SHORT COMMUNICATION
Anim Ind Technol 2025;12(2):177-184
https://doi.org/10.5187/ait.2500014

축산기술과 산업
Animal Industry and Technology
pISSN 2383-5761 eISSN 2383-6385

Replacement value of cashew nuts in swine diets

Thi Kim Thi Pham[1], Yoojin Koh[1], Yeojin An[1], Duc Luc Do[2], Soo-Ki Kim[1], Beob Gyun Kim[1*]

[1]*Department of Animal Science, Konkuk University, Seoul 05029, Korea*
[2]*Department of Animal Breeding and Genetics, Vietnam National University of Agriculture, Hanoi, Vietnam*

Received: Jul 16, 2025
Revised: Aug 7, 2025
Accepted: Aug 11, 2025

***Corresponding author**
Beob Gyun Kim
Department of Animal Science, Konkuk University, Seoul 05029, Korea
Tel: +82-2-2049-6255
E-mail: beobgyun@konkuk.ac.kr

ORCID
Thi Kim Thi Pham
https://orcid.org/0009-0000-7159-9477
Yoojin Koh
https://orcid.org/0009-0004-3936-8950
Yeojin An
https://orcid.org/0009-0005-3547-6513
Duc Luc Do
https://orcid.org/0000-0003-3364-1296
Soo-Ki Kim
https://orcid.org/0000-0003-3499-3330
Beob Gyun Kim
https://orcid.org/0000-0003-2097-717X

Competing interests
No potential conflict of interest relevant to this article was reported.

Funding sources
This work was supported by collaboration between the Korea International Cooperation Agency

Abstract

The objective of the present study was to calculate the replacement value of cashew nuts used in corn-soybean meal (SBM)-based swine diets based on metabolizable energy and nutrient concentrations in cashew nuts by using Microsoft® Excel 2020. The replacement price of cashew nuts was determined by calculating the replacement coefficients (RC) of corn, SBM, crystalline amino acids, choice white grease, limestone, and dicalcium phosphate with cashew nuts based on metabolizable energy, standardized ileal digestible amino acids ($_{L}$-Lys-HCl, $_{DL}$-Met, $_{L}$-Thr, and $_{L}$-Trp), total calcium, and standardized total tract digestible phosphorus to fully replace the conventional feed ingredients with no changes in the nutrient composition of diet. The equation for the RC was: 1 × cashew nuts + 0.16635 × corn + 0.01302 × $_{L}$-Lys-HCl + 0.00163 × $_{DL}$-Met + 0.00521 × $_{L}$-Thr + 0.00143 × $_{L}$-Trp + 0.00139 × limestone = 0.68860 × SBM + 0.49980 × choice white grease + 0.00063 × dicalcium phosphate. Based on the equation for the RC and the current prices of the conventional ingredients, the optimum price of cashew nuts was 1,126 won/kg. When an estimated price of cashew nuts is 1,000 won/kg with inclusion rate of 5% in pig diets, the feed cost is saved by approximately 6.30 won/kg. Overall, the Excel spreadsheet developed in the present study enables the estimation of feed cost changes by updating the price of the ingredients and the inclusion rate of cashew nuts.

Keywords: Cashew nuts, Feed price, Replacement coefficients, Swine

INTRODUCTION

In the swine industry, feeds account for approximately 60% to 70% of costs for pig production [1]. Rising and fluctuating prices of corn, wheat, and soybean meal (SBM) have prompted growing interests in alternative feed ingredients to reduce feed costs and dependence on conventional feed ingredients [2-4]. A large quantity of cashew nuts becomes unsuitable for human consumption due to structural or surface damage during post-harvest treatment and the discarded cashew nuts can be used as an alternative feed ingredient in pig diets because the damaged cashew nuts are still rich in energy, amino acids, and essential fatty acids [5]. A previous study examined the potential use of cashew nuts as an alternative feed ingredient for

(KOICA) and the Industry-Academic Cooperation Foundation of Konkuk University in 2024.

Acknowledgements
Not applicable.

Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Kim BG.
Data curation: Pham TKT, Koh Y.
Formal analysis: Pham TKT, Do DL.
Methodology: Kim SK, Kim BG.
Validation: Koh Y, An Y, Do DL, Kim SK, Kim BG.
Investigation: Pham TKT, Koh Y, An Y.
Writing - original draft: Pham TKT, Koh Y.
Writing - review & editing: Pham TKT, Koh Y, An Y, Do DL, Kim SK, Kim BG.

Ethics approval and consent to participate
This article does not require IRB/IACUC approval because there are no human and animal participants.

pigs, suggesting that cashew nuts can be used in the swine diet at up to 30% without deteriorating growth performance [6]. Furthermore, a recent study indicated that the amino acid digestibility of cashew nuts is comparable to those of SBM, one of the most widely used feed ingredients in swine diets [7], indicating that cashew nuts have a potential as a feed ingredient for pigs.

When using alternative feed ingredients in swine diets, careful considerations are needed for nutritional values, cost-effectiveness, and market availability [8]. The replacement coefficient (RC) is a parameter that defines the proportion of conventional feed ingredients (e.g., corn and SBM) that can be substituted by an alternative feed ingredient without changing the overall nutritional profile of the diet [9,10]. Accurately determining the RC is essential for evaluating the economic potential of alternative feed ingredients. The previous study evaluated the economic value of corn-distiller's dried grains with solubles as an alternative feed ingredient for broilers, using RC by Excel program [10]. However, information on the economic values of using cashew nuts in swine diets is limited. Therefore, the objective of the present study was to assess the cost-effectiveness of using cashew nuts as an alternative feed ingredient for pigs by determining the RC of feed ingredients to cashew nuts.

MATERIALS AND METHODS

Using cashew nuts as an alternative feed ingredient

In the present study, cashew nuts were evaluated as a potential alternative to replace conventional feed ingredients such as SBM and supplemental oil. The metabolizable energy and nutrient composition including standardized ileal digestible amino acids, total calcium, and standardized total tract digestible phosphorus in corn, SBM, and choice white grease were based on data from the NRC [11] whereas those in cashew nuts were obtained from in-house data [7] (Fig. 1).

Calculation of the economic value of cashew nuts

The basic principle for calculating the economic value of alternative feed ingredients is to compare the price difference when they replace conventional feed ingredients without changing the nutrient concentrations. Because the nutrient composition of an alternative feed ingredient differs from that of conventional feed ingredients, maintaining metabolizable energy and nutrient composition is necessary to meet nutritional requirements of pigs when an alternative feed ingredient is incorporated in swine diets. When replacing conventional feed ingredients with an alternative feed ingredient, complete substitution using only one ingredient is impossible due to differences in nutrient composition among feed ingredients. Therefore, corn, SBM, choice white grease, L-Lys-HCl, DL-Met, L-Thr, L-Trp, limestone, and dicalcium phosphate (DCP) were used, along with cashew nuts, to balance the energy and nutrient composition of the diet in the present study.

Spreadsheet configuration

To determine the economic value of cashew nuts, three worksheets were developed using

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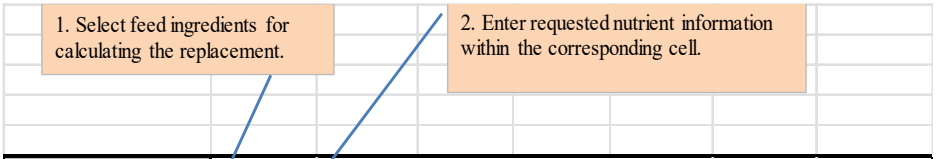

Ingredient Bank		Standardized ileal digestible basis					
	ME	Lys	Met	Thr	Trp	Ca	STTD P
(As-is basis)	kcal/kg	%	%	%	%	%	%
Corn	3395	0.19	0.15	0.22	0.05	0.02	0.09
SBM 48% CP	3294	2.63	0.59	1.58	0.60	0.33	0.34
Choice White Grease	8124	-	-	-	-	-	-
Cashew nuts	5670	0.76	0.22	0.54	0.26	0.19	0.23
L-Lys-HCl	4350	78.80	-	-	-	-	-
DL-Met	5354	-	99.00	-	-	-	-
L-Thr	3776	-	-	99.00	-	-	-
L-Trp	6166	-	-	-	99.00	-	-
Limestone	-	-	-	-	-	35.84	-
Dicalcium phosphate	-	-	-	-	-	24.80	15.30

CP, crude protein; ME, metabolizable energy; SBM, soybean meal; STTD P, standardized total tract digestible phosphorus.

Fig. 1. Nutritional composition of cashew nuts [7] and other feed ingredients [11] used in the present study.

Microsoft® Excel 2020. In the worksheet 1, the nutrient composition of cashew nuts, corn, SBM, and supplements is provided (Fig. 1). Following this step, worksheet 2 was developed to balance the energy and nutrient concentrations using corn, SBM, and supplements while setting cashew nuts as 100%, allowing for the calculation of RC of conventional feed ingredients to cashew nuts (Fig. 2). To ensure balanced nutrient concentrations when using cashew nuts as an alternative ingredient in swine diets, the replacement values in the present study were determined by considering metabolizable energy, standardized ileal digestible amino acids (Lys, Met, Thr, and Trp), total calcium, and standardized total tract digestible phosphorus [10]. In worksheet 3, the change of feed price (won/kg) was calculated based on inclusion rate of cashew nuts and the price of the feed ingredients (Figs. 3–5).

Procedures for calculating replacement values for cashew nuts

Worksheet 2 consists of two tables, upper and lower, for calculating the RC for cashew nuts (Fig. 2). The upper table includes the replacement values with energy and nutrient composition of cashew nuts as well as crystalline amino acids and limestone whereas the lower table includes those of SBM, choice white grease, and DCP to be replaced with cashew nuts. The replacement values for feed ingredients and supplements in both the upper and lower tables are adjusted to ensure that the energy and nutrient concentrations are equivalent across the two tables whereas the replacement value for cashew nuts was fixed at 100%.

Procedures for calculating feed cost changes by the inclusion of cashew nuts

After that, in worksheet 3, the prices of cashew nuts, corn, SBM, and supplements were entered into the table based on the current market prices in won (Fig. 4). At the left bottom

Set the level of alternative inclusion rate to 100. Then, enter directly inclusion rate of each ingredient so that there is no difference between two diets.

Ingredient Bank	Replacement value		Standardized ileal digestible basis					
		ME	Lys	Met	Thr	Trp	Ca	STTD P
(As-is basis)	%	kcal/kg	%	%	%	%	%	%
Cashew nuts	100.00	5670	0.76	0.22	0.54	0.26	0.19	0.23
Corn	16.63	3395	0.19	0.15	0.22	0.05	0.02	0.09
L-Lys-HCl	1.30	4350	78.80	-	-	-	-	-
DL-Met	0.16	5354	-	99.00	-	-	-	-
L-Thr	0.52	3776	-	-	99.00	-	-	-
L-Trp	0.14	6166	-	-	-	99.00	-	-
Limestone	0.14	-	-	-	-	-	35.84	-
	118.903	6329	1.814	0.409	1.088	0.414	0.243	0.245

Ingredient Bank	Replacement value		Standardized ileal digestible basis					
		ME	Lys	Met	Thr	Trp	Ca	STTD P
(As-is basis)	%	kcal/kg	%	%	%	%	%	%
SBM 48% CP	68.86	3294	2.63	0.59	1.58	0.60	0.33	0.34
Choice White Grease	49.98	8124	-	-	-	-	-	-
Dicalcium phosphate	0.06	-	-	-	-	-	24.80	15.30
	118.903	6329	1.814	0.409	1.089	0.414	0.243	0.244
Difference	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

CP, crude protein; ME, metabolizable energy; SBM, soybean meal; STTD P, standardized total tract digestible phosphorus.

Fig. 2. The procedures for calculating the replacement coefficients for cashew nuts. The replacement values for the ingredients were adjusted to balance the metabolizable energy and nutrient concentrations.

Cashew nut calculator
Replacement value of cashew nuts in pig diets

Directions: Update the prices and change cashew nuts inclusion rate (%) in the shaded boxes.

Feed ingredient		Unit
Corn	370	Won/kg
SBM 48% CP	680	Won/kg
Choice White Grease	1,550	Won/kg
Cashew nuts	1,000	Won/kg
L-Lys-HCl	1,900	Won/kg
DL-Met	4,000	Won/kg
L-Thr	2,000	Won/kg
L-Trp	10,000	Won/kg
Limestone	40	Won/kg
Dicalcium phosphate	890	Won/kg

Cashew nuts inclusion: 10.0 %

To be increased	RC	%	Won/kg of feed	To be decreased	RC	%	Won/kg of feed
Cashew nuts	1.00000	10.00	100.00	SBM 48% CP	-0.68860	-6.89	-46.82
Corn	0.16635	1.66	6.15	Choice White Grease	-0.49980	-5.00	-77.47
L-Lys-HCl	0.01302	0.13	2.47	Dicalcium phosphate	-0.00063	-0.01	-0.06
DL-Met	0.00163	0.02	0.65				
L-Thr	0.00521	0.05	1.04				
L-Trp	0.00143	0.01	1.43				
Limestone	0.00139	0.01	0.01				
	Sum:	11.89	111.76		Sum:	-11.89	-124.35

Net change of feed cost by using 10% of cashew nuts is Won -12.59 (=111.76-124.35) per kg of feed.

CP, crude protein; RC, replacement coefficient; SBM, soybean meal.

Fig. 3. Feed cost calculations when the price of cashew nuts was 1,000 won/kg at the inclusion rate of 10%. The net change of feed price by using 10% of cashew nuts was −12.59 won/kg (= 111.76 − 124.35).

https://doi.org/10.5187/ait.2500014

Cashew nut calculator
Replacement value of cashew nuts in pig diets

Directions: Update the prices and change cashew nuts inclusion rate (%) in the shaded boxes.

Feed ingredient		Unit
Corn	370	Won/kg
SBM 48% CP	680	Won/kg
Choice White Grease	1,550	Won/kg
Cashew nuts	1,000	Won/kg
L-Lys-HCl	1,900	Won/kg
DL-Met	4,000	Won/kg
L-Thr	2,000	Won/kg
L-Trp	10,000	Won/kg
Limestone	40	Won/kg
Dicalcium phosphate	890	Won/kg
Cashew nuts inclusion:	5.0	%

To be increased	RC	%	Won/kg of feed	To be decreased	RC	%	Won/kg of feed
Cashew nuts	1.00000	5.00	50.00	SBM 48% CP	-0.68860	-3.44	-23.41
Corn	0.16635	0.83	3.08	Choice White Grease	-0.49980	-2.50	-38.73
L-Lys-HCl	0.01302	0.07	1.24	Dicalcium phosphate	-0.00063	0.00	-0.03
DL-Met	0.00163	0.01	0.33				
L-Thr	0.00521	0.03	0.52				
L-Trp	0.00143	0.01	0.72				
Limestone	0.00139	0.01	0.00				
	Sum:	5.95	55.88		Sum:	-5.95	-62.17

Net change of feed cost by using 5% of cashew nuts is Won -6.3 (=55.88-62.17) per kg of feed.

CP, crude protein; RC, replacement coefficient; SBM, soybean meal.

Fig. 4. Feed cost calculations when the price of cashew nuts was 1,000 won/kg at the inclusion rate of 5%. The net change of feed price by using 5% of cashew nuts was −6.30 won/kg (= 55.88 − 62.17).

Cashew nut calculator
Replacement value of cashew nuts in pig diets

Directions: Update the prices and change cashew nuts inclusion rate (%) in the shaded boxes.

Feed ingredient		Unit
Corn	370	Won/kg
SBM 48% CP	680	Won/kg
Choice White Grease	1,550	Won/kg
Cashew nuts	1,126	Won/kg
L-Lys-HCl	1,900	Won/kg
DL-Met	4,000	Won/kg
L-Thr	2,000	Won/kg
L-Trp	10,000	Won/kg
Limestone	40	Won/kg
Dicalcium phosphate	890	Won/kg
Cashew nuts inclusion:	5.0	%

To be increased	RC	%	Won/kg of feed	To be decreased	RC	%	Won/kg of feed
Cashew nuts	1.00000	5.00	56.30	SBM 48% CP	-0.68860	-3.44	-23.41
Corn	0.16635	0.83	3.08	Choice White Grease	-0.49980	-2.50	-38.73
L-Lys-HCl	0.01302	0.07	1.24	Dicalcium phosphate	-0.00063	0.00	-0.03
DL-Met	0.00163	0.01	0.33				
L-Thr	0.00521	0.03	0.52				
L-Trp	0.00143	0.01	0.72				
Limestone	0.00139	0.01	0.00				
	Sum:	5.95	62.17		Sum:	-5.95	-62.17

Net change of feed cost by using 5% of cashew nuts is Won 0 (=62.17-62.17) per kg of feed.

CP, crude protein; RC, replacement coefficient; SBM, soybean meal.

Fig. 5. Feed cost calculations when the price of cashew nuts was 1,126 won/kg at the inclusion rate of 5%. The net change of feed price by using 5% of cashew nuts was 0 won/kg (= 62.17 − 62.17). This suggests that the price of cashew nuts needs to be less than 1,126 won/kg for cost-effectiveness.

of worksheet 3, the RC was calculated by dividing the replacement value by 100. In the present example, the inclusion rate of cashew nuts was 5% of the diet and the inclusion rates (%) of corn, SBM, and supplements were calculated based on the respective RC. The contribution of each ingredient to the feed cost increased due to the use of cashew nuts was calculated based on the inclusion rate (%) and the price of each ingredient. In this example, the increased cost for using cashew nuts at 5% was 55.88 won/kg. With the same token, the feed cost decreased due to the use of 5% cashew nuts was calculated as 62.17 won/kg at the right bottom.

RESULTS AND DISCUSSION

The calculated RC was used to show the relationship to maintain equal metabolizable energy and nutrient concentrations, as shown in the following equation:

$$1 \times \text{cashew nuts} + 0.16635 \times \text{corn} + 0.01302 \times {}_{L}\text{-Lys-HCl} + 0.00163 \times {}_{DL}\text{-Met} + 0.00521 \times {}_{L}\text{-Thr} + 0.00143 \times {}_{L}\text{-Trp} + 0.00139 \times \text{limestone} = 0.68860 \times \text{SBM} + 0.49980 \times \text{choice white grease} + 0.00063 \times \text{DCP} \quad (1)$$

where the left-hand side represents cashew nuts with 1 of RC and supplements with respective RC to cashew nuts (corn = 0.16635, $_{L}$-Lys-HCl = 0.01302, $_{DL}$-Met = 0.00163, $_{L}$-Thr = 0.00521, $_{L}$-Trp = 0.00143, and limestone = 0.00139) to replace conventional feed ingredients, and the right-hand side represents conventional feed ingredients with respective RC to cashew nuts (SBM = 0.68860, choice white grease = 0.49980, and DCP = 0.00063). By using cashew nuts as an alternative ingredient in swine diets, the cost savings can be estimated using the following equation:

$$\text{Cost saving (won/kg)} = \text{cashew nuts inclusion rate (\%)} \times [0.68860 \times \text{SBM price} + 0.49980 \times \text{choice white grease price} + 0.00063 \times \text{DCP price} - (1 \times \text{cashew nuts price} + 0.16635 \times \text{corn price} + 0.01302 \times {}_{L}\text{-Lys-HCl price} + 0.00163 \times {}_{DL}\text{-Met price} + 0.00521 \times {}_{L}\text{-Thr price} + 0.00143 \times {}_{L}\text{-Trp price} + 0.00139 \times \text{limestone price})] / 100 \quad (2)$$

where the unit for price of each ingredient is won/kg.

The RC model developed in the present study provides a simplified program for evaluating an alternative to replace conventional feed ingredients in pig diets. In the RC model, digestible amino acid concentrations are balanced using crystalline amino acid sources that are critical for the maintenance and protein retention of pigs [12]. Additionally, metabolizable energy, calcium, and digestible phosphorus were also balanced in the model. The market price of alternative feed ingredients is one of the most influential factors in formulating swine diets but can be influenced by supply chain logistics, regional availability, and market demand. Moreover, the nutritional composition of alternative feed ingredients such as cashew nuts can vary considerably due to differences in growing conditions and processing methods, making it essential to consider the variations in nutritional values when formulating swine diets [13,14]. As implemented in the

 https://doi.org/10.5187/ait.2500014

Excel spreadsheet, the program offers a user-friendly interface that facilitates both nutrient balance and cost-effectiveness analyses. Users can easily modify the nutritional information and ingredient prices in the Excel worksheet, enabling flexible calculation of feed ingredient prices under specific conditions. In addition, this program allows for rapid scenario testing, enabling the adjustment of dietary components to meet energy and nutrient requirements of animals with consideration of ingredient availability and economic conditions in the context of fluctuating ingredient resources.

According to Fanimo et al. [15], cashew nuts can be incorporated into pig diets at up to 10% as a partial substitute for SBM without detrimental effects on the growth performance of pigs. With an inclusion rate of 10% and a market price of 1,000 won/kg for discarded cashew nuts, the estimated feed cost decreased by approximately 12.59 won/kg based on the present model (Fig. 3). However, the NRC [11] suggested that the maximum inclusion of added fat in swine diets is approximately 6% because of diet-handling characteristics in practical conditions, which is the reason why the present study selected the inclusion rate of 5% for cashew nuts. By incorporating cashew nuts at 5% of the diet, the calculated feed cost decreased by approximately 6.30 won/kg (Fig. 4). Furthermore, the maximum limit of market price for discarded cashew nuts for formulating swine diets with no change in costs was also calculated to consider the fluctuating cost of the feed ingredient, suggesting that the price of cashew nuts needs to be less than 1,126 won/kg for cost-effectiveness. In addition, the nutritional and economic value of cashew nuts in swine diets may also be influenced by nutritional composition of the ingredient potentially affected by processing methods and regional practices [13,14]. Further research is warranted to determine potential interaction between cashew nuts and other ingredients when fed to pigs and to test cashew nuts after extracting oils.

In conclusion, cashew nuts can be an alternative feed ingredient in swine diets, offering both nutritional and economic benefits when included at appropriate levels. When the market price of cashew nuts is 1,000 won/kg, a 5% inclusion rate in swine diets results in a reduction of the feed cost by approximately 6.30 won/kg. The Excel spreadsheet developed in the present work enables the estimation of feed cost changes by updating the price of the ingredients and the inclusion rate of cashew nuts.

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