADFI during whole period of test. The results in this experiment were constant with the research of Lee et al. that showed no adverse effects of tannin in ADFI of growing pig (Lee et al., 2016). Lee et al (2016) studied nutritional characterization of tannin rich chestnut for pig, and they demonstrated that there was no significant difference in ADFI as chestnut level increased. It is suggested that growing pigs may have some mechanism of neutralizing anti-nutritional effect of tannin (Bernays et al., 1989). Instead, due to high contents of polyphenol in CNT have a positive effects on growth performance in growing pigs.

Based on this experiment, addition 6% of CNT in growing-finishing diet showed no negative effects on growth performance in growing-finishing pigs.

Blood profiles

The effects of dietary level of CNT on BUN, total cholesterol, creatinine, insulin and glucose concentration in growing-finishing pig were presented in table 6. There were no significant differences in BUN, creatinine, insulin and glucose concentration during a total of 12 weeks experimentation. But total serum cholesterol concentration showed highly linear decreased at 6 week and 12 week (linear, $P<0.01$) and linear decreased at 3 week and 9 week (linear, $P=0.01$, 0.02). Total cholesterol concentration was decreased by addition of CNT during whole experimentation. It has already been found that as the fibrin content increases, the digestibility of energy decreases (Ewan 1989, Noblet and Perez , 1993, Noblet et al., 1994) as a result, the reduction of cholesterol in blood also was shown in previous studies (IOM, 2005). The crude fiber content of CNT used in this experiment was

11.8%, therefore the crude fiber content in the experimental diets was also increased by as much as 0.7% compared with the Con treatment. It is presumed that the change of the crude fiber content led to a decrease in the blood cholesterol of the whole growth-finishing phases. These changes in total cholesterol concentration and the results of other blood constituents indicated that addition of up to 6% of CNT in diet does not have a negative effect on the blood characteristics of the growing-finishing pigs.

Pork quality

Table 7 showed effects of supplementation of dietary CNT on pH of pork. No significant difference was found in the whole phase. Also, all the results did not exceed the range of normal meat (5.3 - 6.8). The effects of supplementation of dietary CNT on WHC, cooking loss and shear force after slaughter were shown in Table 8. There were no significant differences in WHC, cooking loss and shear force of pork according to the level of CNT supplementation. Change of pH is used as index of stability of pork (Duston, 1983). Also, WHC and shear force are used as index of meat texture because they are related to fat, (Hamm, 1986) and cooking loss is generally known to have a negative correlation with WHC. The result of this experiment indicated that supplementation of CNT did not affect negative effect because there were no significant differences between treatments. Consequently, this experiment demonstrated that CNT could be used up to 6% in growing-finishing swine diet without any negative effects.

Economic analysis

The effects of the inclusion of CNT on feed cost per gain in growing-finishing pigs are presented in Table 9. A high quadratic effect was observed in the feed cost per gain in growing Ⅰ phase (0-3 week) and the cost were lowest in C6. The feed cost per gain increased linearly (linear, P=0.03) with the increase of CNT inclusion level in growing Ⅱ phase (4-6 week) and the cost of C2, C4 and C6 treated with CNT was higher than those of CON. There were no linear effects in the other phase growing Ⅰ phase, finishing Ⅰ and finishing Ⅱ, but quadratic responses were showed (P<0.01, P=0.05, P=0.04). In finishing Ⅰ and finishing Ⅱ phase, the cost was lowest in C4 and C6 respectively. Feed cost per gain during whole experiment (0-12 week) were lower in the order of C6, C2, CON and C4. The total feed cost and the days to shipment weight were not significantly influenced by the inclusion level of CNT. Feed cost was the lowest in C2, and the days to shipment was the lowest in C4.

Consequently, the feed cost per gain was the lowest when the inclusion level of CNT increased up to 6%, and it is expected that the effect of shortening the days of shipment as using CNT in growing-finishing pig diet.

Conclusion

The purpose of this study was to investigate the effect of different level of CNT in growing-finishing pig diets on growth performance, blood profile and carcass characteristics.

In growth performance, linear decrease was showed in ADFI during growing Ⅰ phase (0-3 week) as inclusion rate of CNT increased, but ADFI linearly increased in finishing Ⅰ phase (7-9 week) as CNT increase. Also, feed efficiency increased as inclusion rate of CNT increased (linear, $P<0.01$, $P=0.02$). In blood profile, there were no significant differences in BUN, creatinine, insulin and glucose concentration among treatments in all phase, but total cholesterol linearly decreased as the inclusion rate of CNT increased (linear, $P<0.01$). Also, there were no significant differences in WHC, shear force and cooking loss among treatments in all phase.

In economic analysis, the feed cost per gain could be minimized by using CNT up to 6% in growing-finishing diet and it is expected that the effect of shortening the days of shipment. Hence, it is recommended to use CNT up to 6% in growing-finishing pigs.

REFERENCES

Akinhanmi T. and V. Atasie, 2008. Chemical composition of physicochemical properties of cashew nut oil and cashew nut shell liquid, J. Agri. Food and Environ. Sci. 2: 1 – 10.

AOAC. 1995. Official Methods of Analysis. 16th Edition. Association of Official Analytical Chemist. Washingtons, D.C., U.S.A.

Armstrong D., V. Attoh-Kotoku, R. Kwame and R. Gascar. 2012. Evaluation of nutritional quality of dried cashew nut testa using laboratory rat as a model for pigs, The Sci. J. 1: 5.

Bernays E. A., D. G. Cooper and M. Bilgener. 1989. Herbivores and plant tannins. Adv Ecol Res. 19: 263–302.

Cisneros F., 1997. Performance and body composition in swine as affected by environmental temperature. Ph D. dissertation.

Cole D., B. Hardy, and D. Lewis, 1971. Nutrient density of pig diets, Agr. Sci. Proc., 243.

Dutson T., 1983. The measurement of pH in muscle and its importance to meat quality, Proceedings of the Reciprocal Meat Conf., 36: 92 - 96.

Ewan R., 1989. Predicting the energy utillization of diets and feed ingredients by pigs, 40th annual meeting of EAAP, 43.

Galassi, G., G. M. Crovetto, L. Rapetti and A. Tamburini. 2003. Energy and nitrogen balance in heavy pigs fed different fibre sources. Livest. Prod. Sci**.**

Giles L., M. Lorschy, H. Bray and J. Black, 1998. Progress in pig science, Nottingham University Press, 209.

Hamm R., 1986. Functional properties of the myofibrillar system and their measurements, Food and Agri. Organi. of Unites nations.

Honikel, K., 1998. Reference methods for the assessment of physical characteristics of meat, Meat Science, 49: 447–457.

Institute of Medicine (IOM), 2005. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids, National Academies Press.

Johnston lee. J., S. Noll, A. Renteria, and J. Shurson. 2003. Feeding by-products high in concentration of fiber to nonruminants. Third National Symposium on Alternative Feeds for Livestock and Poultry held in Kansas City. West Central Research and Outreach Center, University of Minnesota.

Krueger WK, K. Gutierrez-Banuelos, G. E. Carstens, B. R. Min, W. E. Pinchak, R. R. Gomez, R. C. Anderson, N. A. Krueger and T. D. A. Forbes. 2010. Effects of dietary tannin source on performance, feed efficiency, ruminal fermentation, and carcass and non-carcass traits in steers fed a high-grain diet. Anim Feed Sci Technol. 159: 1–9.

Kornegay, E. T. 1981. Soybean hull digestibility by sows and feeding value for growing-finishing swine. J. Anim. Sci. 53: 138-145.

Laakkonen E., J. Sherbon, and G. Wellington, 1970. Low -temperature, long-time heating of bovine muscle 3. collagenolytic activity, J. Food science, 35: 181 – 184.

Lee H. J., I. H. Choi, D. H. Kim, M. Sadar and S. C. Kim. 2016. Nutritional characterization of tannin rich chestnut (Castanea) and its meal for pig. J. Applied Animal Research. 44: 258-262.

Madsen A., 1985. Energy density in pig diets, 36th annual meeting of European

Association for Animal Production, 1.

Noblet J. and J. Perez, 1993. Prediction of digestibility of nutrients and energy values of pig diets from chemical analysis, J. Anim. Sci. 71: 3389.

Noblet J., J. Fortune, X. Shi and S. Dubois. 1994. Prediction of net energy value of feeds for growing pigs, J. Anim. Sci. 72: 344.

NRC, 1998. Nutrient Requirements of Swine (10th Ed.). National Academy press, Washington, D. C.

Oddoye E., F. Alemawor, A. Agyente-Badu and P. Dzogbefia, 2012. Proximate analysis of shea nut kernel cake/meal samples from industry and cottage industry and some methods of removal of anti-nutritional factors, J. Biochem. Biotech, 239-242.

Ocheja J., A. Aduku A, J. Ayoade and B. Lalabe, 2013. Effect of steaming and soaking on chemical composition of cashew nut shell: implications for ruminant animal nutrition, Pak. J. Nutri., 683-687.

Poommarin P., R. Sulabo, R. Vega, D. Depositario and C. Sevilla, 2015. Feeding value of dried cashew nut testa in finishing pigs: effects on growth performance, economic return and carcass characteristics sustain, Ani. Agri. for Developing Countries, 175 - 180.

Shriver, J. A., S. D. Carter, A. L. Sutton, B. T. Richert, B. W. Senne and L. A. Petty. 2003. Effects of adding fiber sources to reduced-crude protein, amino acid-supplemented diets on nitrogen excretion, growth performance, and carcass traits of finishing pigs. J. Anim. Sci. 81:492-502.

Sogunle O., A. Fanimo, S. Abiola and A. Bamgbose, 2009. Performance of growing pellets fed cassava peel meal diet supplemented with cashew nut reject meal, Archivos de Zootecnia, 58: 23 – 31.

US grains, 2014. US grains council, Washington, D. C.

Table 1. Formula and chemical composition of the diet in growing phase Ⅰ (0-3 week)

	CON	C2	C4	C6
Ingredient, %				
Corn	68.26	66.57	64.60	62.58
SBM-46	28.70	28.55	28.31	28.09
Cashew nut testa	0.00	2.00	4.00	6.00
Wheat bran	0.41	0.06	0.04	0.05
L-lysine-HCL	0.00	0.00	0.00	0.00
DL-methionine	0.00	0.00	0.01	0.01
Tallow	0.38	0.55	0.77	1.00
Limestone	1.01	0.97	0.97	0.97
MDCP	0.74	0.80	0.80	0.80
Vit. Mix 1)	0.10	0.10	0.10	0.10
Min. Mix 2)	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Sum	100	100	100	100
Chemical composition				
ME, kcal/kg	3,265.00	3,265.03	3,265.03	3,265.00
CP,%	18.00	18.00	18.00	18.00
CF.%	2.66	2.86	3.08	3.30
Lysine,%	0.96	0.96	0.96	0.96
Methionine,%	0.28	0.28	0.28	0.28
Ca,%	0.60	0.60	0.60	0.60
Total P,%	0.50	0.50	0.50	0.50

1) Provided as following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600IU; vitamin E, 32IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12g; vitamin K, 2.4mg

2) Provided as following per kilogram of diet : Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; $CuSO_4$, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg

Table 2. Formula and chemical composition of the diet in growing phase Ⅱ (4-6 week)

	CON	C2	C4	C6
Ingredient, %				
Corn	73.00	71.41	69.40	67.34
SBM-46	24.27	24.13	23.92	23.70
Cashew nut testa	0.00	2.00	4.00	6.00
Wheat bran	0.42	0.02	0.02	0.03
L-lysine-HCL	0.01	0.01	0.00	0.00
DL-methionine	0.00	0.00	0.00	0.01
Tallow	0.20	0.34	0.57	0.81
Limestone	0.90	0.89	0.88	0.88
MDCP	0.70	0.70	0.71	0.73
Vit. Mix 1)	0.10	0.10	0.10	0.10
Min. Mix 2)	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Sum	100	100	100	100
Chemical composition				
ME, kcal/kg	3,266.00	3,265.05	3,265.02	3,265.02
CP,%	16.30	16.30	16.30	16.30
CF.%	2.57	2.76	2.98	3.21
Lysine,%	0.85	0.85	0.85	0.85
Methionine,%	0.25	0.25	0.25	0.25
Ca,%	0.54	0.54	0.54	0.54
Total P,%	0.47	0.47	0.47	0.47

1) Provided as following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600IU; vitamin E, 32IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12g; vitamin K, 2.4mg

2) Provided as following per kilogram of diet : Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; $CuSO_4$, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg

Table 3. Formula and chemical composition of the diet in finishing phase Ⅰ (7-9 week)

	CON	C2	C4	C6
Ingredient, %				
Corn	75.12	73.69	71.64	69.66
SBM-46	22.17	22.06	21.84	21.62
Cashew nut testa	0.00	2.00	4.00	6.00
Wheat bran	0.62	0.05	0.07	0.06
L-lysine-HCL	0.00	0.00	0.00	0.00
DL-methionine	0.00	0.00	0.00	0.00
Tallow	0.12	0.23	0.47	0.69
Limestone	0.83	0.84	0.83	0.80
MDCP	0.64	0.63	0.65	0.67
Vit. Mix 1)	0.10	0.10	0.10	0.10
Min. Mix 2)	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Sum	100	100	100	100
Chemical composition				
ME, kcal/kg	3,265.04	3,265.01	3,265.04	3,265.05
CP,%	15.50	15.50	15.50	15.50
CF.%	2.54	2.73	2.95	3.17
Lysine,%	0.79	0.79	0.79	0.79
Methionine,%	0.24	0.24	0.24	0.24
Ca,%	0.50	0.50	0.50	0.50
Total P,%	0.45	0.45	0.45	0.45

[1)] Provided as following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600IU; vitamin E, 32IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12g; vitamin K, 2.4mg

[2)] Provided as following per kilogram of diet : Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; $CuSO_4$, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg

Table4. Formula and chemical composition of the diet in finishing phaseⅡ(10-12 week)

	CON	C2	C4	C6
Ingredient, %				
Corn	80.82	79.9	78.09	76.04
SBM-46	16.13	16.02	15.9	15.68
Cashew nut testa	0.00	2.00	4.00	6.00
Wheat bran	1.24	0.6	0.00	0.02
L-lysine-HCL	0.00	0.00	0.00	0.00
DL-methionine	0.00	0.00	0.00	0.00
Tallow	0.02	0.11	0.22	0.46
Limestone	0.82	0.78	0.78	0.78
MDCP	0.47	0.50	0.51	0.52
Vit. Mix 1)	0.10	0.10	0.10	0.10
Min. Mix 2)	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Sum	100	100	100	100
Chemical composition				
ME, kcal/kg	3,265.00	3,265.04	3,265.00	3,265.03
CP,%	13.20	13.20	13.20	13.20
CF.%	2.46	2.64	2.82	3.04
Lysine,%	0.63	0.63	0.63	0.63
Methionine,%	0.21	0.21	0.21	0.21
Ca,%	0.45	0.45	0.45	0.45
Total P,%	0.40	0.40	0.40	0.40

1) Provided as following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600IU; vitamin E, 32IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12g; vitamin K, 2.4mg

2) Provided as following per kilogram of diet : Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; $CuSO_4$, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg

Table 5. Effects of dietary level of cashew nut testa in growing-finishing swine diet on growth performance.[1)]

Criteria	Treatment[2)]				SEM[3)]	P-Value	
	CON	C2	C4	C6		Linear	Quadratic
Body weight, kg							
Initial	28.05	28.05	28.05	28.05	2.089	0.21	0.67
3 week	39.95	40.53	39.81	40.71	2.625	0.55	0.28
6 week	58.18	55.00	58.32	57.88	3.183	0.47	0.09
9 week	75.14	76.30	75.48	77.47	3.438	0.16	0.66
12 week	96.08	96.26	98.15	96.63	3.393	0.56	0.54
ADG, g							
0-3 week	583	611	560	606	27.2	0.75	0.50
4-6 week	849	692	889	812	37.3	0.64	0.33
0-6 week	716	645	723	709	29.0	0.47	0.12
7-9 week	807	1,011	816	934	29.9	0.33	0.31
10-12 week	997	950	1,064	917	19.7	0.43	0.18
7-12 week	902	981	947	901	13.6	0.76	0.09
0-12 week	809	813	835	817	17.2	0.53	0.51
ADFI, g							
0-3 week	1,407	1,380	1,415	1,093	102.5	0.02	0.06
4-6 week	2,238	2,250	2,372	2,348	134.9	0.37	0.87
0-6 week	1,823	1,777	1,893	1,736	116.7	0.58	0.25
7-9 week	2,695	2,819	2,884	2,963	102.6	0.04	0.79
10-12 week	3,317	3,168	3,385	3,297	56.9	0.75	0.78
7-12 week	3,006	2,994	3,102	3,130	68.2	0.06	0.69
0-12 week	2,417	2,386	2,550	2,443	86.5	0.23	0.27
G:F, ratio							
0-3 week	0.414	0.443	0.396	0.554	0.028	<0.01	0.02
4-6 week	0.379	0.308	0.375	0.346	0.015	0.94	0.49
0-6 week	0.393	0.363	0.382	0.408	0.015	0.20	0.16
7-9 week	0.299	0.359	0.283	0.315	0.011	0.74	0.39
10-12 week	0.301	0.300	0.314	0.278	0.006	0.27	0.13
7-12 week	0.300	0.328	0.305	0.288	0.006	0.25	0.12
0-12 week	0.335	0.341	0.327	0.336	0.006	0.54	0.28

1) A total of 160 growing pigs were fed from average initial body weight 28.05 ± 8.470 kg

2) CON : corn-SBM based diet, C2: basal diet + cashew nut testa 2%, C4: basal diet + cashew nut testa 4%, C6: basal diet + cashew nut testa 6%

3) Standard error of the mean

Table 6. Effects of dietary level of cashew nut testa in growing-finishing swine diet on blood profile[1]

Criteria	Treatment[2]				SEM[3]	P-Value	
	CON	C2	C4	C6		Linear	Quadratic
BUN, mg/dL							
Initial	----------------------10.50--------------------				0.945	-	-
3 week	12.10	13.42	10.68	11.98	0.490	0.52	0.99
6 week	12.78	14.54	12.98	10.58	0.722	0.24	0.18
9 week	11.56	13.96	12.66	11.90	0.599	0.95	0.16
12 week	10.26	9.28	10.32	9.82	0.425	0.95	0.82
Total cholesterol, mg/dL							
Initial	----------------------90.60--------------------				8.286	-	-
3 week	82.60	82.00	74.80	63.00	2.964	0.01	0.27
6 week	83.00	82.60	70.80	53.20	3.443	<0.01	0.09
9 week	84.40	74.40	72.60	69.00	2.574	0.02	0.44
12 week	91.20	76.20	62.60	71.00	3.267	<0.01	0.03
Creatinine, mg/dL							
Initial	----------------------0.67--------------------				0.037	-	-
3 week	0.72	0.76	0.68	0.84	0.039	0.45	0.47
6 week	0.66	0.70	0.54	0.74	0.054	0.86	0.44
9 week	0.94	0.94	1.06	0.84	0.054	0.73	0.36
12 week	0.96	1.10	1.12	1.38	0.069	0.05	0.65
Insulin, µU/mL							
Initial							-
3 week	0.54	0.44	0.32	0.43	0.086	0.89	0.72
6 week	0.46	0.30	0.22	0.26	0.058	0.25	0.45
9 week	0.66	0.72	0.20	0.28	0.109	0.12	0.97
12 week	0.58	0.36	0.72	0.52	0.099	0.87	0.97
Glucose, mg/ mg/dL							
Initial	----------------------68.80--------------------				3.247		-
3 week	81.40	75.80	67.00	83.00	3.169	0.89	0.12
6 week	83.80	86.40	92.60	80.60	1.751	0.83	0.06
9 week	91.80	86.80	79.40	87.80	1.713	0.22	0.07
12 week	83.60	77.20	85.60	85.80	1.398	0.18	0.19

[1] Least squares means of 5 observations per treatment

[2] CON : corn-SBM based diet, C2: basal diet + cashew nut testa 2%, C4: basal diet + cashew nut testa 4%, C6: basal diet + cashew nut testa 6%

[3] Standard error of mean

Table 7. Effects of dietary level of cashew nut testa in growing-finishing swine diet on pH of pork after slaughter[1)]

Criteria	Treatments[2)]				SEM[3)]	P-value	
	CON	C2	C4	C6		Linear	Quadratic
pH							
0 hour	5.81	5.98	5.95	5.91	0.052	0.58	0.34
3 hour	5.53	5.61	5.57	5.70	0.030	0.10	0.70
6 hour	5.50	5.57	5.54	5.66	0.027	0.10	0.66
12hour	5.58	5.66	5.63	5.77	0.029	0.06	0.55
24hour	5.63	5.64	5.60	5.72	0.028	0.42	0.37

1) Least squares means of 4 observations per treatment

2) CON : corn-SBM based diet, C2: basal diet + cashew nut testa 2%, C4: basal diet + cashew nut testa 4%, C6: basal diet + cashew nut testa 6%

3) Standard error of mean

Table 8. Effects of dietary level of cashew nut testa in growing-finishing swine diet on WHC, cooking loss and shear force of pork[1)]

Criteria	Treatments[2)]				SEM[3)]	P-value	
	CON	C2	C4	C6		Linear	Quadratic
Water holding capacity, %	74.71	73.02	71.17	71.23	0.052	0.14	0.93
Cooking loss, %	32.80	35.58	35.22	34.26	0.030	0.32	0.65
Shear force, kg/0.5 inch[2)]	81.24	87.57	99.38	96.99	0.027	0.26	0.54

1) Least squares means of 4 observations per treatment
2) CON: corn-SBM based diet, C2: basal diet + cashew nut testa 2%, C4: basal diet + cashew nut testa 4%, C6: basal diet + cashew nut testa 6%
3) Standard error of mean

Table 9. Effects of dietary level of cashew nut testa in growing-finishing swine diet on economical analysis[1)]

Criteria	Treatments[1)]				SEM[2)]	P-value	
	CON	C2	C4	C6		Linear	Quadratic
Feed cost per weight gain, won/kg							
0 - 3 week	803.0	753.0	845.0	604.0	37.20	0.60	<0.01
4 - 6 week	847.0	1,045.0	859.0	934.0	91.50	0.03	0.39
7 - 9 week	1,053.0	879.0	1,117.0	1,004.0	96.30	0.10	0.05
10 - 12 week	996.0	998.0	953.0	1,079.0	20.60	0.51	0.04
0 - 12 week	925.0	919.0	943.0	905.0	22.80	0.06	0.06
Total feed cost per pig, won/head							
0 - 3 week	18,410.0	18,450.0	19,035.0	19,069.0	915.30	0.98	0.96
4 - 6 week	16,903.0	17,379.0	18,405.0	17,530.0	1263.80	0.48	0.51
7 - 9 week	14,891.0	18,405.0	15,761.0	14,523.0	1195.40	0.55	0.32
10 - 12 week	13,421.0	17,530.0	13,184.0	12,948.0	1339.30	0.42	0.61
0 - 12 week	63,626.0	63,430.0	66,384.0	64,070.0	4537.20	0.81	0.34
Days to market weight (reached at 115 kg BW), days							
	108.0	108.0	104.7	107.1	2.31	0.80	0.50

1) CON : corn-SBM based diet, C2: basal diet + cashew nut testa 2%, C4: basal diet + cashew nut testa 4%, C6: basal diet + cashew nut testa 6%

2) Standard error of mean

Chapter IV: Effects of dietary cashew nut testa levels as an alternative of wheat bran in gestating sow

Abstract: 40 multiparous sows (Yorkshire × Landrace) were used to determine the effect of dietary cashew nut testa (CNT) instead of wheat bran as an ingredient on reproductive performance, litter performance, milk composition, and blood profiles of sows in gestation. The experiment was started when sows were on their 35 days of pregnancy with an initial average body weight (BW) of 211.53 ± 3.52 kg. Each sow was allotted to each treatment based on BW, backfat thickness and parity with 10 replicates. Treatments were as followed: 1] C0: corn-SBM based diet, 2] C2: basal diet with CNT 2%, 3] C4: basal diet with CNT 4%, 4] C6: basal diet with CNT 6%. Experimental diet (gestating sows' diet) contained 3,265 kcal ME/kg, 12.90% crude protein, 0.74% lysine, 0.20% methionine, 0.90% calcium, and 0.70% total phosphorus. Other nutrients were met or exceed NRC requirement (1998). There were no statistically significant differences in body weight, body weight change, backfat thickness, and backfat thickness changes of gestating sows at 35 day, 70 day and 110 day, 24hour after parturition and 21day of lactation. But the body weight change of sows tended to decrease linearly (P=0.09) and the daily feed intake of sows tended to increase (P=0.09) during the lactation period. The quadratic response was shown on the weaning to estrus interval (WEI) after weaning (P=0.02), and the treatment added 2% of CNT (C2) showed the shortest WEI. There was no significant difference in total born piglets, alive piglets and weaned piglets, but C2 showed 10% higher total born piglets than control, and treatment that added 4% of CNT (C4) showed 12.5% higher than control. Litter birth weight (p = 0.04), after cross-foster litter weight (p = 0.01) and after cross-foster piglet weight (p = 0.01) were reduced by addition of CNT in diet. However, litter weight gain and piglet weight gain had no significant difference in 21 day of lactation. In milk composition, the percentage of fat (p = 0.03), lactose (p = 0.02)

and total solid (p = 0.03) in 24 h postpartum showed a quadratic correlation with the increasing CNT level during gestation while lactation progressed showed no correlation. Along with the increasing CNT level in diets, insulin concentration in 70 d of gestating was reduced linearly (p = 0.03). Consequently, there are no negative effects of addition of 4% CNT instead of wheat bran in gestating sow. Therefore, addition 4% of CNT in gestating sows diet is feasible as a replacement.
Key words: Cashew nut testa, wheat bran, Gestation sow, Lactating sow, Litter performance

Introduction

It is well known that feed costs comprise about 65% of the pork production, so feeding is the highest costly item in pig farm (Armstrong, 2012). Therefore, feed costs play a major role in determining the profitability of a swine farm (Stein, 2007). The price of feedstuff increased since 2006 as biofuel business developed (Patience, 2013). So several studies have been conducted to find alternative ingredient for reducing the feed cost, for example cocoa pod husks, brewers spent grains, rice bran and maize bran.

High fiber concentration feedstuff, especially in wheat bran which contains 7.77% crude fiber, was frequently added to gestating sows diets in Korea in order to prevent constipation (Swine management and nutrition, 2012). CNT (CNT) is one of the by-products obtained from the processing of cashew nuts what has not been considered in monogastric animal feed. CNT is a reddish-brown colored skin that cover the cashew kernel. This skin was reported to be rich in hydrolysable tannins, as well as in polyphenols and contain above 10.3% of crude fiber, which is higher than wheat bran (Dendena, 2015). It has been rarely considered as a feed ingredient in monogastric animals due to its high contents of fiber (Armstrong, 2012). However, as the price of the world grain has been very unstable, it became important to find a cheaper alternative ingredient which contain optimum fiber and can replace wheat bran in gestating sows diet (Wall Street Journal, 2015). Since cashew nut`s healthful nutrient content was known, the the production of cashew nut has rapidly increased. Inclusion of CNT in gestation sows feeds instead of wheat bran could reduce the cost of feeding because of its cheap price.

In this study, therefore, consider using CNT as an ingredient substitute for wheat bran in gestating sows diet and conduct to investigate how the reproduction and progeny of sows response to the different CNT dietary levels.

Material and methods

Experimental animals and housing environment

A total of 40 multiparous sows (Yorkshire × Landrace) with the BW at 211.53 ± 8.86kg were used. Each sow was allotted to an individual gestation stall (2.4 × 0.64 m/pen) with a feeder and a nipple waterer to provide food ad libitum. Second parity sows fed 2.2kg/day and over 2 parity sows fed 2.4kg/day. On day 110 of gestation, sows were moved into environmentally controlled farrowing rooms and placed in individual farrowing crates (2.5 × 1.8 m). Each farrowing crate was equipped with a feeder and a nipple waterer.

Experimental design, treatment and animal management

A total of 40 multiparous sows (Yorkshire × Landrace) with the BW at 211.53 ± 8.86kg were allotted to 4 treatments with 10 replicates with similar BW, backfat thickness and parity in a completely randomized design (CRD). Experimental diet was added and formulated based on corn-soybean meal, which contains 3,265kcal of ME/kg, 12.90% crude protein, 0.74% lysine, 0.20% methionine, 0.90% Ca, and 0.70% total P. Four diet treatments were formulated with 0%, 2%, 4% and 6% of

CNT along with 6%, 4%, 2% and 0% of wheat bran, respectively. All of nutrients were formulated to meet or exceed NRC requirement (1998) [11]. The formula its chemical composition of experimental diets are presented in Table 1 and 2.

Sows were housed in temperature-controlled rooms with automatic fans used to regulate air flow and placed in an individual create (2.4×0.65 m) installed on concrete floor. After 110 days of gestation, pregnant gilts were washed and placed into farrowing crates (2.5 × 1.8 m).

After farrowing, lactation diet was restricted to 1kg at first day and its amount was increased gradually with 1.0 kg extra per day in the first 5 days, then the postpartum sows feed diet was provided with no limitation during lactation period. Within 24 hours of farrowing, Fe-dextran (150 ppm) was injected and treatments such as ear-notched, clipped needle teeth and tails were conducted. Weaning was done at approximately 24±2 day then sows were transferred to gestating crate.

Measurements and analysis

Gestation and lactation period, BW and backfat thickness of sows were measured at P2 position and blood samples were collected at 35, 70, 90, 110 days of gestation at 24 hours post farrowing, 21 days of lactation. The number of piglets born alive, still born, mummified fetuses, total born and BW were measured at 24 hours post farrowing and 21 days of lactation. Lactating sows were bled weekly from the anterior vena cava and other four pigs from each litter were also bled via cardiac puncture. Blood samples were collected into heparinized tubes, centrifuged at 1,500×g for 15 min, and plasma was harvested from all blood samples and stored at -20°C until further analysis. After injection of oxytocin, colostrum, milk samples were collected into falcon tube and stored at -20°C until further analysis.

Insulin in serum was assayed using Coat-A-Count® insulin kits (DPC, Los

Angeles, CA). The concentration of progesterone in the peripheral blood plasma was determined using a solid-phase radioimmunoassay kit (Coat-A-Count® Progesterone, Diagnostic Products Corporation, Los Angeles, CA, USA). Glucose Glucose concentration were analyzed using a blood analyzer (Ciba-Corning model, Express Plus, Ciba Corning Diagnostics Co.).

Colostrum and milk samples were taken from functional mammary glands of each sow at 24 hour and 21 day postpartum, respectively. After collection, samples were stored in a freezer (-20^{o}C) until further analysis. Proximate analysis of colostrum and milk was conducted using Milkoscan FT 120 (FOSS Electric).

Statistical analysis

Statistical analysis was carried out according to LSD (least significance difference) multiple test, using general linear model (GLM) and a procedure of SAS (2009) package program. Each sow was an experimental unit for analysis of the performance data. The individual pig was considered as the experimental unit. Both the ANOVA and linear quadratic model show the significance level was at $p < 0.05$.

RESULTS AND DISCUSSION

Sow and litter performance

The effects of supplementation of dietary CNT levels on BW, backfat thickness, WEI and ADFI in gestating to lactating sows were shown on Table 3. There were no statistical differences in BW and BW change of sows from gestating day 35 to 21st day of lactation. BW change of sows decreased linearly (P=0.09) during lactation, but BW change at 21st day of lactation in C4 was reduced by 87% compared with control. Generally, the BW of the sows at weaning is reduced compared to the weight at parturition. This is because nutrients are consumed more than that obtained through feed. For this reason, the nutrients accumulated in the body are mobilized to use for lactation (Mullan and Williams, 1989; Yang et al., 1989). BW loss of sow can lead to a negative effects on WEI (Kim et al., 2011). The result of this experiment showed that the addition of 4% CNT in pregnant sow diets resulted in the lowest BW loss during lactation.

The effects of supplementation of dietary CNT levels on backfat thickness and backfat thickness change in gestation and lactation period were shown on Table 3. There were no significant differences in backfat thickness and backfat thickness change among all treatments, but the change in backfat thickness was the lowest in C4. The addition of up to 4% of CNT in pregnant feeds does not seem to mobilize much of the accumulated nutrients in sows.

The results for ADFI of sows are shown in Table 3. The increase in CNT levels in pregnant sow diets showed linear increase ADFI of the lactating sows (P=0.09). It did not affect the ADFI statistically but the treatment with CNT of the gestation period showed more ADFI than the control. Generally, if the feed intake of the sows is too low, the body condition of sows turns into negative state, and the problem of increased WEI (King and Williams, 1984; Baidoo et al., 1992) and decreased ovulation (Foxcroft et al., 1995) can occur. In this experiment, the level of addition of CNT in gestating sow diet showed quadratic response on WEI. The WEI was showed the shortest in C2 and these results suggest that the ADFI of sows affected the WEI.

Reproductive performance and piglet growth performance

The effects of supplementation of dietary CNT levels on total born per litter, litter weight, litter weight gain, average BW per piglet and average BW gain of piglet were shown in Table 4. Studies on the effects of the level of CNT on the piglet weight have not been conducted before. There were no significant differences in total born per litter, No. of alive and No. of weaned piglet. However, C2 showed 10% higher total born piglets than control, and C4 showed 12.5% higher than control.

In litter performance, litter birth weight was linearly decreased with increasing CNT (P=0.04) and there was no significant trend in response to CNT after 21 day of lactation. The addition of CNT in gestating diets does not negatively affect the body weight of piglets during lactation.

Piglet birth weight decreased linearly with increasing CNT in gestating diet (P=0.06). So the piglet weight after cross-foster showed linear decrease as the level of CNT increased (P=0.01) and control showed the highest score in piglet weight after cross-foster (P<0.01). Consequently, supplementation of dietary CNT levels has no negative effects on nursing piglet during lactation.

Milk composition

The effects of supplementation of dietary CNT levels on chemical compositions of sow milk were shown in Table 5. Generally, the composition of sow milk depends on the body condition of sow (Klaver et al., 1981; Jackson et al., 1995; Daza et al., 2004) and this affect the growth performance of piglets directly. In 24h postpartum, there were no significant differences in percentage of casein, protein and solid not fat with increasing dietary CNT level. However, the percentage of fat (p = 0.03), lactose (p = 0.02) and total solid (p = 0.03) showed quadratic correlation with the increasing CNT level during gestation. Dietary CNT levels in gestation did not affect milk composition on 21 d of lactation. Consequently, supplementation of dietary CNT levels has not negative effects on growth performance of piglet.

Blood profiles of sows

The effects of supplementation of dietary CNT levels on blood insulin and glucose concentration during gestation-lactation period were shown on Table 6. In 70 d of gestation, blood insulin concentration was reduced linearly when sows fed with increasing levels of CNT (p = 0.03), but from 110 d of gestation to 21 d of lactation, it showed no significant difference. Insulin concentration is the breast of sow, metabolism and fat synthesis (fulks et al., 1975; Scham et al., 1994). In this experiment, because there were no significant differences in BW and backfat of sow on 70 day, decrease of insulin did not seem to affect sow negatively.

Blood glucose concentration did not show any significant trends from 70 d of gestation to 21 d of lactation when added different levels of CNT in gestation sows diet. There are some studies reported that concentration of blood glucose decreased with increasing insulin in sows (Weldon et al., 1994; Le et al., 1998). In the present study, there was no difference in blood insulin and glucose concentration in each treatment but only concentration of blood insulin was linearly decreased with the increasing CNT levels on gestation of 70 d. However, there are a limitation of insulin and glucose concentration from 0.051 (μl U/L) to 0.114 (μl U/L) in gestating sows which found by Long et al. (2010) with no negative effects on sow performance. However, the high concentrations of blood insulin and glucose showed no detrimental effects on sows and litter performance.

Consequently, supplementation of dietary CNT levels has no negative effects on blood glucose concentration and blood profile of sow.

Conclusions

The purpose of this study was to investigate the effect of CNT as an alternative of wheat bran on the reproduction and progeny of sows. There were no significant differences in BW, BW change, backfat thickness and backfat thickness change in gestating and lactating period with the increasing CNT level, however BW change in C4 was smaller than other treatments.

As the level of CNT increased, the feed intake of lactating sows linearly increased. Estrus interval drops to 4.93 in C2 while other treatments showed over 5. C2 and C4 showed higher number of total born than control. But, number of weaned piglet at 21day decreased 9.5% when CNT added 6%.

In reproductive performance, litter performance did not show the significant difference between treatments. As CNT increased, litter birth weight was linearly decreased, but it was numerically similar from 0% to 4% CNT levels. In milk composition, fat, lactose and total solid showed quadratic correlation in colostrum with the increasing CNT level during gestation. Fat and total solids in colostrum were lowest in C2, and Lactose was the highest in C4. But there was no significant difference in percentage of casein, protein, and slid fat with the increasing CNT level. In blood profile, the insulin concentration in sow blood did not show significant difference among treatments in 110day, 24h postpartum and 21d of lactation, but insulin concentration decreased linearly with increasing levels of CNT in sow diet at 70 days of gestation.

Based on these results, additional 6% of CNT instead of wheat bran in gestating sow diet showed no negative effects on sows. When CNT was added 4%, the best results were obtained in reproductive performance, milk composition and blood profile of sow. As a result, addition 6% of CNT in gestating sows diet is recommended.

REFERENCE

Adesehinwa A. O. K. 2007. Utilization of palm kernel cake as an energy source by growing pigs: effects on growth, serum metabolites, nutrient digestibility and cost of feed conversion. Bulg J Agr Sci, 13: 593–600.

Armstrong D., V. Attoh-Kotoku, R. O. Kwame and R. Gascar. 2012. Evaluation of nutritional quality of dried cashew nut testa using laboratory rat as a model for pigs. The Scientific World J. 10: 1100-5.

Darroch C. S., C. R. Dove, C. V. Maxwell, Z. B. Johnson and L. L. Southern. 2008. A regional evaluation of the effect of fiber type in gestation diets on sow reproductive performance. J Anim Sci. 86: 1573–1578.

Donkoh A. and H. K. Zanu. 2010. Development of feed package for layers using low energy agro-industrial by products. Afr J Agr Res. 20: 2782-2786.

Donkoh A. and V. Attoh-Kotoku. 2009. Nutritive value of feedstuffs for poultry in Ghana: chemical composition, apparent metabolizable energy and ileal amino acid digestibility. LRRD. 3: 1-9.

Everts H. 1991. The effect of feeding different sources of crude fiber during pregnancy on the reproductive performance of sows. Anim Prod. 52: 175-184.

Farmer C., S. Robert and J. J. Matte. 1996. Lactation performance of sows fed a bulky diet during gestation and receiving growth hormone-releasing factor during lactation. J Anim Sci. 74: 1298-1306.

Göransson L. 1989. The effect of dietary crude fibre content on the frequency of postpartum agalactia in the sow. J Vet Med. A 36: 474-479.

Göransson L. 1989. The effect of late pregnancy feed allowance on occurrence of agalactia postpartum in the sow. J Vet Med. A Physiol Pathol Clin Med. 36:

505–513.

Stein H. H. 2007. Distillers dried grains with solubles (DDGS) in diets fed to swine. HHS-Swine Focus-001.

Holt J. P., L. J. Johnston, S. K. Baidoo and G. C. Shurson. 2006. Effects of a high-fiber diet and frequency of feeding on behavior, reproductive performance, and nutrient digestibility in gestating sows. J Anim Sci. 84: 946–955.

Le C. Y., C. David, V. Beaumal, S. Johansen, and J. Y. Dourmad. Effect of the feeding level during rearing on performance of Large White gilts. Part 2: Effect on metabolite profiles during gestation and lactation, and on glucose tolerance. Nutr Dev. 38: 377–390.

Long H. F., W. S. Ju, L. G. Piao and Y. Y. Kim. 2010. Effect of dietary energy levels of gestating sows on physiological parameters and reproductive performance. Asian-Aust J Anim Sci. 8:1080–1088.

Lee P. A. and W. H. Close. 1987. Bulky feeds for pigs: A consideration of some non-nutritional aspects. Livest Prod Sci. 16:395–405.

McGlone J.J. and S. D. Fullwood. 2001. Behavior, reproduction, and immunity of crated pregnant gilts: Effects of high dietary fiber and rearing environment. J Anim Sci. 79:1466–1474.

Nelson F. S., G. Y. Ameleke, A. Donkoh and V. Lamptey. 2007. Use of locally available agro-industrial by-products (AIBPs) for egg production in the western region of Ghana. Gh Soc of Anim Prod Symp. 15:103-107.

NRC. Nutrient Requirements of Swine. 10th ed. Washington, DC. Natl Acad Press; 1998.

NRC. Nutrient Requirements of Swine. 11th ed. Washington, DC. 2012. Natl Acad Press.

Okon B. I. and B. K. Ogunmodede. 1995. Effects of replacing dietary fish meal with periwinkle flesh on the performance of broiler chickens, B. Sc Dissertation. Dept. of Animal Sci, University of Ibadan, Ibadan, Nigeria.

Patience J. F. 2013. Managing energy intake and costs of grow-finish pigs. Proc. 29–35.

Ramonet Y., M. C. Meunier-Salaun and J. Y. Dourmad. 1999. High-fiber diets in pregnant sows: Digestive utilization and effects on the behavior of animals. J Anim Sci. 77:591–599.

Rhule S. W. A., D. B. Okai, S. Addo-Kwafo and G. Y. Ameleke. 2007. Feed package for pigs in Ghana using AIBPs: solution to feeding constraints. Gh Soc of Anim Prod Symp. 15:135-139.

Stevenson J. S. and J. H. Britt. 1981. Interval to estrus in sows and performance of pigs after alteration of litter size during late lactation. J Anim Sci. 53:177–181.

Swine management and nutrition. Seoul. Seoul National University Press; 2012.

Van der Peet-Schwering C. M. C., B. Kemp, G. P. Binnendijk, L. A. den Hartog, H. A. M. Spoolder and M. W. A. Verstegen. 2003. Performance of sows fed high levels of nonstarch polysaccharides during gestation and lactation over three parities. J Anim Sci. 81:2247-2258.

Vestergaard E.M. and V. Danielsen. 1998. Dietary fiber for sows: Effects of large amounts of soluble and insoluble fibers in the pregnancy period on the performance of sows during three reproductive cycles. Anim Sci. 68:355–362.

Veum T. L., J. D. Crenshaw, T. D. Crenshaw, G. L. Cromwell, R. A. Easter, R. C. Ewan, J. L. Nelssen, E. R. Miller, J. E. Pettigrew and M. R. Ellersieck. 2009. The addition of ground wheat straw as a fiber source in the gestation diet of sows and the effect on sow and litter performance for three successive parities.

J Anim Sci. 87:1003–1012.

Weldon W.C., A. J. Lewis, G. F. Louis, J. L. Kovar and P. S. Miller. 1994. Postpartum hypophagia in primiparous sows. II. Effects of feeding level during gestation and exogenous insulin on lactation feed intake, glucose tolerance, and epinephrine stimulated release of nonesterified fatty acids and glucose. J Anim Sci. 72:395–403.

Table 1. Formula of experimental diet in gestating sow

Item	Cashew nut testa (%)			
	0	2	4	6
Ingredient, %				
Corn	72.63	73.39	74.14	74.20
SBM	14.75	14.77	14.79	14.81
Tallow	2.65	1.83	1.02	0.90
Wheat bran	6.00	4.00	2.00	0.00
Cashew nut testa	0.00	2.00	4.00	6.00
L-lysine HCl	0.17	0.17	0.17	0.17
DL-methionine	0.03	0.03	0.03	0.03
MDCP	1.80	1.84	1.92	2.00
Limestone	1.37	1.37	1.33	1.29
Vit. Mix1	0.10	0.10	0.10	0.10
Min. Mix[2]	0.10	0.10	0.10	0.10
Choline chloride-50	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00

[1)] Provided per kg of diet: Vit A, 16,000IU; Vit D_3, 3,200IU; Vit. E, 35IU; Vit. K_3, 5mg; Rivoflavin, 6mg; Pantothenic acid, 16mg; Niacin, 32mg; d–Biotin, 128ug; Vit.B_{12}, 20ug.

[2)] Provided per kg of diet: Fe, 281mg; Cu, 143mg; Mn, 49mg; I, 0.3mg; Se, 0.3mg.

Table 2. Chemical composition of experimental diet in gestating sow

Item	Cashew nut testa (%)			
	0	2	4	6
Chemical composition (calculated value)				
ME, kcal/kg[3]	3,265	3,251	3,248	3,235
Crude protein, %[3]	12.89	12.89	12.89	12.89
Crude ash, %[3]	5.56	5.55	5.55	5.54
Crude fiber, %[3]	2.69	2.86	2.99	3.06
NDF, %[3]	12.13	12.29	12.46	12.63
ADF, %[3]	3.75	3.79	3.82	3.85
Total lysine[3]	0.74	0.74	0.74	0.74
Total methionine[3]	0.23	0.23	0.23	0.23
Calcium[3]	0.91	0.91	0.91	0.91
Total Phosphorus[3]	0.70	0.70	0.70	0.70
Chemical composition (analyzed value)				
Crude protein, %[4]	11.84	13.02	12.76	13.46
Crude ash, %[4]	3.33	4.24	5.00	4.81
Crude fiber, %[4]	3.36	3.78	3.35	3.37
NDF, %[4]	15.55	17.86	19.28	18.15
ADF, %[4]	3.67	4.70	4.46	4.51
Calcium[4]	1.36	1.32	1.94	1.37
Total Phosphorus[4]	0.72	0.73	0.72	0.71

3) Calculated value. 4) Analyzed value.

Table 3. **Effects of cashew nut testa level on BW, back-fat thickness, WEI and ADFI in gestating to lactating sows**

Item	Cashew nut testa (%)				SEM[1]	p-value	
	0	2	4	6		Lin.	Quad.
No. of sows	10	10	10	10			
BW (kg) in gestating sows							
35 d	212.20	210.30	211.05	212.55	3.523	0.96	0.83
70 d	230.35	230.20	224.80	228.75	3.572	0.77	0.79
110 d	257.30	261.20	251.44	253.75	3.441	0.55	0.91
35 d to 110 d change	45.10	50.90	40.39	41.20	1.614	0.12	0.43
BW (kg) in lactating sows							
24h postpartum	230.05	233.85	223.25	227.20	3.733	0.61	0.99
21 d of lactation	210.30	218.70	212.69	215.75	3.659	0.77	0.74
Farrowing to 21 d	-19.75	-15.15	-10.56	-11.45	-1.988	0.09	0.47
Backfat thickness (mm) in gestating sows							
35 d	17.35	17.90	19.75	17.65	0.858	0.74	0.48
70 d	16.95	17.40	19.45	16.35	0.882	0.98	0.34
110 d	19.80	18.15	18.94	18.20	0.950	0.67	0.83
35d to 110 d change	2.45	0.25	-0.81	0.55	0.600	0.25	0.17
Backfat thickness (mm) in lactating sows							
24h postpartum	17.90	18.30	18.75	18.85	0.902	0.71	0.93
21 d of lactation	15.45	16.30	18.13	16.30	0.772	0.57	0.44
Farrowing to 21 d	-2.45	-2.00	-0.62	-2.55	-0.554	0.84	0.32
Daily feed intake in lactation (kg/day)							
	4.20	5.14	5.02	5.14	0.181	0.09	0.24
Weaning to estrus interval (day)							
	6.00	4.93	5.30	5.7	0.163	0.69	0.02

[1] Standard error of mean.

Table 4. Effects of cashew nut testa level on reproductive performance, litter performance in gestating to lactating sows

Item	Cashew nut testa (%)				SEM[1)]	p-value	
	0	2	4	6		Lin.	Quad.
No. of sows	10	10	10	10			
Reproductive performance							
Total born/litter	14.00	15.40	15.78	13.90	0.492	0.99	0.15
No. of born alive	13.00	13.80	14.25	13.10	0.374	0.40	0.49
No. of stillbirths	1.00	1.60	1.53	0.80	0.222	0.96	0.24
After cross-foster	11.90	11.90	11.85	11.80	0.083	0.62	0.87
21 day of lactation	11.40	11.10	11.50	10.50	0.183	0.15	0.33
Litter weight, kg							
Litter birth weight	21.79	21.72	21.07	18.26	0.059	0.04	0.26
After cross-foster	19.30	17.80	16.22	16.17	0.038	0.01	0.30
21 day of lactation	55.93	56.65	55.36	52.69	1.752	0.48	0.62
Litter weight gain	36.63	38.85	39.14	36.52	1.563	0.99	0.44
Piglet weight, kg							
Piglet birth weight	1.59	1.42	1.34	1.39	0.044	0.06	0.18
After cross-foster**	1.62^{A}	1.50^{AB}	1.37^{B}	1.37^{B}	0.031	0.01	0.28
21 day of lactation	4.90	5.09	4.78	4.94	0.098	0.85	0.92
Piglet weight gain	3.28	3.59	3.41	3.57	0.087	0.41	0.68

[1)] Standard error of mean.

[A,B,C)] means with different superscripts within the same row significantly differ (P<0.01)

Table 5. Effect of cashew nut testa level on milk composition of gestating and lactating sows

Item	Cashew nut testa (%)				SEM[1)]	p-value	
	0	2	4	6		Lin.	Quad.
No. of sows	10	10	10	10			
Casein, %							
24h postpartum	4.98	4.49	4.22	6.07	0.321	0.32	0.10
21 d of lactation	4.36	4.57	4.30	4.22	0.073	0.22	0.26
Fat, %							
24h postpartum	7.62	5.27	7.11	8.24	0.482	0.25	0.03
21 d of lactation	6.18	7.35	6.44	6.29	0.198	0.68	0.06
Protein, %							
24h postpartum	6.37	5.76	5.23	7.91	0.438	0.31	0.10
21 d of lactation	4.81	5.00	4.72	4.61	0.082	0.22	0.35
Lactose, %							
24h postpartum	4.48	4.66	4.77	4.17	0.081	0.22	0.02
21 d of lactation	6.22	6.06	6.25	6.09	0.044	0.49	0.95
Total solid, %							
24h postpartum	20.28	17.30	18.57	22.68	0.852	0.21	0.03
21 d of lactation	18.29	19.71	18.49	18.06	0.267	0.38	0.07
Solid not fat, %							
24h postpartum	10.86	10.56	10.01	12.15	0.365	0.34	0.14
21 d of lactation	11.10	11.19	11.07	10.88	0.049	0.09	0.16

[1)] Standard error of mean.

Table 6. Effect of cashew nut testa level on blood profiles of gestating and lactating sows

Item	Cashew nut testa				SEM[1)]	p-value	
	0	2	4	6		Lin.	Quad.
Insulin (µl U/L)							
35 day	0.065	0.065	0.065	0.065	-	-	-
70 day	0.088	0.086	0.054	0.059	0.0071	0.03	0.73
110 day	0.079	0.081	0.062	0.075	0.0082	0.62	0.68
24h postpartum	0.081	0.102	0.087	0.093	0.0811	0.84	0.75
21 d of lactation	0.095	0.087	0.088	0.061	0.0948	0.14	0.51
Glucose (mg/dL)							
35 day	71.167	71.167	71.167	71.167	-	-	-
70 day	66.500	68.500	67.250	67.250	1.2579	0.92	0.65
110 day	79.750	77.000	76.250	74.750	1.3148	0.28	0.84
24h postpartum	84.750	95.500	83.000	89.750	2.2502	0.95	0.81
21 d of lactation	82.667	74.500	74.250	78.250	3.4723	0.34	0.07

1) Standard error of mean.

Chapter V: Effect of dietary cashew nut testa supplementation levels on nutrient digestibility in gestating sows

ABSTRACT: This experiment was conducted to evaluate the effect of cashew nut testa (CNT) supplementation levels on nutrient digestibility and its availability in gestating sows. A total of 20 gestating sows (Yorkshire × Landrace, d 90 of gestation) with initial BW of 252.61 ± 24.69 kg, BF thickness (P2 position) of 23.4 mm and average parity 6.5 was used in a digestibility trial. Sows were allotted to one of four treatments in a completely randomized design (CRD) by their body weight, backfat thickness and their parity. Treatments were as followed: 1] C0: corn-SBM based diet, 2] C2: basal diet with CNT 2%, 3] C4: basal diet with CNT 4%, 4] C6: basal diet with CNT 6%. Experimental diet (gestating sows' diet) contained 3,265 kcal ME/kg, 12.90% crude protein, 0.74% lysine, 0.20% methionine, 0.90% calcium, and 0.70% total phosphorus. Other nutrients were met or exceed NRC requirement (1998). There was no significant difference in BW at initial and final of digestibility trial and BF thickness had not significantly affected by dietary CNT level during digestibility trial. Increasing the supplementation of CNT level decreased digestibility of dry matter (linear, P=0.03), crude protein (linear, P=0.04), ether extract (linear, P=0.05) in gestating sows. Also, crude fiber, ADF and NDF digestibility tended to be deceased linearly by dietary CNT level increased (linear, P=0.07; linear, P=0.06, linear, P=0.02). These results indicated that supplementation of CNT had negative effects on nutrient digestibility with no detrimental effect on growth performance in gestating sows.

Key words: Cashew nut testa, gestating sows, nutrient digestibility,

INTRODUCTION

Feed costs comprised about 65% of the pork production, so feeding was the highest costly item (Armstrong, 2012) and feed costs played a major role in determining the profitability of swine farm (Stein, 2007). Using alternative ingredient in swine diet could be an economical choice. However, the nutritional value of the raw material should be evaluated. Before using alternatives, an examination on the nutritive value in terms of their metabolizable energy, nutrient content and palpability needs to be examined (Alimon, 2009). Especially, many grain byproducts contain high level of fiber that known as the factor decrease digestibility of nutrient in mono-gastric animals and it was resistant to digestion by endogenous enzymes in the small intestine (Knudsen, 2009).

Due to the high cost of breeding in developing countries, there is an absolute need to find the possibility of using agro-industrial by products and wastes such as discarded cashew nut-waste (Oddoye, 2011). While the raw cashew nuts being processed in many of the producing countries (Olunloyo, 1996), only around 60-65% are suitable for human food and the rest are discarded as broken or burned kernels (Fetuga et al., 1974). USDA (2004) have shown that cashew nut meal extracted from whole kernels contains 42% crude protein, 1% crude fat, 0.5% calcium and 0.2% phosphorus, respectively. It has excellent quality protein containing 4.6% lysine, 1.3% tryptophan, 2% cysteine and 1.6 % methionine (Stamford et al., 1988). Considering the chemical composition of the dried flour of cashew waste, this product can be used for animal consumption (Stamford et al., 1988). Other analytical data showed that the rejected cashew nut could be important alternative protein (whole cashew nut meal: 34%; defatting rejected cashew nut: 45.5%) and it could be used as an energy contributors to compound non ruminant animal feed (Aletor et al., 2007).

Cashew nut meal could be fed at up to 6% level to post-weaning pigs (6 to 12 week-old) without harmful effect on growth performance (Yao et al., 2013). Fanimo et al. (2004) indicated that cashew nut meal could be included in the diets of weaner pigs to replace soybean meal at up to 10% level without harmful effect on growth performance. In addition, Oddoye et al. (2011) demonstrated that inclusion of cashew nut meal up to 30% had no harmful effect on animal performance and reduced feed costs.

Therefore, present study was conducted to evaluate the effect of CNT supplementation levels on nutrient digestibility and its availability in gestating sows.

MATERIALS AND METHODS

Animal and housing

A total of 20 gestating sows (Yorkshire × Landrace, d 90 of gestation) with initial BW of 252.61 ± 24.69 kg, BF thickness (P2 position) of 23.4 mm and average parity 6.5 was used in a digestibility trial. Sows were allotted to one of four treatments in a completely randomized design by their body weight, backfat thickness and their parity. Sows were housed in an individual metabolic crate (2.5×1.8 m, height 0.50 m) like lactating barn.

Each treatment diet was provided 2,400 g/d once daily to gestating sows. Water is provided to sows ad libitum. Sows were moved into individual farrowing crates (2.5 × 1.8 m) for digestibility trial and housed until end of digestibility trial. After 3days of adaptation period (87-89d gestation), sows were fed the experimental diet to each treatment during 4 days (90-93d gestation) with collecting the feces samples during 2-5 days (92-98d gestation). BW and BF thickness of sows were measured at d 90 of gestation and end of collection.

Treatment and experimental diet

Each treatment was designed based on supplementation level of CNT as instead of wheat bran in the gestation diet. Four diet treatments were formulated with 0%, 2%, 4% and 6% of CNT along with 6%, 4%m 2% and 0% of wheat bran, respectively. Treatments were as followed: 1) C0: corn-SBM based diet, 2) C2: basal diet with CNT 2%, 3) C4: basal diet with CNT 4%, 4) C6: basal diet with CNT 6%. Experimental diet (gestating sows' diet) contained 3,265 kcal ME/kg, 12.90% crude protein, 0.74% lysine, 0.20% methionine, 0.90% calcium, and 0.70% available phosphorus. Other nutrients were met or exceed NRC requirement (1998). The formula and chemical composition of experimental diets were presented in Table 1.

Sample collection and analysis

Total collection method was used for the apparent nutrient digestibility. After a 3 day adaptation period, 4 days of feeding period and 7 days of collection period were followed. Total amount of feed consumed was recorded daily for 4 days and weight of collected excreta was recorded daily for 2-7 days after feeding the experimental diet. After 4 days of feeding experiment diet period, sows were fed the same treatment diet for minimizing the variation of digestibility. Each treatment diet was provided 2,400 g/d once daily to gestating sows and water also provided freely. Ferric oxide and chromium oxide were used as indigestible markers. To determine the first and last day of collection days, 0.5% of ferric oxide added in the first experimental diet and 0.5% of chromium oxide added in the fifth experimental diet (after 4 days of feeding time) as selection marker, respectively. Collected excreta from each sow were pooled, sealed in plastic bags and kept frozen at -20℃. When end of the collecting excreta, total amount of excreta was weighted by weighing machine (CAS, Korea) and restored in freezer at -20℃ until further analysis. Then, after air-forced oven dried at 60℃ for 72 h and weighed those samples, those samples were ground by a Wiley mill to pass 1 mm screen for chemical analysis. Ground diets and fecal samples were analyzed for dry matter (DM) (967.03; AOAC, 1995); crude ash (923.03; AOAC, 1995); ether extract (920.39; AOAC, 1995), nitrogen by using the Kjeldahl procedure with Kjeltec (KjeltecTM 2200, Foss Tecator, Sweden) and calculated CP content (Nitrogen × 6.25; 981.10; AOAC, 1995). The content of crude fiber (1-3), ADF (2-2), NDF (2-1) was analyzed by Feed Standard Analytic Method (2011). Considering the analyzed data and DM digestibility, digestibility of dry matter, crude protein, ether extract, crude ash, crude fiber, ADF and NDF were calculated.

<Calculation>

Nutrient digestibility, % (DM basis)

$$\text{Digestibility (\%)} = \frac{\text{Nutrient intake} - \text{nutrient in feces}}{\text{Nutrient intake}} \times 100$$

Statistical analysis

All statistical analyses by least squares mean comparisons were carry out using the PDIFF option with the General Linear Model procedure of SAS (SAS Institute, 2004). Orthogonal polynomial contrasts were used to determine linear and quadratic effects by increasing CNT levels in growth performance and nutrient digestibility. Individual sows were used as the experimental unit in digestibility trial and each total collected sample was used as the experimental unit in digestibility analysis. Probability values less than 0.05 ($P<0.05$) were considered as significant difference;

0.05≤P<0.10 were indicative of a trend; and values equal to or greater than 0.10 were considered as non-significant difference.

RESULTS AND DISCUSSION

The analytical data for CNT, in comparison of corn and wheat bran, is showed in Table 3. Compared to wheat bran, CNT contained more protein, fiber and fat but had less ash and phosphorus. The calculated ME content of CNT was higher than that of wheat bran. This may be due to the difference higher contents of fat in CNT.

The effects of CNT supplementation level on body weight and backfat thickness of gestating sows during digestibility trial were presented in Table 4. There was no significant difference in BW, BF thickness at initial and final of digestibility trial

The effect of CNT supplementation level on digestibility of dry matter, crude protein, ether extract, crude ash, crude fiber, ADF, NDF in gestating sows were presented in Table 5. Increasing the supplementation of CNT level decreased digestibility of dry matter (linear, P=0.03), crude protein (linear, P=0.04), ether extract (linear, P=0.05) in gestating sows. Also, crude fiber and ADF digestibility tended to be deceased linearly as dietary CNT level increased (linear, P=0.07; linear, P=0.06) and NDF digestibility was decreased linearly as supplementation level of CNT increased (linear, P=0.02). In present study, high level of CNT supplementation included high fiber content decreased the nutrient digestibility. These results were in accordance with the previous studies about dietary fiber and nutrient digestibility of pig (Wenk, 2001; Stanogias and Pearce, 1985; Fernadez and Jogensen, 1986; Ehle et al., 1982).

Dietary fiber influenced transit time with a reduction in the upper and increase in the lower digestive tract and, therefore, decreased the digestibility of most nutrients and energy (Wenk, 2001). Stanogias and Pearcet (1985) presented that fiber amount affect the apparent digestibility by growing pigs of NDF and NDF components, nitrogen balance and rate of passage of digesta. Fernandez and Jorgensen (1986) indicated that increasing fiber content in swine diet decreased digestibility of nutrient consistently, regardless of the analytical method used. Also, Ehle et al. (1982) showed that digestibility of dry matter, cell wall, cellulose, hemicellulose and protein were affected by dietary fiber.

Many studies with growing-finishing pigs have shown a decrease in the apparent faecal crude protein and amino acid digestibility when additional fiber is included in the diets (Sauer et al. 1980; Partridge et al. 1982). The energy value of feeds is negatively correlated to their dietary fiber content (Morgan et al., 1987; Noblet and Perez, 1993). Because digestibility of dietary fiber was lower than other nutrients, an increase of dietary fiber content is logically associated with a reduced digestibility of the diet energy (Noblet and Le Goff, 2001). Moreover, Ehle et al. (1982) showed that dietary fiber had a significant effect on large intestinal turnover time and Stanogias and Pearcet (1985) indicated that the rate of passage tended to increase with increasing NDF intake. Like with previous studies, increasing level of dietary fiber content with dietary CNT supplementation had negative effects on the nutrient digestibility in gestating sows.

In this study, the growth and reproductive performance in sow showed no significant difference despite the digestibility decreased as the inclusion of CNT increased. This result is consistent with many previous tests (Jindal et al., 1996; Greshop et al., 2001). According to Grieshop`s review (2001), various previous studies had reported improvements in reproductive performance of sows fed diets containing high level of fiber. He summarized 20 trials that studied effects of high contents of fiber in diets on reproductive performance of sows. Among the 20 studies he reviewed, 13 studies showed that litter size increased when sows consumed a high fiber diet during gestation, and only six studies showed no difference or an adverse effect in litter size.

There are two possible explanations for positive effects of dietary fiber in sow. Firstly, when sows consume the diet containing high level of fiber during early pregnancy, they may consume less energy than sow consume normal diet. These changes can lead to improved embryo survival in early stage. Jindal et al. (1996) reported positive responses in litter size to dietary fiber may be attributable to the energy dilution that occurs when diets contain high levels of fiber. He stated sows fed high fiber diets may have consumed less energy during the critical early stages of pregnancy and it enhanced embryo survival. Therefore it ultimately increased litter size.

Secondly, dietary NSP may improve insulin sensitivity of peripheral tissues and sustained postprandial insulin secretion improving ovulation rate and litter size at birth, ultimately (Johnston, 2003). Many previous studies showed that sensitivity of peripheral tissues to insulin increased in humans who suffer from diabetes when they had high level of NSP (Hjollund et al., 1983; Karlstrom et al., 1984; Landin et al., 1992). High concentration of insulin in blood increases ovulation rate (Cox et al., 1987) and litter size in sow, consequently (Ramirez et al., 1993).

Conclusion

This study was conducted to evaluate the effect of dietary CNT supplementation on nutrient digestibility in gestating sows. Although body weight and backfat thickness were not affected by dietary CNT levels, the nutrient digestibility of dry matter, crude protein, ether extract, crude fiber, ADF, and NDF decreased significantly as dietary CNT level increased. Consequently, supplementation of CNT resulted in negative influence on nutrient digestibility but there was no detrimental effect on body weight and backfat thickness in gestating sows.

REFERENCES

AOAC. 1995. Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Arlington, Virginia. National Research Council.

Aletor, O., J. O. Agbede, S. A. Adeyeye and V. A. Aletor. 2007. Chemical and physio-chemical characterization of the flours and oils from whole and rejected cashew nuts cultivated in Southwest Nigeria. Pakistan Journal of Nutrition, 6: 89-93.

Alimon, A. R. 2009. Alternative raw materials for animal feed. Makalah diterima. Faculty of Agriculture Universiti Putra Malaysia.

Armstrong D, V. Attoh-Kotoku, R. O. Kwame and R. Gascar. Evaluation of nutritional quality of dried cashew nut testa using laboratory rat as a model for pigs. The Scientific World J. 10: 1100-1105.

Cox, N. M., M. J. Stuart, T. G. Althen, W. A. Bennett and H. W. Miller. 1987. Enhancement of ovulation rate in gilts by increasing dietary energy and administering insulin during follicular growth. J. Anim. Sci. 64: 507-516.

Ehle, F. R., J. L. Jeraci, J. B. Robertson and P. J. Van Soest. 1982. The influence of dietary fiber on digestibility, rate of passage and gastrointestinal fermentation in pigs. J. Anim. Sci, 1071-1081.

Fanimo, A. O., T. E. Oduguwa, T. E. Adewunmi, and A. I. Lawal. 2004. Utilization Of Diets Containing Cashew-Nut Reject Meal By Weaner Pigs. Nigerian JAP, 31: 22-26.

Feed standard analytic method. 2001. National Institute of Animal Science. Wanju-gun, Jeollabukdo, Korea.

Fetuga, B.L., G.M. Babatunde and V.A. Oyenuga, 1974. The feeding stuff potential of cashewnut scrap kernel meal. Proc. of tropical products Institute on animal feeds of tropical and subtropical origins. Tropical products Institute, London, (UK). 208-214.

Fernández, J. and J. N. Jørgensen. 1986. Digestibility and absorption of nutrients as affected by fibre content in the diet of the pig. Quantitative aspects. Livestock Production Science, 15: 53-71.

Grieshop, C. M., D. E. Reese, and G. C. Fahey, Jr. 2001. Nonstarch polysaccharides and oligosaccharides in swine nutrition. Page 107 in Swine Nutrition. A. J. Lewis and L. L. Southern, Eds. CRC Press, Boca Raton, FL.

Hjollund, E., O. Pedersen, B. Richelsen, H. Beck-Nielsen and N. S. Sorensen. 1983. Increased insulin binding to adipocytes and monocytes and increased insulin sensitivity of glucose transport and metabolism in adipocytes from non-insulin-dependent diabetics after a low-fat/high-starch/high-fiber diet. Metabolism 32:1067-1075.

Jindal, R., J. R. Cosgrove, R. X. Aherne and G. R. Foxcroft. 1996. Effect of nutrition on embryonal mortality in gilts: association with progesterone. J. Anim. Sci. 74:620-624.

Johnston L. J., S. Noll, A. Renteria, and J. Shurson. 2003. Feeding by-products high in concentration of fiber to nonruminants. Third National Symposium on Alternative Feeds for Livestock and Poultry held in Kansas City. West Central Research and Outreach Center, University of Minnesota.

Karlstrom, B., B. Vessby, N. G. Asp, M. Boberg, I. B. Gustafsson, H. Lithell and I. Werner. 1984. Effects of an increased content of cereal fibre in the diet of Type 2 (non-insulin-dependent) diabetic patients. Diabetologia 26:272-277.

Knudsen E. B. 2009. Dietary fibre in nutrition and health of piglets.

Landin, K., G. Holm, L. Tengborn, and U. Smith. 1992. Guar gum improves insulin sensitivity, blood lipids, blood pressure, and fibrinolysis in healthy men. Am. J. Clin. Nutr. 56:1061-1065.

Li, S., W. C. Sauer and R. T. Hardin. 1994. Effect of dietary fibre level on amino acid digestibility in young pigs. Canadian journal of animal science, 74: 327-333.

Marcel, B. K., K. B. André, Z. T. Viviane, and K. C. Séraphin. 2011. Cashew in Breeding: Research synthesis. IJAAR. 1: 1-8.

Morgan, C. A., C. T. Whittemore, P. Phillips and P. Crooks. 1987. The prediction of the energy value of compounded pig foods from chemical analysis. Ani feed sci. 17: 81-107.

Noblet, J. and G. Le Goff. 2001. Effect of dietary fibre on the energy value of feeds for pigs. Animal feed science and technology, 90: 35-52.

Noblet, J., and J. M. Perez. 1993. Prediction of digestibility of nutrients and energy values of pig diets from chemical analysis. J. Anim. Sci. 71: 3389-3398.

NRC. 1998. Nutrient requirements of swine, 10th ed. Natl. Acad. Press, Washington, DC.

Oddoye, E. O. K., K. Agyente-Badu, V. Anchirina, and V. Johnson. 2011. Effects on performance of growing pigs fed diets containing different levels of cashew nut reject meal. Bulletin of Animal Health and Production in Africa. 59.

Olunloyo, O.A. 1996. Marketing outlets for cashew nuts. Proc. of the National workshop on cashew production technology. Cocoa Research Institute of Nigeria, Ibadan.

Partridge, I. G., H. D. Keal and K. G. Mitchell. 1982. The utilization of dietary cellulose by growing pigs. Animal Production, 35: 209-214.

Ramirez, J. L., N. M. Cox, A. B. Moore, A. J. Holtcamp, and R. C. Tubbs. 1993. Administration of insulin to first litter sows on a commercial farm: Effects on conception rate and litter size in relation to body condition. Proc. 4th International Conf. on Pig Reprod. 96.

Sauer, W. C., A. Just, H. H. Jorgensen, M. Fekadu, and B. O. Eggum. 1980. The influence of diet composition on the apparent digestibility of crude protein and amino acids at the terminal ileum and overall in pigs. Acta agriculturae scandinavica, 30: 449-459.

Stamford, T. L. M., R. Vieira, N. B. Guerra, R. B. de Medeiros and M. L. Cavalcante. 1988. Protein enrichment of cashew wastes for animal. Food and Nutrition Bulletin (UNU).

Stanogias, G. and G. R. Pearcet. 1985. The digestion of fibre by pigs. Brit J Nutr. 53: 513-530.

Stein, H. H. 2008. Use of distillers co-products in diets fed to swine. Midwest agribusiness trade research and information center at the center for agricultural and rural development, Iowa State University. 79-97.

Wenk, C. 2001. The role of dietary fibre in the digestive physiology of the pig. Ani feed sci, 90: 21-33.

Table 1. Formula of experimental diet in gestating sow

Item	Cashew nut testa (%)			
	0	2	4	6
Ingredient, %				
Corn	72.63	73.39	74.14	74.20
SBM	14.75	14.77	14.79	14.81
Tallow	2.65	1.83	1.02	0.90
Wheat bran	6.00	4.00	2.00	0.00
Cashew nut testa	0.00	2.00	4.00	6.00
L-lysine HCl	0.17	0.17	0.17	0.17
DL-methionine	0.03	0.03	0.03	0.03
MDCP	1.80	1.84	1.92	2.00
Limestone	1.37	1.37	1.33	1.29
Vit. Mix[1]	0.10	0.10	0.10	0.10
Min. Mix[2]	0.10	0.10	0.10	0.10
Choline chloride-50	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00

1) Provided per kg of diet: Vit A, 16,000IU; Vit D_3, 3,200IU; Vit. E, 35IU; Vit. K_3, 5mg; Rivoflavin, 6mg; Pantothenic acid, 16mg; Niacin, 32mg; d–Biotin, 128ug; Vit.B_{12}, 20ug.

2) Provided per kg of diet: Fe, 281mg; Cu, 143mg; Mn, 49mg; I, 0.3mg; Se, 0.3mg.

Table 2. Chemical composition of experimental diet in gestating sow

Item	Cashew nut testa (%)			
	0	2	4	6
Chemical composition (calculated value)				
ME, kcal/kg	3,265	3,251	3,248	3,235
Crude protein, %	12.89	12.89	12.89	12.89
Crude ash, %	5.56	5.55	5.55	5.54
Crude fiber, %	2.69	2.86	2.99	3.06
NDF, %	12.13	12.29	12.46	12.63
ADF, %	3.75	3.79	3.82	3.85
Total lysine	0.74	0.74	0.74	0.74
Total methionine	0.23	0.23	0.23	0.23
Calcium	0.91	0.91	0.91	0.91
Total Phosphorus	0.70	0.70	0.70	0.70
Chemical composition (analyzed value)				
Crude protein, %	11.84	13.02	12.76	13.46
Crude ash, %	3.33	4.24	5.00	4.81
Crude fiber, %	3.36	3.78	3.35	3.37
NDF, %	15.55	17.86	19.28	18.15
ADF, %	3.67	4.70	4.46	4.51
Calcium	1.36	1.32	1.94	1.37
Total Phosphorus[4]	0.72	0.73	0.72	0.71

Table 3. Chemical composition of dried cashew nut testa, wheat bran and corn[1]

Item	Cashew nut testa	Corn	Wheat bran
Dry Matter, %	88.3	86.6	88.8
Crude Protein, %	13.32	6.90	15.00
Crude Fat, %	9.44	3.30	3.70
Crude Fiber	11.07	2.04	9.64
Ash, %	2.16	1.08	4.67
ME, kcal/kg	2,765	3,276	2,290
Ca, %	0.10	0.03	0.11
P, %	0.16	0.24	1.02
ADF, %	14.91	2.50	14.30
NDF, %	40.23	8.06	40.30
Tannin[2]**, %**	22.03		

1) Analyzed value.
2) Analyzed by Korea feed ingredient association.

Table 4. Effect of dietary cashew nut testa levels in gestation on body weight, backfat thickness and their changes of sows during collection period

Items	Treatment[1)]				SEM[2)]	*P*-value	
	C0	C2	C4	C6		Lin.	Quad.
Body weight, kg							
Initial	250.4	253.9	250.4	253.9	5.666	0.90	1.00
Final	252.0	255.4	251.6	254.8	5.685	0.93	0.99
Changes	1.6	1.5	1.2	0.9	0.323	0.45	0.89
Backfat thickness, mm							
Initial	22.5	22.4	22.5	22.4	1.387	0.99	1.00
Final	22.2	22.4	23.0	22.4	1.360	0.93	0.89
Changes	-0.3	0	0.5	0	0.149	0.30	0.19

[1)] A total of 20 gestating sows (Yorkshire × Landrace, 90d gestation) and initial BW 252.61 ± 24.69 kg.
[2)] Standard error of mean.

Table 5. Effect of dietary cashew nut testa levels in gestation on nutrient digestibility in gestating sows[1)]

Items	Treatment[2]				SEM[3]	*P*-value	
	C0	C2	C4	C6		Lin.	Quad.
Nutrient digestibility, %							
Dry matter	91.08	89.29	86.11	81.44	1.637	0.03	0.64
Crude protein	86.32	84.59	78.77	73.54	2.298	0.04	0.69
Ether extract	70.26	62.83	53.91	48.36	4.088	0.05	0.91
Crude ash	44.47	49.04	44.83	41.61	4.216	0.76	0.68
Crude fiber	74.59	71.48	64.09	56.10	3.618	0.07	0.73
ADF	67.64	60.81	49.73	40.53	5.154	0.06	0.91
NDF	78.11	74.86	69.56	56.81	3.413	0.02	0.45

[1)] A total of 20 gestating sows (Yorkshire × Landrace, 90d gestation) and initial BW 252.61 ± 24.69 kg.
[2)] Treatment: C0: corn-SBM based diet, C2: basal diet + CNT 2%, C4: basal diet + CNT 4%, C6: basal diet + CNT 6%.
[3)] Standard error of mean.

Chapter VI. Overall Conclusion

The feed prices of swine are too high in Korea so the feed cost reaches at least 70% in total cost of pig production. Therefore, it is vital to find an alternative ingredient of swine feed in Korea to increase competitiveness of swine industry. Cashew has been cultivated essentially for food and medicine purposes by using the whole cashew fruit, the apple and the kernel (Bianca Dendena, 2015). Cashew nuts are known as abundant sources of essential minerals and rich in "heart-friendly" monounsaturated-fatty acids such as oleic and palmitoleic acids. Increasing demands for cashews and Vietnam government effort to promote cashew cultivation have led to increase in cashew nut area and production. It has grown at a rate of 4.97%/year since 2001. Cashew nut testa (CNT) is the reddish-brown skin that covers the kennel and this skin has been utilized as a raw material for feed subsequently its production was continually increased.

In the first study, there was no significant differences in average daily gain (ADG) among treatments, but ADFI showed linear response in growing I(P=0.02) and finishing I phase(P= 0.04), respectively. Although ADFI was decreased in growing I but it was increased in finishing I phase consequently there was no significant difference in whole experimental period. Feed efficiency in growing I phase showed significant linear difference and quadratic response as the amount of CNT increased (linear, P<0.01; quadratic, P=0.02). Total cholesterol concentration was decreased by addition of CNT during the whole experimental period. There were no significant differences in BUN, creatinine, insulin and glucose concentration for 12 weeks of experimental period. There were no significant differences in WHC, cooking loss and shear force of pork regardless of the dietary CNT levels. In economic efficiency, feed cost per gain during the whole experimental period (0-12 weeks) was lowered in the order of C6, C2, CON and C4. Consequently, up to 6% of CNT can be supplemented in growing-finishing pig's diet without any negative effect on growth performance, pork quality and feed cost.

In the second study, a quadratic response was observed in weaning to estrus interval (WEI) after weaning (P=0.02), and the treatment added 2% of CNT (C2) showed the shortest WEI among treatments. There were no significant differences in body weight, body weight change, backfat thickness, and backfat thickness changes of gestating sows at 35 day, 70 day, and 110 day, 24 hour after parturition and 21day of lactation among treatments. Total born alive piglets were 10% higher in C2 and 12.5% higher in C4 treatment, respectively compared to control treatment. Litter birth weight (P = 0.04) and piglet weight (P = 0.01) after cross-fostering were reduced by addition of CNT in diet. Litter birth weight (P = 0.04) and piglet weight (P = 0.01) after cross-fostering were reduced by addition of CNT in diet. However, litter weight gain and piglet weight gain had no significant difference in 21 day of lactation. In milk composition, the percentage of fat, lactose and total solid in 24 h postpartum showed quadratic correlation with the increasing CNT level during gestation while lactation progressed showed no correlation. Along with the increasing CNT level in diets, insulin concentration in 70 d of gestating was reduced linearly. Consequently, negative effect was not observed by addition of 4% CNT instead of wheat bran in diet of gestating sows.

In the third experiment, digestibilities of dry matter, crude protein, ether extract, crude fiber, ADF, and NDF were decreased significantly as CNT level increased although body weight and backfat thickness of sows were not affected by dietary CNT levels. Consequently, supplementation of CNT had negative effects on nutrient digestibility with no detrimental effect on growth performance in gestating sows.

Digestibility of most nutrients was decreased as dietary levels of CNT increased in gestating sows. However, the addition of CNT did not show adverse response in growth and reproductive performance in the first and second experiments. In addition, there was no decrease in growth performance despite of the increase of fiber in the first experiment. Although dietary fiber resulted in negative response on growth performance in monogastric animals (Knudsen, 2001), there was no detrimental effect on growth performance when dietary CNT was provided up to 6% in swine diet.

Tannin is a naturally occurring polyphenol in plants (Haslam, 1989) and it has antioxidative and antibacterial properties (Min et al., 2005). This polyphonic compound could reduce parasites in digestive organs, and prevent diarrhea by enhancing gastro intestinal tract (Choi et al., 2009). It is known that CNT containes more than 20% of tannin, approximately of 0.4% tannin will be provided by every 2% of dietary CNT. There was a previous report that tannin showed a toxicity when it was added more than 5% in swine feed (Smulikowska et al., 2001), present studies did not show negative response due to the fact that total tannin content was about 1.2% by 6% of dietary CNT. Therefore, dietary CNT does not cause any detrimental effect on growth, productivity and carcass quality when it is used as an alternative ingredient in swine feed. Further, dietary CNT may have some beneficial effects on reproductive performance in gestating sows and have an economical benefit by reducing cost of feed in growing-finishing pigs. As CNT contains high level of fiber and tannins, these studies demonstrated that dietary CNT could be supplemented up to 6% in growing-finishing pig diet and approximately 4% in gestating diet.

.

Chapter VII. Summary in Korea

본 학위논문에서는 사료비 절감을 목적으로 캐쉬넛 내피를 대체원료로서 양돈사료에 사용시 모돈의 번식 성적 및 육성비육돈의 육성 성적에 미치는 영향과 모돈에서의 영양소 소화율을 조사하기 위하여 총 3개의 실험이 진행되었다. 첫째로는 육성비육돈 사료에서 캐쉬넛 내피를 대체원료로 사용시 육성비육돈의 육성 성적 및 도체 품질을 수행하였으며, 둘째로는. 임신모돈 사료에서 캐쉬넛 내피로 소맥피를 대체하였을 때 모돈의 번식 성적에 미치는 영향을 조사하였다. 마지막으로는 임신 모돈 사료에 캐쉬넛 내피의 수준별 사용시 영양소 소화율을 조사하였다.

실험 1: 육성-비육돈 사료의 대체원료로서 캐쉬넛 내피의 사용 시 성장 성적 및 도체 품질에 미치는 영향

평균 체중 28.08 ± 8.47의 3원 교잡종 ([Landrace X Yorkshire] X Duroc) 육성돈 160두가 12주간의 사양시험을 위해 공시되었다. 시험 돈들은 각각 4처리구에 4반복으로 성별 및 개시 체중에 따라서 펜당 10마리씩 배치되었다 (RCBD). 처리구는 1)CON(대조구): NRC (1998)의 요구량을 충족하는 옥수수 대두박 기반의 기초 사료 2) C2: 대조구 + 캐쉬넛 내피 2% 적용 3) C4: 대조구 + 캐쉬넛 내피 4% 4) C6: 대조구 + 캐쉬넛 내피 6%로 구성되었다. 처리구간 평균 일당 증체량 (ADG)에서는 유의적인 차이가 없었으나, 일당 사료섭취량(ADFI)은 육성Ⅰ구간 및 비육 Ⅰ 구간에서 유의적인 반응을 보였다 (linear, P=0.02; P=0.04). 캐쉬넛 내피의 증가에 따라서, 육성Ⅰ구간에서 사료 효율이 유의적인 차이를 보여주었다 (P<0.01). 총 시험기간 동안 캐쉬넛 내피의 첨가에 의해서 총 콜레스테롤 수준이 감소하였다. 12주간의 시험 동안 BUN, creatinine, insulin 그리고 glucose의 수준에서 유의적인 차이를 보이지 않았다. 캐쉬넛 내피의 첨가에 따라서 WHC, 가열 감량 및 전단력에서 유의적인 차이를 보이지 않았다. 경제성

분석 결과 전체 시험 기간 동안 증체에 필요한 비용이 C6, C2, CON, C4의 순으로 낮았다. 따라서, 이 실험을 통하여 육성 비육돈 사료에서 캐쉬넛 내피라 6%까지 사용시 성장 성적, 도체 품질, 그리고 사료 비용에 부정적인 영향을 미치지 않는 것을 증명하였다.

실험 2: 임신 모돈에서 소맥피 대체원료로서 캐쉬넛 내피(Cashew nut testa) 사용시 모돈의 번식성적에 미치는 영향

임신 모돈 사료에서 소맥피를 대체하여 캐쉬넛 내피를 사용시 번식 성적, 자돈 성적, 모유 성분 및 임신돈의 혈액 성상을 조사하기 위하여 40두의 경산돈 (Yorkshire X Landrace) 이 공시되었다. 본 실험은 임신 모돈들이 임신 35일이 되었을 때 시작되었으며, 시험 개시 평균 체중은 211.53 ± 3.52 kg 이었다. 모돈들은 체중, 등지방 두께 및 산차에 따라 10반복으로 각각 배치 되었다. 임신 35일, 70일, 110일, 분만 후 24시간 이후, 그리고 포유 21일에 측정한 임신 모돈의 체중, 체중 변화, 등지방 두께 그리고 등지방 두께 변화에 있어서 통계적인 유의차이가 없었다. 그러나, 모돈의 체중은 캐쉬넛 내피의 증가에 따라서 유의적으로 감소(p=0.09)하였고, 포유기간에 모돈의 일당 사료섭취량이 증가하였다(p=0.09). 이유 후 재귀발정 시간은 감소하는 경향을 보였으며(quadratic response, p=0.02), 캐쉬넛 내피를 2% 사용한 처리구에서 재귀 발정이 가장 짧았다. 총 산자수, 실 산자수, 이유 두수에 있어서 유의적인 차이가 없었지만, C2 처리구에서 대조구 보다 10% 높은 총 산자수를 보였으며, 캐쉬넛 내피를 4% 사용한 C4 처리구는 대조구 보다 12.5% 높은 총 산자수를 보였다. 자돈의 총 체중(p=0.04), 이유 후 총 자돈의 체중(p=0.01) 그리고 이유자돈 체중은 캐쉬넛 내피의 사용량 증가에 따라서 감소하였다. 그러나, 포유 21일에 측정 결과, 총 자돈의 체중 증가와 자돈의 체중 증가에는 유의적인 차이가 없었다. 모유 성분 검사 결과, 분만 후 24시간 후에 측정시 지방(p=0.03), 유당 (p=0.02) 그리고 총 유지고형성분(p=0.03)의 함량에서 임신

기간 내 캐쉬넛 내피의 사용량 증가에 따라 quadratic correlation을 보여 주었다. 사료 내 캐쉬넛 내피의 증가에 따라서 임신 70일령에 인슐린 농도가 유의적으로 감소하였다 (p=0.03). 결과적으로 임신 모돈 사료에서 소맥피를 캐쉬넛 내피로 4%까지 대체하여도 부정적인 영향을 미치지 않았다. 그럼으로 임신모돈 사료에 캐쉬넛 내피 4%까지 사용하는 것이 가능하다.

실험 3: 임신 모돈에서 사료에 캐쉬넛 내피의 사용이 영양소 소화율에 미치는 영향

임신모돈 사료에 캐쉬넛 내피의 수준별 첨가가 영양소 소화율 및 이의 이용성에 미치는 영향을 조사하기 위하여 총 20두의 임신 90일령 Yorkshire × Landrace 교잡종 경산 모돈이 공시되었다. 시험 개시시 공시된 모돈의 평균 체중은 252.61 ± 24.69kg, 등지방 두께는 23.4mm (P2 지점), 그리고 평균 산차는 6.5를 보였다. 모돈들은 난괴법 (completely randomized design)에 의해서 그들의 체중, 등지방 두께, 그리고 산차에 따라 배치되었다. 처리구는 1) C0: 옥수수 대두박 기반의 기초사료, 2) 기초 사료에 캐쉬넛 내피 2% 적용 3) 기초 사료에 캐쉬넛 내피 4% 적용 4) 기초 사료에 캐쉬넛 내피 6% 적용 처리구로 구성되었다. 시험사료(임신 모돈 사료)는 3,265 kcal ME/kg, 12.9%의 조단백질, 0.74%의 라이신, 0.2%의 메치오닌, 0.9%의 칼슘 그리고 0.7%의 유효 인을 함유 하였다. 기타 영양소들은 NRC(1998) 요구량을 충족하거나 초과하였다. 소화율 시험의 개시 체중과 종료 체중에 있어서 유의적인 차이를 보이지 않았으며, 시험 기간 동안 등지방 두께는 사료 내 캐쉬넛 내피 사용에 따른 영향을 받지 않았다. 캐쉬넛 내피의 사용량 증가에 따라서 임신돈에서의 건물(linear, p=0.03), 조단백 (linear, p=0.04), 지방(p=0.05)의 소화율이 감소하였다. 또한, 조섬유 (linear, p=0.07)와 ADF (linear, p=0.06)의 소화율이 캐쉬넛 내피의 첨가량 증가에 따라서 감소하였으며, NDF(linear, p=0.02)도 감소하였다. 이러한 결과는 캐쉬넛 내피의 임신 모돈 사료에서의 적용은 임신 모돈의 성장성적에

는 부정적인 영향을 미치지는 않으면서, 영양소 소화율에는 부정적인 영향을 미치는 것을 보여주었다.

세 번째 실험의 결과에 따르면, CNT의 증가에 따라서, 대부분의 영양소 시험에서 섬유소의 증가에도 불구하고 성적에 영향을 주지 않았는데, 이러한 이유는 CNT의 높은 tannin 함량 때문인 것으로 추측 된다. Tannin은 식물에서 자연적으로 발생되는 polyphenol 성분으로서, 항 산화 및 항 세균 성질을 갖고 있어서, 소화기관 내에서 기생충 등을 줄일 수 있으며, 장을 건강하게 하여 연변 등을 예방할 수 있는 효능을 발휘한다. CNT는 약 20%이상의 tannin을 포함되어 있는데, 따라서, CNT 2% 첨가시 마다 0.4%의 tannin 첨가 효과를 기대할 수 있다. 본 실험에서는 결과적으로 CNT 증량에 따라서 처리구별로 tannin 0.4%, 0.8% 그리고 1.2%가 첨가된 것과 동일한 효과를 보았다고 할 수 있다. 탄닌이 양돈 사료에서 5% 이상 첨가 시 독성을 발휘한다는 사전 보고가 있었으나, 본 실험에서는 최대 1.2%까지 사용되었기 때문에, 긍정적인 영향을 미쳤을 것으로 사료된다.

결론적으로 양돈사료의 대체원료로서 캐쉬넛 내피는 육성, 비육돈에서는 최대 4%까지, 임신 모돈에서는 최대 6%까지 부정적인 영향 없이 경제적으로 사용할 수 있는 것으로 사료된다..