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Optimization of instant corn cream soup formulation containing chicken bone and moringa leaf using linear programming

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KEYWORDS

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Formulation

Instant cream soup

Linear programming

Moringa leaf

ABSTRACT

Chicken bone and moringa leaf can be used as raw materials in food products because of their high protein, calcium, and phosphorus content. This study aimed to identify the optimal formulation for producing instant corn cream soup with added chicken bones and moringa leaf meal, having a high protein, calcium, and phosphorus content with minimal raw material costs. The formulation was developed using a randomized group design with a combination of chicken bone (0%, 1.4%, 2.8%) and moringa leaf (0%, 1.1%, 2.2%). Then, the formulation was analyzed using linear programming with constraints based on SNI 01-4967-1999 regarding instant cream soup and PerBPOM No. 1 of 2022 regarding the supervision of claims on labels and advertisements of processed food. The three best formulas were subjected to a sensory test. The results showed that three of the nine formulas had the highest protein, calcium, and phosphorus content with the lowest raw material cost, i.e., Formula 5 (2.8% chicken bone, without moringa leaf), Formula 7 (2.8% chicken bone and 1.1% moringa leaf), and Formula 9 (2.8% chicken bone and 2.2% moringa leaf). These formulations also met the requirement for high calcium and high phosphorus in accordance with PerBPOM No. 1 of 2022. However, the samples did not reach the minimum requirement to be considered high protein. The sensory test results showed that Formula 7 was the closest to the ideal product and was also preferred by respondents.

Introduction

The green economy is an effort to carry out production activities and use natural resources efficiently and sustainably (Ministry of Investment, Republic of Indonesia, 2017). To date, the green economy has focused on using waste to produce alternative energy, whereas the production of alternative foods is still rare. Organic waste can be used, taking into account safety protocols. As a result of the high production of chicken meat in Indonesia, chicken bone waste has also increased. According to Statistics of Food Consumption released by the Ministry of Agriculture, Republic of Indonesia (2022), the average per capita consumption in 2022 amounts to 7,151 (kg/capita/year) for broilers and 828 (kg/capita/year) for local or native chicken. Chicken bone waste is often ignored because it has low economic value. Nevertheless, chicken bone waste could be used as a source of raw materials in food production because its nutritional content is still high, especially the content of protein (P), calcium (Ca), and phosphorus (P), which are beneficial for bone and muscle development. Chicken bones have calcium content ranging from 30.42 to 49.01 mg/100g, phosphorous 17.67 to 19.23 mg/100g (Okwunodulu et al., 2022), and protein content in the range of 20,240 to 25,590 mg/100g (Dong et al., 2014; Yessimbekov et al., 2023).

Utilization of chicken bone waste as a component of the green economy can have a positive effect, considering a high consumption of chicken meat in the catering industry, public restaurants, and fast-food outlets. Some food industry players and researchers have used chicken bones as raw food materials. However, these trials have been limited to the production of cookies and crackers, which are non-staple food products (Purwarsih et al., 2019; Raharja et al., 2016). The added value of chicken bones can be increased by

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utilizing them as raw materials in staple foods consumed by people of all backgrounds or as a component in emergency foods. According to the Food and Agriculture Organization of the United Nations (FAO), a staple food “is one that is eaten regularly and, in such quantities, as to constitute the dominant part of the diet and supply a major proportion of energy and nutrient needs of a population” (FAO, 2009). One example of such a staple food product is instant cream soup, which generally uses corn as the base raw material. The product is easy to obtain highly palatable based on data released by Ministry of Agriculture (2022) regarding supply, utilization and per capita availability of corn, 2018–2022. In addition to chicken bones, other raw materials (such as moringa leaves) can also be added to enhance the product’s nutritional value. Dewi et al. (2020) and Fadhilatunnur et al. (2021) reported that moringa leaves contain high levels of protein, iron, calcium, magnesium, and beta-carotene (vitamin A precursor). Instant cream soup has the advantages of being ready-to-cook and ready-to-eat, making it easy to serve for the elderly, children, urban communities, or disaster victims. Thus, adding chicken bones and moringa leaves to the instant corn cream soup formulation would maximize the content of macro and micronutrients.

When formulating healthy food products, in addition to quality factors (such as sensory and nutritional acceptance), cost factors should be considered to create quality products at a minimal cost (Parlesak et al., 2016). This is a way for business owners to avoid losses so that the price of the products can compete in the market. Cost minimization is needed when manufacturing a product that also remains in accordance with the standards set by the government. Production costs are crucial for companies to earn high profits. Coronado-Hernández et al. (2021) said that all industries must reduce the production cost to obtain sustainable profit.

A product like instant corn cream soup with added chicken bones and moringa leaves can be formulated using the linear programming method. This method is used to find the formula with the optimal value that provides the best nutrition. The method begins with the analysis of raw materials and raw material costs. Both are applied to two mathematical models: an objective function and a constraint function. The objective function is used to minimize or maximize the tested factors. In contrast, the constraint function is used to determine the minimum or maximum amounts of raw materials and the chemical content of the product. Ihwah et al. (2018) used linear programming to formulate food products for breastfeeding mothers using Moringa leaves. Sheibani et al. (2018) reported that the linear programming method could be applied to formulating emergency foods. Therefore, this research aimed to develop an instant corn cream soup added with chicken bones and moringa leaves using the linear programming method. The results of the study may: 1) support the government's efforts in intensifying green economy activities; 2) increase the added value of chicken bones to be used as a business basis for industry players; and 3) help the population (especially the elderly, children, urban communities, and disaster victims) meet their daily nutritional needs.

Research Methods

The research was conducted in the Food Microbiology Laboratory, Food Processing Laboratory, and Chemistry Laboratory of Universitas Prasetiya Mulya from March to December 2022. The raw materials used to make instant corn cream soup were sweet corn (*Golden Farm*), fresh chicken bone meal (*Berkah Broiler*), moringa leaf meal (*Granology*), butter (*Blue Band*), wheat flour (*Segitiga Biru*), chicken stock powder (*Jay’s Kitchen*), all-purpose cream (*Fiber Creme*), cornstarch (*Maizenaku*), shallots, onions, pepper, and water. Chicken bones and moringa leaves were obtained from an online marketplace in West Jakarta. Sweet corn and other supporting raw materials were purchased from supermarkets. All materials used are food grade.

Research design

The study was conducted in several stages: 1) analysis of protein, fat, calcium, and phosphorus in each raw material; 2) analysis of costs for each raw material; 3) formulation of the instant soup using linear programming; 4) manufacture of the instant soup with added chicken bone meal and moringa leaf based on the designed formulation; 5) validation of product suitability with the constraint function; and 6) sensory test of the selected formula. The best formula was the one in accordance with the constraint function, which showed the maximum nutritional value (protein, calcium, and phosphorus) with the minimum raw material costs. The soup was formulated using linear programming similar to that described for cookies by Varghese et al. (2022)

The formulation stage began with a three-factorial randomized group design so that there were nine experimental designs (three amounts of chicken bones (0, 1.4, and 2.8%) and three amounts of moringa leaves (0, 1.1, and 2.2%) (Table 1).

These percentages or treatment levels were chosen by considering consumers can still accept the product from the sensory aspect.

These nine formulas were processed using linear programming with the help of POM-QM v. 5.3 build 177. POM-QM is a mathematical analysis software for operational management, quantitative methods, and management science. The software includes 30 calculation methods, one of which is a linear program to find solutions to modeling problems (Weiss, 2020). Sensory tests were conducted with the help of Excel with XLSTAT 2022.3.1.

Research stages

Analysis of protein, fat, calcium, and phosphorus in each raw material

The raw materials used to make the instant corn cream soup were first analyzed for protein, fat, calcium, and phosphorus, both by referring to publicly available information and in the laboratory. The nutritional information was obtained from the nutrition facts label on the packaging of each ingredient or from data published by the Ministry of Health of the Republic of Indonesia if no nutrition label was available. Protein and fat analyses were performed according to SNI 01-2891-1992 (BSN, 1992) regarding methods for analyzing food and beverages. The Kjeldahl method was used for protein and the Soxhlet method was used for fat. While calcium and phosphorus were determined by inductively coupled plasma-optical emission spectrometry (ICP-OES). Nutrition facts labels were available for butter, powdered chicken broth, all-purpose cream, peeled sweet corn, and cornstarch. The ingredients subjected to the laboratory analysis were chicken bone meal and moringa leaf meal. Nutritional information on onion and pepper was obtained from the Ministry of Health of the Republic of Indonesia. This nutritional analysis was chosen as a constraint function in the formulation, using linear programming.

Analysis of the raw material cost

The costs of raw materials were determined based on the purchase price per package and then converted to the purchase price per 1 g of the material. This cost was chosen as the objective function in the formulation using linear programming.

Formulation of instant corn cream soup, using linear program

The mathematical model formulation of instant cream soup was determined using the linear program simplex method. The purpose of this analysis was to determine the difference in the results of instant corn cream soup with various variations of chicken bone meal and moringa leaves. The mathematical model for the formulation of the instant cream soup was determined using the simplex method of linear programming. This analysis aimed to determine the differences in the protein, calcium, and phosphorus contents of the resulting soup formulations with variations in the amounts of chicken bone meal and moringa leaf. The objective function was the minimization of raw material costs. The constraint function was the limit of raw materials as well as the contents of protein, calcium, and phosphorus to produce a soup at a minimum cost while meeting the quality requirements set by SNI 01-4967-1999 (BSN, 1999) regarding instant cream soup, and achieve high calcium and phosphorus claims regulated in PerBPOM No. 1 of 2022 (BPOM, 2022). Calcium or phosphorus is categorized as a mineral requiring not less than 15% Nutrition Label Reference (or *Acuan Label Gizi*/ALG)) per 100 g for source claims and two times the amount of "source" for high or rich claims.

Production of the instant corn cream soup

The instant corn cream soup was manufactured according to the formulation selected based on the linear programming results. All raw materials were mixed until they became puree and stirred until thickened. After the puree was obtained, it was dried using a food dehydrator at 65 °C for 24 h, with a thickness of no more than 1/4 inches. After the puree was dried, it was placed into a disc mill to produce soup powder. Then, the powder was mixed with cornstarch at a ratio of 16:3. Instant corn cream soup in powder form was produced.

Table 1. 3-factorial randomized group design on corn cream soup formulation

Experimental Design		
T0K0 (Formula 1)	T1K0 (Formula 4)	T2K0 (Formula 5)
T0K1 (Formula 2)	T1K1 (Formula 8)	T2K1 (Formula 7)
T0K2 (Formula 3)	T1K2 (Formula 6)	T2K2 (Formula 9)

Note: K = Moringa leaf meal; K0 = 0% ; K1 = 1.1%; K2 = 2.2% ; T = Chicken bone meal; T0 = 0%; T1 = 1.4%; T2 = 2.8%

Product suitability validation test

The best formula recommended by the linear program was validated by analyzing its nutritional components (protein, calcium, and phosphorus) in the laboratory. The suitability of the nutritional composition was evaluated based on the constraint function, namely, the quality standards for instant cream soup products (SNI 01-4967-1999) and PerBPOM No. 1 of 2022 regarding the claims on processed food labels and advertisements. Subsequently, a claim analysis of protein, calcium, and phosphorus were conducted.

Sensory test of selected formula

Sensory evaluation testing was carried out by sending instant corn cream soup samples to panelists so that the panelists cooked by the panelists themselves following a predetermined cooking method. To serve the soup, 16 g of instant soup powder was put into a pot containing 120 mL of water and stirred until the mixture became homogeneous. Afterward, the soup was heated on a stove while stirring. Once it boiled and started to thicken, the fire was turned off, and the soup was stirred for an additional one minute. Then, the instant corn cream soup was ready to be served hot.

Sensory evaluation was conducted using the hedonic and check-all-that-apply (CATA) tests. The hedonic test was carried out by asking panelists about their overall preference and their preference for each sensory attribute in the sample. A 5-point hedonic scale was used, and the preferred sample was identified. On the other hand, CATA is a descriptive test with a structured question format where respondents are given a list of variables and asked to select all the variables the sample has. Panelists were asked about the ideal perception of the sensory profile of corn cream soup with the addition of chicken bone meal and moringa leaves by ticking the sensory attributes considered capable of describing the ideal instant corn cream soup. The CATA method is useful for understanding the perception of sensory attributes in a product. The data from the hedonic and CATA tests were analyzed using Excel with XLSTAT 2022.3.1.

Before conducting the sensory evaluation, a focus group discussion (FGD) was conducted with 11 people aged 11–23 years to obtain in-depth information regarding the samples to be tested. The samples used in the FGD were those with the highest contents of chicken bones and moringa leaves (2.8% and 2.2%, respectively). These samples were chosen so the FGD participants could better perceive the sensory attributes of the chicken bone meal and moringa leaves. The FGD participants were selected among individuals who did not have allergies to any of the ingredients in the corn cream soup and could describe the sensory attributes well.

Results and Discussion

Protein, fat, calcium, and phosphorus in the raw materials

Based on the nutritional analysis results (Table 2), the raw material that contributed the most protein, calcium, and phosphorus was chicken bone meal. The contents of these nutrients in this study were higher than those in the study by Dong et al. (2014) and Yessimbekov et al. (2023) which showed 20.24 g and 25.5 g/100 g protein, respectively, and by Cornelia et al. (2018) which showed 14,368 mg/100 g calcium. However, the phosphorus content of this research is less than Abdulla et al. (2016) which showed 16,200 – 17,100 mg/100 g phosphorus, and more than Saputro et al. (2021) which showed 6,700 mg/100 g phosphorus. It indicates that the nutritional content of chicken meat varies greatly depending on how it was isolated (Cansu et al., 2015). In fact, more protein will be found in chicken bones if extraction is carried out using hot-pressure method enzymatic methods and ultrasonic pretreatment as done by Dong et al. (2014) and Dong et al. (2019). In this research, there are no such methods that were conducted. In addition to chicken bone meal, moringa leaves were the next largest contributor to protein, calcium, and phosphorus. Therefore, these two raw materials were used as the determining factors for whether or not the protein, calcium, and phosphorus claims were achieved.

Raw material cost analysis

All raw material costs per soup package were calculated on a 1 g base. Table 3 shows the results of the conversion of the cost of the soup's raw materials. The raw material with the highest cost was all-purpose cream, followed by pepper. On the other hand, the costs of the chicken bone meal and moringa leaves were fairly low (IDR 37/g for chicken bones and IDR 62/g for moringa leaves).

Instant corn cream soup formulation

The nutritional and raw material cost analyses revealed that chicken bone meal and moringa leaf meal contributed greatly to the nutritional value (protein, calcium, and phosphorus) and also reduced the cost of the instant corn cream soup formulation. Therefore, through trial and error, the limits of the amounts of other raw materials were determined, based on the experimental design summarized in Table 1. The resulting formula is shown in Table 4.

Table 2. Nutritional components of raw materials for instant corn cream soup per 100 g

Raw materials (per 100 g)	Protein (g)	Fat (g)	Water	Calcium (mg)	Phosphorus (mg)
Chicken bone meal (X_1)[a]	34.01	13.15	0*	18,830	8,460
Moringa leaf meal (X_2)[a]	16.72	5.21	0*	2,540	160
Butter (X_3)[b]	0	73.33	0*	15	16
Shallots (X_4)[c]	1.5	0.3	0*	36	40
Onions (X_5)[c]	1.4	0.2	0*	32	44
Wheat flour (X_6)[b]	10	1	0*	22	150
Chicken broth powder (X_7)[b]	17	0.12	0*	0**	0**
All-purpose cream (X_8)[b]	0	33.33	0*	0**	0**
Peeled sweet corn (X_9)[b]	3	0.5	0*	65	538
Pepper (X_{10})[c]	11.5	6.8	0*	460	200
Corn starch flour (X_{11})[b]	1	0	0*	2	256
Water (X_{12})[c]	0**	0**	100	0**	0**

Note: [a] = empirical results in the laboratory following the procedure of SNI 01-2891-1992 (1992) for protein, fat, and water, as well as AOAC (2002) for calcium and phosphorus, [b] = packaging label, [c] = Indonesian Ministry of Health (2018), * = assumed 0 because it is included in the test for the moisture content of corn cream soup powder (4.14 to 4.4 g of water), ** = data not found

Table 3. Conversion of raw materials cost of instant corn cream soup

Raw materials	Cost per package (IDR)	Weight per package (g)	Cost per 1 g (IDR)
Chicken bone meal (X_1)	7,000	188	37
Moringa leaf meal (X_2)	62,000	1,000	62
Butter (X_3)	23,990	500	48
Shallots (X_4)	11,790	200	59
Onions (X_5)	5,500	100	55
Wheat flour (X_6)	5,500	250	22
Chicken broth powder (X_7)	10,690	1,000	11
All-purpose cream (X_8)	29,000	150	193
Peeled sweet corn (X_9)	42,500	450	94
Pepper (X_{10})	8,800	50	176
Corn starch flour (X_{11})	33,000	1,000	33
Water (X_{12})	19,000	19,000	1

Table 4. Total raw materials on the formulation of instant corn cream soup per 100 g

Raw Materials	Amount (g)								
	Formula								
	1	2	3	4	5	6	7	8	9
Chicken bone meal (X_1)	0	0	0	1.44	2.83	1.40	2.79	1.42	2.76
Moringa leaf meal (X_2)	0	1.16	2.28	0	0	2.24	1.12	1.14	2.21
Butter (X_3)	29.31	28.9	28.51	28.8	28.32	28.04	27.94	28.42	27.58
Shallots (X_4)	8.79	8.67	8.55	8.64	8.5	8.41	8.38	8.52	8.27
Onions (X_5)	0.59	0.58	0.57	0.58	0.57	0.56	0.56	0.57	0.55
Wheat flour (X_6)	4.4	4.34	4.28	4.32	4.25	4.21	4.19	4.26	4.14
Chicken broth powder (X_7)	7.33	7.23	7.13	7.2	7.08	7.01	6.99	7.1	6.89
All-purpose cream (X_8)	5.86	5.78	5.7	5.76	5.66	5.61	5.59	5.68	5.52
Peeled sweet corn (X_9)	23.44	23.12	22.81	23.04	22.66	22.43	22.36	22.73	22.06
Pepper (X_{10})	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Corn starch flour (X_{11})	15.79	15.79	15.79	15.79	15.79	15.79	15.79	15.79	15.79
Water (X_{12})	4.39	4.33	4.28	4.33	4.24	4.20	4.19	4.27	4.13
Total	100	100	100	100	100	100	100	100	100

When running a linear program, two functions should be determined: the objective and the constraint functions. The objective function of this study was the minimum possible raw material cost. The cost of the raw materials per 1 g was used to obtain Equation (1) (Table 3) by summing up all components to yield the minimal cost (Z_{min}).

$$Z_{min} = 37\,X_1 + 62\,X_2 + 48\,X_3 + 59\,X_4 + 55\,X_5 + 22\,X_6 + 11\,X_7 + 193\,X_8 + 94\,X_9 + 176\,X_{10} + 33\,X_{11} + 1\,X_{12} \quad (1)$$

The constraint functions in this study were as follows:

1) The total amounts of chicken bone meal (X_1), moringa leaf meal (X_2), butter (X_3), shallots (X_4), onions (X_5), wheat flour (X_6), chicken broth powder (X_7), all-purpose cream (X_8), peeled sweet corn (X_9), pepper (X_{10}), cornstarch (X_{11}), and water (X_{12}) must amount to 100 g, where the quantity of each raw material must be the same as stated in Table 4.
2) In accordance with SNI 01-4967-1999, the protein content must be at least 10%, the fat content must be at least 5%, and the moisture content must be at least 8%.
3) In accordance with BPOM Regulation No. 1 of 2022, where ALG refers to BPOM Regulation No. 9 of 2016, the calcium content must be more than or equal to 330 mg per 100 g to be considered high calcium. While, the phosphorus content must be more than or equal to 210 mg per 100 g to be considered as high phosphorus.
4) All variables have non-negative constraints. The following mathematical model of the overall constraint function of the instant corn cream soup was used as an input for the POM-QM v. 5.3 build 177 application:

• Protein content (per 1 g)
$0.3401 X_1 + 0.1672 X_2 + 0 X_3 + 0.015 X_4 + 0.014 X_5 + 0.01 X_6 + 0.017 X_7 + 0 X_8 + 0.03 X_9 + 0.115 X_{10} + 0.01 X_{11} + 0 X_{12} \geq 0.1$

• Fat content (per 1 g)
$0.1315 X_1 + 0.0521 X_2 + 0.7333 X_3 + 0.003 X_4 + 0.002 X_5 + 0.01 X_6 + 0.0012 X_7 + 0.3333 X_8 + 0.005 X_9 + 0.0068 X_{10} + 0 X_{11} + 0 X_{12} \geq 0.05$

• Moisture content
$0 X_1 + 0 X_2 + 0 X_3 + 0 X_4 + 0 X_5 + 0 X_6 + 0 X_7 + 0 X_8 + 0 X_9 + 0 X_{10} + 0 X_{11} + 1 X_{12} \leq 8$

• Calcium content (high-calcium claim)
$18830 X_1 + 2540 X_2 + 15 X_3 + 36 X_4 + 32 X_5 + 22 X_6 + 0 X_7 + 0 X_8 + 65 X_9 + 460 X_{10} + 2 X_{11} + 0 X_{12} \geq 330$

• Phosphorus content (high-phosphorous claim)
$8460 X_1 + 160 X_2 + 16 X_3 + 40 X_4 + 44 X_5 + 150 X_6 + 0 X_7 + 0 X_8 + 538 X_9 + 200 X_{10} + 256 X_{11} + 0 X_{12} \geq 210$

• Total weight of the instant corn cream soup (100 g)
$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12} = 100$

• Amount of chicken bone meal in each formula
X_1 (F1) = 0; (F2) = 0; (F3) = 0; (F4) = 1.44; (F5) = 2.83; (F6) = 1.40; (F7) = 2.79; (F8) = 1.42; (F9) = 2.76

• Amount of moringa flour in each formula
X_2 (F1) = 0; (F2) = 1.16; (F3) = 2.28; (F4) = 0; (F5) = 0; (F6) = 2.24; (F7) = 1.12; (F8) = 1.14; (F9) = 2.21

• Amount of peeled sweet corn in each formula
X_3 (F1) = 29.31; (F2) = 28.9; (F3) = 28.51; (F4) = 28.8; (F5) = 28.32; (F6) = 28.04; (F7) = 27.94; (F8) = 28.42; (F9) = 27.58

• Amount of butter in each formula
X_4 (F1) = 8.79; (F2) = 8.67; (F3) = 8.55; (F4) = 8.64; (F5) = 8.5; (F6) = 8.41; (F7) = 8.38; (F8) = 8.52; (F9) = 8.27

• Amount of shallot in each formula
X_5 (F1) = 0.59; (F2) = 0.58; (F3) = 0.57; (F4) = 0.58; (F5) = 0.57; (F6) = 0.56; (F7) = 0.56; (F8) = 0.57; (F9) = 0.55

• Amount of onion in each formula
X_6 (F1) = 4.4; (F2) = 4.34; (F3) = 4.28; (F4) = 4.32; (F5) = 4.25; (F6) = 4.21; (F7) = 4.19; (F8) = 4.26; (F9) = 4.14

• Amount of wheat flour in each formula
X_7 (F1) = 7.33; (F2) = 7.23; (F3) = 7.13; (F4) = 7.2; (F5) = 7.08; (F6) = 7.01; (F7) = 6.99; (F8) = 7.1; (F9) = 6.89

• Amount of chicken broth powder in each formula
X_8 (F1) = 5.86; (F2) = 5.78; (F3) = 5.7; (F4) = 5.76; (F5) = 5.66; (F6) = 5.61; (F7) = 5.59; (F8) = 5.68; (F9) = 5.52

• Amount of all-purpose cream in each formula
X_9 (F1) = 23.44; (F2) = 23.12; (F3) = 22.81; (F4) = 23.04; (F5) = 22.66; (F6) = 22.43; (F7) = 22.36; (F8) = 22.73; (F9) = 22.06

• The pepper amount was equal to 0.10 g
$X_{10} = 0.10$

• The amount of corn starch was equal to 15.79 g
$X_{11} = 15.79$

• Amount of water in each formula
X_{12} (F1) = 4.39; (F2) = 4.33; (F3) = 4.28; (F4) = 4.32; (F5) = 4.24; (F6) = 4.20; (F7) = 4.19; (F8) = 4.27; (F9) = 4.13

• Non-negativity constraints
$x \geq 0$; $y \geq 0$

Note: F in (F1), (F2),… etc. means "Formula"

After the mathematical equation was entered into the linear program, the results showed that Formula 9 was the most feasible because it had the highest amount of chicken bone meal and moringa flour, which added protein, calcium, and phosphorus to the soup. Chicken bone meal and moringa leaf meal replace several other raw materials to provide a lower cost per 100 g of instant corn cream soup (IDR 5,929.83). It was related to Khalil et al. (2017), who said that chicken bone meal could be an alternative renewable and low-cost dietary phosphorus source. Besides that, Hicks (2016) also said that chicken bone meal can be used as low-cost pet food because of its high protein content. The formulation was composed of 2.76 g of chicken bone meal, 2.21 g of moringa leaf meal, 27.58 g of sweet corn flakes, 8.27 g of butter, 0.55 g of shallots, 4.14 g of onions, 6.89 g of wheat flour, 5.52 g of chicken broth powder, 22.06 g of all-purpose cream, 0.1 g of peppercorns, 15.79 g of cornstarch, and 4.13 g of water. Regarding feasibility, Formula 9 was followed by Formulas 8 and 7, which had the same raw materials. Formulas 8 and 7 had costs per 100 g of IDR 5,969.03 and IDR 5,931.65, respectively. The results of linear programming are shown in Table 5.

Preparation of instant corn cream soup

After preparing the nine formulations of instant corn cream soup, different color characteristics were observed. T0K0 (Formula 1) showed the brightest yellow color, whereas T2K2 (Formula 9) showed the most intense brown color (Figure 1). All formulas showed a brown color when they were rehydrated (Figure 2).

Table 5. The result of linear programming of instant corn cream soup for 9 formulas

Raw Materials	Amount (g)								
	Formula								
	1	2	3	4	5	6	7	8	9
Chicken bone meal (X_1)	0	0	0	1.44	2.83	1.40	2.79	1.42	2.76
Moringa leaf meal (X_2)	0	1.16	2.28	0	0	2.24	1.12	1.14	2.21
Butter (X_3)	29.31	28.9	28.51	28.8	28.32	28.04	27.94	28.42	27.58
Shallots (X_4)	8.79	8.67	8.55	8.64	8.5	8.41	8.38	8.52	8.27
Onions (X_5)	0.59	0.58	0.57	0.58	0.57	0.56	0.56	0.57	0.55
Wheat flour (X_6)	4.4	4.34	4.28	4.32	4.25	4.21	4.19	4.26	4.14
Chicken broth powder (X_7)	7.33	7.23	7.13	7.2	7.08	7.01	6.99	7.1	6.89
All-purpose cream (X_8)	5.86	5.78	5.7	5.76	5.66	5.61	5.59	5.68	5.52
Peeled sweet corn (X_9)	23.44	23.12	22.81	23.04	22.66	22.43	22.36	22.73	22.06
Pepper (X_{10})	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Corn starch flour (X_{11})	15.79	15.79	15.79	15.79	15.79	15.79	15.79	15.79	15.79
Water (X_{12})	4.39	4.33	4.28	4.33	4.24	4.20	4.19	4.27	4.13
Total Cost (IDR)	6,012.77	6,009.38	6,005.42	5,972.02	5,933.63	5,967.34	5,931.65	5,969.03	5,929.83

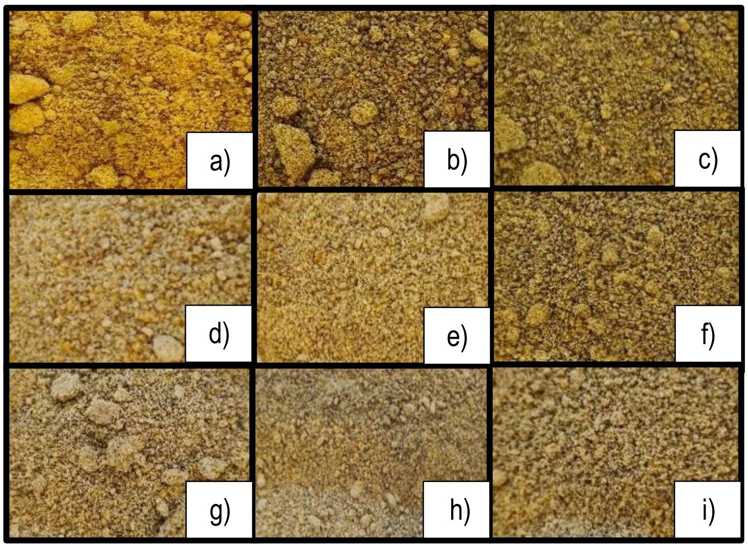

Figure 1. Instant corn cream soup formula added with chicken bone meal and moringa leaves: a). T0K0 (Formula 1), b). T0K1 (Formula 2), c). T0K2 (Formula 3), d). T1K0 (Formula 4), e. T2K0 (Formula 5), f). T1K2 (Formula 6), g. T2K1 (Formula 7), h. T1K1 (Formula 8), and i. T2K2 (Formula 9).

Figure 2. The rehydrated instant corn cream soup

Product suitability validation test

The validation test was conducted for all nine formulas using linear programming. The validation test was conducted by comparing proximate analysis data and the results of the laboratory analyses (i.e., calcium and phosphorus) by applying SNI 01-4967-1999 for instant corn cream soup and PerBPOM No. 1 of 2022 for the claims on food labels, where ALG refers to BPOM Regulation No. 9 of 2016 (BPOM, 2016). A comparison was carried out to determine the model's suitability, considering both the programming results and the requirements of SNI and PerBPOM. The results of the model suitability test are shown in Table 6.

Each soup formula had different model suitability values for the test parameters. The formula with the highest model suitability was Formula 9, in which 100 g of instant corn cream soup contains 5.64% protein with a minimum SNI reference of 10%. This yields a model suitability for the protein of 56.4%. For fat content, the value was 20.87%, with a minimum SNI reference of 5%. This shows that the fat content meets the requirements of the SNI reference, and the model fit for fat is thus 100%. In addition, the water content was 6.05%, which is below the maximum SNI reference of 8%. Therefore, the suitability of the model for water is 100% because it meets the standard. Formula 9 contains 714.07 mg per 100 g of calcium, which meets the minimum ALG (330 mg per 100 g), thus resulting in 100% model suitability for calcium. Regarding the phosphorus content, Formula 9 contains 1067.38 mg of this element, while the ALG is fulfilled at a minimum of 210 mg; thus, the model suitability reaches 100% for phosphorous.

Table 6. The results of the model suitability of the linear program to the results of the proximate analysis, and analysis of calcium and phosphorus of instant corn cream soup

Formula	Parameter	Standard Requirement	Value	Model Suitability
1	Protein (%)	Min. 10 [a]	4.26	42.60%
	Fat (%)	Min. 5 [a]	18.72	100%
	Moisture (%)	Max. 8 [a]	2.43	100%
	Calcium (mg)	Min. 330 [b,c]	9.11	2.76%
	Phosphorus (mg)	Min. 210 [b,c]	516.74	100%
2	Protein (%)	Min. 10 [a]	4.46	44.60%
	Fat (%)	Min. 5 [a]	18.56	100%
	Moisture (%)	Max. 8 [a]	3.5	100%
	Calcium (mg)	Min. 330 [b,c]	47.87	14.51%
	Phosphorus (mg)	Min. 210 [b,c]	480.23	100%
3	Protein (%)	Min. 10 [a]	4.31	43.10%
	Fat (%)	Min. 5 [a]	20.97	100%
	Moisture (%)	Max. 8 [a]	6.11	100%
	Calcium (mg)	Min. 330 [b,c]	87.05	26.38%
	Phosphorus (mg)	Min. 210 [b,c]	457.58	100%
4	Protein (%)	Min. 10 [a]	4.45	44.50%
	Fat (%)	Min. 5 [a]	19.92	100%
	Moisture (%)	Max. 8 [a]	6.06	100%
	Calcium (mg)	Min. 330 [b,c]	343.24	100%
	Phosphorus (mg)	Min. 210 [b,c]	767.6	100%
5	Protein (%)	Min. 10 [a]	5.33	53.30%
	Fat (%)	Min. 5 [a]	21.38	100%
	Moisture (%)	Max. 8 [a]	6.17	100%
	Calcium (mg)	Min. 330 [b,c]	650.25	100%
	Phosphorus (mg)	Min. 210 [b,c]	1070.6	100%
6	Protein (%)	Min. 10 [a]	4.94	49.40%
	Fat (%)	Min. 5 [a]	20.36	100%
	Moisture (%)	Max. 8 [a]	2.2	100%
	Calcium (mg)	Min. 330 [b,c]	391.45	100%
	Phosphorus (mg)	Min. 210 [b,c]	737.68	100%
7	Protein (%)	Min. 10 [a]	5.24	52.40%
	Fat (%)	Min. 5 [a]	20.64	100%
	Moisture (%)	Max. 8 [a]	4.33	100%
	Calcium (mg)	Min. 330 [b,c]	668.46	100%
	Phosphorus (mg)	Min. 210 [b,c]	1046.32	100%
8	Protein (%)	Min. 10 [a]	4.63	46.30%
	Fat (%)	Min. 5 [a]	21.7	100%
	Moisture (%)	Max. 8 [a]	4.37	100%
	Calcium (mg)	Min. 330 [b,c]	377.57	100%
	Phosphorus (mg)	Min. 210 [b,c]	841.15	100%
9	Protein (%)	Min. 10 [a]	5.64	56.40%
	Fat (%)	Min. 5 [a]	20.87	100%
	Moisture (%)	Max. 8 [a]	6.05	100%
	Calcium (mg)	Min. 330 [b,c]	714.07	100%
	Phosphorus (mg)	Min. 210 [b,c]	1067.38	100%

Note: a based on SNI 01-4967-1999; b based on PerBPOM no. 1 of 2022; c based on PerKa BPOM no. 9 of 2016

Calcium and phosphorus claims

The calcium content in Formulas 1, 2, and 3 did not meet the requirements of PerBPOM No. 1 of 2022, which states a minimum of 330 mg per 100 g sample to consider a product high in calcium. This may be due to the low calcium contribution of moringa flour compared to chicken bone meal. This is in line with the results of the calcium analysis of chicken bone meal, which had a higher (18.83%) content of this mineral than moringa leaf meal (2.54%) (Table 2). Hence, these three formulas did not meet the high-calcium claim.

Nevertheless, the moringa leaf meal in this study had a higher calcium content than that reported by Sultana (2020) (1.3–2.6%, equivalent to 1300–2600 mg of calcium per 100 g of moringa meal). Formulas 4, 5, 6, 7, 8, and 9 met the requirements of PerBPOM No. 1 of 2022 and were claimed to be high in calcium because they met the minimum ALG value for this mineral (330 mg).

All nine formulas met the minimum ALG value to be considered high in phosphorus (210 mg). Although, there are differences in the phosphorus content of chicken bone meal and moringa leaf meal according to Abdulla et al. (2016), Saputro et al. (2021), and Sultana (2017). Abdulla et al. (2016) found that the P content in chicken bone is 16.2%, equivalent to 16.200 mg of phosphorus per 100 g of chicken bone), Saputro et al. (2021) found 6.7% P, whereas this research found 8.46 % P. On the other hand, Sultana (2020) found that moringa leaves contained 0.15–0.30% phosphorus, whereas our results indicated 0.16% phosphorus. However, in PerBPOM No. 1 of 2022, processed food that achieves a high calcium claim must have a calcium and phosphorus ratio of 1-2:1. This is because this ratio is the optimal proportion of calcium absorption in the body. As Khalil et al. (2017) explained, the content of Ca and P of the bone meal should achieve a 2:1 ratio to be absorbed optimally by the body. Whereas, in Formulas 4, 5, 6, 7, 8, and 9, even though the calcium is high, the ratio between calcium and phosphorus ranged from 1:2 to 7:10 where the calcium content is less than phosphorus. It might harm the body because the high phosphorus can stimulate the secretion of parathyroid hormone (PTH) to reabsorb calcium from the bone to the blood serum, leading to decreased bone density (Loughrill et al., 2016). Therefore, it is necessary to do further processing so that the ratio of calcium and phosphorus meets the BPOM regulation.

Protein claims

Neither soup formula met the protein requirement of SNI 01-4967-1999, which stated that the protein content must be at least 10%. The value is also met with the PerBPOM No 1. of 2022, which stated that the product should contain 12 g protein to achieve a source of protein claim. This is because the protein contents in moringa leaf meal (16.72%) and chicken bone meal (34.01%) were insufficient. These protein contents were lower than those in previous studies, which reported that chicken bone meal contained 46.75% protein (Cornelia et al., 2018) and moringa leaf meal contained 33.12% protein (Fadhilatunnur et al., 2021). The low protein content in the instant corn cream soup may be due to the small amount of chicken bone meal and moringa leaf flour added, i.e., only 1.1-2.8%. The determination of 1.1-2.8% was carried out based on preliminary tests on 10 panelists who said that adding chicken bone meal and moringa flour of more than 2.8% was not sensory acceptable (i.e.. taste, aroma, color, and texture attributes). Cornelia et al. (2018) said that the higher the chicken bone meal added to the cookies, the less sensory it was accepted by the panelists. Yessimbekov et al. (2023) said that in order for chicken bone meal to have good physicochemical properties (high water holding capacity, consistent homogeneity, and a balanced chemical composition), it is necessary to grind it with initial freezing, 50% water addition, and ultrafine grinding, so that result in good sensory attribute. Chicken bone meal and moringa flour used in this research were only ground without initial freezing, water addition, and ultrafine grinding.

Besides that, the low protein in all Formulas might be due to structural changes caused by high temperatures during processing (protein denaturation). Proteins are sensitive to temperature and begin to deteriorate at 318.15 K (45 °C). During the denaturation process, the structures that are destroyed are not primary structures (amino acid sequences) but secondary structures (the helix and sheets) and tertiary structures (hydrogen bonds, salt bridges, disulfide bonds, and non-polar hydrophobic interactions) (Belitz, 2009). Generally, the denaturation process can be detected when the protein precipitates or coagulates, resulting in changes to its functional properties (e.g., decreased water solubility and ceased enzyme function). However, protein denaturation is not always negative. For example, only 50% of raw egg protein can be absorbed by the body, whereas 90% of denatured cooked egg protein can be absorbed (Evenepoel et al., 1998). Wang et al. (2018) also said that the higher the heating temperature in the egg, the higher its protein digestibility. His research showed that 100°C heating made the egg have 80% in-vitro digestibility. Hence, although the protein content of all nine Formulas is low because of the heating, the protein digestibility may be high.

Based on the regulations of the National Standardization Agency (SNI 01-4967-1999) regarding the quality requirements of instant cream soup, all of the developed formulas met the fat (min. 5%) and water (max. 8%) requirements but not that of protein (min. 10%). The three formulas that exhibited the highest model fit for the protein parameter were Formula 9 (56.4%), Formula 5 (53.3%), and Formula 7 (52.4%), with protein contents of 5.64%, 5.33%, and 5.24%, respectively. Yet, the unmet protein content is not a problem because commercial products have protein contents below the quality requirements for instant cream soups. For example, instant corn cream soups of Brand A and Brand B contain 0% and 6% protein, respectively. Although these commercial products do not meet the requirements of SNI 01-4967-1999, they are eligible for commercialization because they meet BPOM Regulation No. 21 of 2016 concerning food categories. PerKa BPOM No. 21 of 2016 states that, in food category No. 12.5 (soups and broths), the basic characteristics of instant cream soups are typical odor and taste, a moisture content of no more than 8%, and no minimum protein content. Here, Formula 9 contains 5.64% protein, which may exceed the protein content of commercial products. In addition, Formula 9 contains high levels of calcium and phosphorus, which commercial products may lack. The product may need to be improved to meet the source of protein claim.

Selection of the three best formulas

After obtaining the minimum cost and model suitability values, the next step was to rank the formulas based on the minimum cost and maximum model suitability. Table 7 shows the ranking of the soups based on the minimization of the cost of the raw materials while meeting the quality requirements of SNI 01-4967-1999 and achieving the high-calcium and high-phosphorus claims regulated in PerBPOM No. 1 of 2022. The formulations are ordered based on the percentage of model suitability from the validation test.

The three instant corn cream soups with the highest model fit were Formulas 9, 5, and 7 (Table 7). Chicken bone meal and moringa leaf meal can be used as raw materials to manufacture products high in calcium and phosphorus. This agrees with the computational results of the linear program, which yielded the three best formulas based on the objective function (minimizing raw material costs according to the requirements of SNI 01-4967-1999 and PerBPOM No. 1 of 2022). These formulas were Formula 9, (with a cost of IDR 5,929.83), Formula 7 (with a cost of IDR 5,931.65), and Formula 5 (with a cost of IDR 5,933.63). By contrast, the other formulas had higher minimum costs, ranging from IDR 5,967.34 to IDR 6,012.77.

The validation test results revealed that, in terms of effectiveness, adding chicken bone meal has a greater effect than the addition of moringa flour on the calcium and protein content of the instant corn cream soup. The addition of moringa flour resulted in a substantial increase in cost but had no substantial effect on the calcium and protein content. Nevertheless, moringa flour contributed to the additional nutrients (such as nitrogen, vitamin B complex, vitamin C, pro-vitamin A as beta-carotene, vitamin K, and manganese) that gave a positive impact on the body (Mahfuz et al., 2019; Dewi et al., 2020; Fahdilatunnur et al., 2021). Rehman et al. (2018) also said that *Moringa oleifera* leaf powder increased the density indices of the tibia bone of broilers chicken. Formula 9 contained 2.8% chicken bone meal and 2.2% moringa flour, Formula 5 contained 2.8% chicken bone meal without moringa flour, and Formula 7 contained 2.8% chicken bone meal and 1.1% moringa flour. Therefore, the addition of chicken bone meal and moringa flour can be an approach to developing a food product in line with the green economy. The three formulas identified can be further tested to determine consumer preferences.

Table 7. The order of the best formulas based on the results of cost minimization and the average of model suitability

Order	Formula	Cost Minimization	Order	Formula	Average of model suitability
1	Formula 9	IDR 5,929.83	1	Formula 9	91.28%
2	Formula 7	IDR 5,931.65	2	Formula 5	90.66%
3	Formula 5	IDR 5,933.63	3	Formula 7	90.48%
4	Formula 6	IDR 5,967.34	4	Formula 6	89.88%
5	Formula 8	IDR 5,969.03	5	Formula 8	89.26%
6	Formula 4	IDR 5,972.02	6	Formula 4	88.90%
7	Formula 3	IDR 6,005.42	7	Formula 3	73.90%
8	Formula 2	IDR 6,009.38	8	Formula 2	71.82%
9	Formula 1	IDR 6,012.77	9	Formula 1	69.07%

Sensory test of the selected formula

A total of 40 panelists aged 18–56 years and residents in Jakarta, Bogor, Tangerang, and South Tangerang took part in the sensory test. The samples were given a three-digit code sorted by sample formulation. A total of 21 sensory attributes for inclusion in the scoresheet were generated based on the FGD results, similar studies, and inputs from panelists who had tasted the soup samples with added chicken bones and moringa leaves.

The sensory test results revealed that different formulations had different sensory profiles. CATA is the method that was frequently used to identify drivers of liking and directions for product reformulation (Ares et al., 2014). The analysis using the CATA method revealed that the formulation containing 2.8% chicken bone meal and 1.1% moringa leaf meal (Formula 7) was the closest to the ideal product. This is because the products had the texture of corn kernels, a savory aftertaste, and a savory taste which was considered optimal. The sensory tests conducted using this method also indicated that the ideal product must possess several attributes, such as a corn-like aroma, a savory aftertaste, and a savory taste (Figure 3). Aroma is one of the crucial attributes as it plays an important role in increasing the value of a product. Besides that, chicken bone contributed to the umami and meaty taste during heating. Heating on the cream soup initiated the Maillard reaction, resulting in 50 volatile compounds that act as umami and meaty taste. On the other hand, the heating process also reduced the bitter taste of chicken bone (Sun et al., 2014).

An ANOVA test of the hedonic data was used to determine the significant differences between the samples based on the panelists' overall preference for the products. Table 8 shows the results obtained and p-values ($p < 0.05$ was considered statistically significant). The formula that contained 2.8% chicken bone meal and 2.2% moringa leaf meal (Formula 9) was the most significantly different, with an average hedonic value of 3.150 out of 5. Furthermore, the formula with 2.8% chicken bone meal and 1.1% moringa leaf meal (Formula 7) was preferred by the panelists (with a hedonic value of 3.825 out of 5) (Table 9).

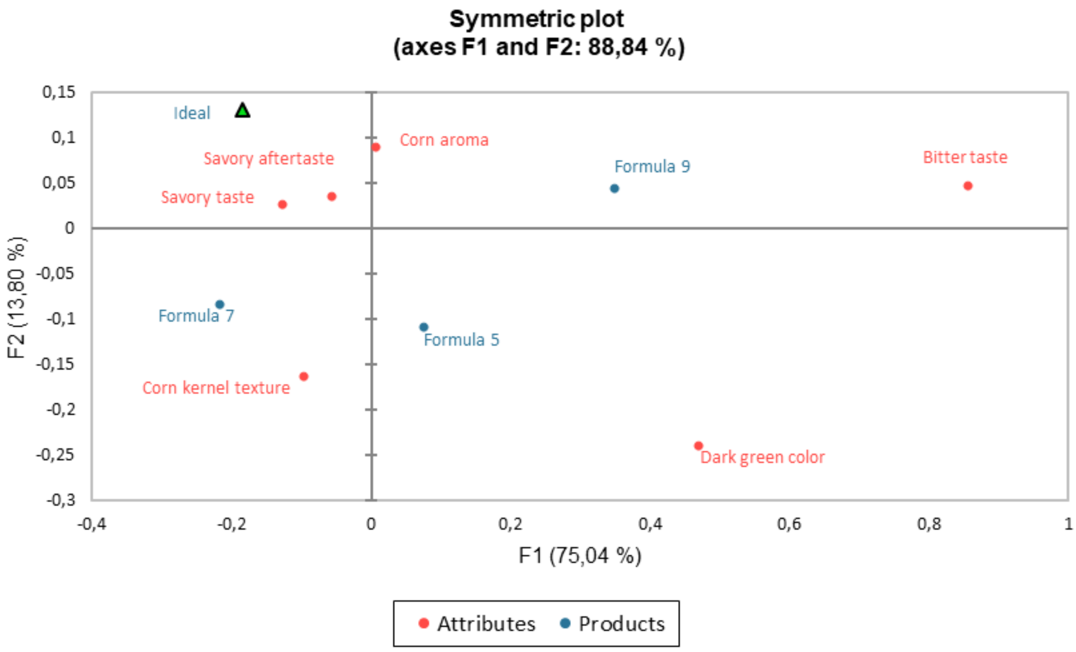

Figure 3. Representation of the ideal corn cream soup profile

Table 8. Sum of Square Analysis

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	3	9.485	3.162	4.559	**0.005**
Error	116	80.440	0.693		
Corrected Total	119	89.925			

Table 9. Summary all pairwise comparison of the sample

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
Formula 7	3.825	0.132	3.564	4.086	A
Formula 5	3.600	0.132	3.339	3.861	A
Formula 9	3.150	0.132	2.889	3.411	B

Conclusions

Among the nine instant soup formulations, Formula 7, which contained 2.8% chicken bone meal and 1.1% moringa leaf meal, was the best in terms of nutritional content and raw material cost. Formula 7 was produced following the quality requirements of SNI 01-4967-1999 for instant cream soup, with model suitability of 90.48%, and can also be claimed to be high in calcium and phosphorus based on PerBPOM No. 1 of 2022. The raw material cost of this formulation was only IDR 5,931.65. However, Formula 7 did not meet the source of protein claim. Nevertheless, Formula 7 is still suitable for commercialization according to BPOM Regulation No. 21 of 2016, which does not require a minimum protein content as long as the odor and taste are typical and the moisture content is up to 8%. In addition, the sensory test results using the CATA method revealed that Formula 7 was the closest to the ideal product, with the mandatory attributes being a savory aftertaste, a savory taste, a corn kernel-like texture, and a corn-like aroma. The sensory test results using the hedonic method also showed that the respondents preferred Formula 7. To improve the product with a source protein claim, ultrafine grinding with the initial freezing and 50% water addition on chicken bone meal may be necessary.

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Declarations

Conflict of interests The authors declare no competing interests.

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