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8 Abstract

9 The objective of the present study was to calculate the replacement value of cashew nuts used in corn-
10 soybean meal-based swine diets based on metabolizable energy and nutrient concentrations in cashew nuts
11 by using Microsoft® Excel 2020. The replacement price of cashew nuts was determined by calculating the
12 replacement coefficients of corn, soybean meal, crystalline amino acids, choice white grease, limestone,
13 and dicalcium phosphate with cashew nuts based on metabolizable energy, standardized ileal digestible
14 amino acids (L -Lys-HCl, DL -Met, L -Thr, and L -Trp), total calcium, and standardized total tract digestible
15 phosphorus to fully replace the conventional feed ingredients with no changes in the nutrient composition
16 of diet. The equation for the replacement coefficient was: $1 \times \text{cashew nuts} + 0.16635 \times \text{corn} + 0.01302 \times L$ -
17 $\text{Lys-HCl} + 0.00163 \times DL\text{-Met} + 0.00521 \times L\text{-Thr} + 0.00143 \times L\text{-Trp} + 0.00139 \times \text{limestone} = 0.68860 \times$
18 $\text{soybean meal} + 0.49980 \times \text{choice white grease} + 0.00063 \times \text{dicalcium phosphate}$. Based on the equation
19 for the replacement coefficients and the current prices of the conventional ingredients, the optimum price
20 of cashew nuts was 1,126 won/kg. When an estimated price of cashew nuts is 1,000 won/kg with inclusion
21 rate of 5% in pig diets, the feed cost is saved by approximately 6.30 won/kg. Overall, the Excel spreadsheet
22 developed in the present study enables the estimation of feed cost changes by updating the price of the
23 ingredients and the inclusion rate of cashew nuts.

24
25 **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 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 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 replacement coefficients 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 (Fig. 3, Fig. 4, and Fig. 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 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:

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

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:

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

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 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 Fanimó 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.

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

ACCEPTED

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194

1. Select feed ingredients for calculating the replacement.		2. Enter requested nutrient information within the corresponding cell.					
Ingredient Bank	Standardized ileal digestible basis					Ca	STTD P
	ME	Lys	Met	Thr	Trp		
(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.

195

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

197

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	ME	Standardized ileal digestible basis				Ca	STTD P
			Lys	Met	Thr	Trp		
(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	ME	Standardized ileal digestible basis				Ca	STTD P
			Lys	Met	Thr	Trp		
(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
Cashew nuts	1.00000	10.00	100.00
Corn	0.16635	1.66	6.15
L-Lys-HCl	0.01302	0.13	2.47
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
To be decreased	RC	%	Won/kg of feed
SBM 48% CP	-0.68860	-6.89	-46.82
Choice White Grease	-0.49980	-5.00	-77.47
Dicalcium phosphate	-0.00063	-0.01	-0.06
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).

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
Cashew nuts	1.00000	5.00	50.00
Corn	0.16635	0.83	3.08
L-Lys-HCl	0.01302	0.07	1.24
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
To be decreased	RC	%	Won/kg of feed
SBM 48% CP	-0.68860	-3.44	-23.41
Choice White Grease	-0.49980	-2.50	-38.73
Dicalcium phosphate	-0.00063	0.00	-0.03
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
Cashew nuts	1.00000	5.00	56.30
Corn	0.16635	0.83	3.08
L-Lys-HCl	0.01302	0.07	1.24
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
To be decreased	RC	%	Won/kg of feed
SBM 48% CP	-0.68860	-3.44	-23.41
Choice White Grease	-0.49980	-2.50	-38.73
Dicalcium phosphate	-0.00063	0.00	-0.03
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.