



Research article

Ready-to-eat Chevron Sinina: Novel Formulation Using Extreme Vertices Mixture Design Optimization

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Abstract

Importance of the work: The supply of ready-to-eat (RTE) halal chevon sinina, a traditional spiced goat-meat stew from Mindanao, Philippines, remains underdeveloped despite strong market demand for convenient, culturally rooted halal foods.

Objectives: To optimize the tomato puree-palapa-chili powder proportions in RTE chevon sinina using an extreme vertices mixture design to maximize sensory acceptability.

Materials and Methods: Optimization involved varying the proportions of tomato puree (32–43%), palapa (55–65%) and chili powder (2–3%) using an extreme vertices mixture design applied to RTE chevon sinina. Nine formulations were processed thermally at 121°C for 41 min. Then, 50 untrained panelists evaluated the samples using a 9-point hedonic scale. Quadratic models were fitted and the superimposed contour and desirability analyses produced two optimized formulations, which were validated in triplicate.

Results: Tomato puree, palapa and chili powder significantly affected sensory responses. Quadratic models for appearance, taste, spiciness and overall acceptability had high coefficients of determination (0.92–0.95). Superimposition of contour plots for each response variable identified an optimum region, with a consumer overall acceptability rating ≥ 7.0 . Within this region, optimum formulations comprised all combinations of tomato puree, palapa and chili powder that met the multi-response desirability criteria, including two global solutions: 37.5% tomato puree, 59.8% palapa, 2.7% chili powder and 32.4% tomato puree, 64.9% palapa, 2.7% chili powder. Validation sensory tests gave overall acceptability scores of 7.68 and 7.76, both significantly higher than model predictions and within the “like moderately” to “like very much” range.

Main finding: High palapa and chili with low-to-moderate tomato optimally balanced the flavor, spiciness and appearance in RTE chevon sinina, demonstrating the usefulness of extreme vertices mixture design for culturally specific RTE product development.

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Introduction

The global food industry has witnessed a growing demand for halal-certified products, driven not only by Muslim consumers but also by non-Muslims who associate halal standards with food safety, hygiene and quality assurance (Ambali and Bakar, 2014). The global halal food market is projected to reach USD 5.9 trillion by 2033 (IMARC Group, 2025), underscoring its substantial economic potential, particularly for countries with large Muslim populations and halal production sectors.

In the Philippines, Muslims comprise approximately 6.4% of the total population, with the majority residing in the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) (Philippine Statistics Authority, 2023). Within these communities, halal goat production is considered one of the most economically viable and culturally important livestock enterprises, as chevon is served during Muslim festivities (Sanchez et al., 2020) and is promoted as a healthier red meat alternative (Valdez, 2023; Domingo et al., 2023).

Sinina is a traditional Muslim dish usually prepared with goat meat (chevon) or beef in tomato, palapa, ginger, garlic, onion, coconut milk, soy sauce, potatoes and various spices and is served typically during Kalilang (celebration or festival) and Kanduli (thanksgiving banquet), underscoring its roles as a festive and traditional dish in Muslim Mindanao (Ortil, 2021). Despite its culinary and cultural importance, chevon sinina remains predominantly home- or foodservice-prepared and ready-to-eat (RTE) retort-pouch versions remain uncommon in the Philippine market and the scientific literature.

Response surface methodology (RSM) is a quantitative, model-based approach that uses designed experiments to explore the relationships between multiple formulation or process variables and one or more responses, enabling efficient optimization with relatively few experimental runs compared with full-factorial approaches (Tirado-Kulieva et al., 2021). In meat products, various RSM designs, such as Box-Behnken, central composite and D-optimal mixture designs, have been applied successfully to optimize thermal processing of 'lechon paksiw de leyte' or Leyte pork stew (Patindol et al., 2025), beef patties produced with vegetable oils (Los et al., 2020), prebiotic beef snacks and deep frying conditions of chevon sausage (Sobowale et al., 2019), demonstrating their usefulness in modelling non-linear and interaction effects in complex flavor systems.

However, typically, these designs assume an unconstrained or simplex-type mixture space, whereas formulations for traditional chevon sinina are bounded by culturally acceptable taste ranges, safety and processing requirements, which restrict the feasible proportions of key ingredients. Therefore, an extreme vertices design was applied in the current study because it is suited specifically to mixtures studied near the boundaries of their components, where practical interest is restricted to only the vertices and edges of the constrained mixture space that satisfy lower and upper bounds. Recent applications in materials and process optimization have shown that extreme vertices designs are effective for optimizing constrained mixtures, while requiring fewer experiments than designs that explore the entire mixture space (Yildizel et al., 2020; Akinwande et al., 2023; Attah et al., 2023).

Applied to RTE chevon sinina, this approach makes it possible to optimize systematically the proportions of key flavor-driving ingredients within realistic Muslim culinary limits and retort-processing constraints. Tomato puree, palapa and chili powder were treated as essential flavor-driving components because they collectively define the characteristic color, flavor and pungency profile of chevon sinina. Tomato contributes natural acidity, sweetness and umami. At the same time, its lycopene-rich pigment enhances the reddish-orange color of the stew, a key visual quality cue for tomato-based meat dishes (Li et al., 2018). Palapa, a traditional Muslim condiment made from finely chopped scallions (sakurab), pounded ginger, turmeric, bird's eye chili and toasted grated coconut, imparts a complex aromatic base of sulfurous, spicy and nutty notes (Romato and Daud, 2025). On the other hand, chili powder primarily modulates capsaicinoid-driven pungency and oral burn, which strongly influences overall flavor intensity, mouthfeel and consumer liking for spicy meat dishes, including tomato- and curry-type matrices (Lyu et al., 2023).

To the authors' knowledge, there are currently no published studies that apply RSM-based extreme vertices mixture design to the development of RTE retort-pouched chevon sinina, leaving a clear methodological gap at the interface of traditional halal cuisine, mixture-design-based optimization and RTE product development. Within this context, the present study aimed: 1) to quantify the effects of variations in tomato puree-palapa-chili powder ratios on consumer-perceived sensory quality; and 2) to identify an optimal formulation to maximize overall acceptability while preserving the characteristic sensory profile of traditional chevon sinina.

Materials and Methods

Raw materials

Boer goats raised in accordance with the Philippine National Standard for halal goat production (BAFS, 2018) were slaughtered at the Sultan Kudarat State University halal-compliant slaughterhouse in Lutayan, Sultan Kudarat, Philippines. After slaughter, the chevon was portioned and stored at -18°C until further use. All ingredients, including tomatoes, chili powder, bell pepper, black pepper, brown sugar, coconut milk, garlic, ginger, guar gum, vegetable oil, onion, potato, salt, flavor enhancer, soy sauce, turmeric powder, vinegar and xanthan gum were procured from local markets in Isulan, Sultan Kudarat, Philippines. Palapa was sourced from Cotabato City, Philippines. Retort pouches ($12\text{ cm} \times 18\text{ cm}$, $100\text{ }\mu\text{m}$ thick) were used as the primary packaging of the RTE chevon sinina and were obtained from a commercial online supplier (Entrepouch.com).

Experimental design

An extreme vertices mixture design was used to optimize the chevon sinina formulation, consisting of three components—tomato puree (X_1), palapa (X_2) and chili powder (X_3)—constrained to sum to one with bounds of 32–43%, 55–65% and 2–3%, respectively. All other ingredients and processing conditions were held constant. Nine unique formulations were generated using Minitab Version 8 (Minitab, LLC, PA, USA).

Processing method

The list of ingredients used for processing chevon sinina is shown in Table 1. The first part of the process involved preparing the chevon by obtaining lean cuts from the leg, loin and shoulder, along with the bones; these pieces were cut into chunks measuring approximately $2\text{ cm} \times 3\text{ cm} \times 1\text{ cm}$. The chevon was soaked in a vinegar and turmeric powder solution and subsequently rinsed thoroughly with water to reduce the gamey odor commonly associated with chevon. Then, it was marinated overnight in a mixture composed of onion, garlic, ginger, black pepper, soy sauce, vinegar, salt, brown sugar and water. This was followed by scalding the meat in boiling water for 4 min.

The broth was prepared by initially precooking the chevon and bones in boiling water for 20 min, then roasting them in an oven at 180°C for 1 hr with onion, garlic and ginger. Next, the roasted chevon and bones were simmered for 1 hr in water and seasoned with the same spices used in the marinade, to develop a rich, flavorful broth. The sauce base was prepared from the chevon broth by sautéing garlic, onion, ginger and blended bell pepper in vegetable oil, followed by the addition of turmeric powder, black pepper, brown sugar, coconut milk, water, lemongrass, salt, flavor enhancer, guar gum and xanthan gum, until a homogeneous mixture was achieved. Afterward, the sauce was formulated by adding tomato puree, palapa and chili powder into the sauce base according to the proportions specified in Table 2. Potatoes were cut into slices measuring approximately $4\text{ cm} \times 4\text{ cm} \times 3\text{ cm}$.

Table 1 List of ingredients for processing chevon sinina

Ingredient	Weight (g)
Chevon ($2\text{ cm} \times 3\text{ cm} \times 1\text{ cm}$)	2,250.00
Goat meat and bones (for broth)	2,250.00
Sliced potatoes ($4\text{ cm} \times 4\text{ cm} \times 3\text{ cm}$)	1,620.00
Onion	281.25
Garlic	166.50
Ginger	144.25
Black pepper	4.37
Bell pepper	33.75
Soy sauce	1,192.41
Vinegar	267.48
Salt	85.19
Brown sugar	155.25
Coconut milk	400.00
Turmeric powder	13.50
Lemongrass stalk	17.30
Vegetable oil	84.38
Flavor enhancer	0.60
Xanthan gum	14.01
Guar gum	14.01
Water	6,669.29

Table 2 Component proportions (%) of tomato puree, palapa and chili powder for the nine chevon sinina formulations

Formulation number	Tomato puree (X_1)	Palapa (X_2)	Chili powder (X_3)
1	43.00	55.00	2.00
2	34.75	62.50	2.75
3	40.25	57.50	2.25
4	32.00	65.00	3.00
5	37.50	60.00	2.50
6	42.00	55.00	3.00
7	33.00	65.00	2.00
8	35.25	62.50	2.25
9	39.75	57.50	2.75

In the third part, each retortable pouch (12 cm × 18 cm) was filled with 62.50 g of chevon and 45 g of potato slices, after which 142.50 g of hot-filled sauce was added, yielding a total net weight of 250 g per pouch. After filling, the pouches were sealed using a continuous heat-band vertical sealer and loaded into a water retort machine. Retort processing was carried out at 121°C for 41 min excluding come-up and cooling times, following the conditions described by Valdez (2023).

Sensory evaluation

The RTE chevon sinina samples were coded with random three-digit numbers, placed on serving plates and held in a warming container at temperatures above 60°C before serving. Sensory evaluation was conducted by 50 untrained panelists composed of instructors, students and staff members from Sultan Kudarat State University, Philippines, all aged 18 years and above and with no reported food sensitivities. This panel size was considered adequate for consumer hedonic testing, as 50–100 consumers are sufficient to obtain reliable data for this type of sensory evaluation (Mammasse and Schlich, 2014).

The panelists were asked to evaluate the potato, meat and sauce components of each sample and were instructed to cleanse their palates with mineral water before and between samples. Each panelist assessed the appearance, taste, spiciness and overall acceptability of the samples using a 9-point hedonic scale, where 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely.

Validation experiment

The optimized formulations, or global solutions, were generated using Minitab Version 8 from superimposed contour plots of appearance, taste, spiciness and overall acceptability based on their target sensory scores. The first formulation was designed to achieve an overall acceptability score of 7, representing acceptable sensory quality, while the second formulation targeted scores >7 for all attributes, reflecting a superior overall sensory profile. Both optimized formulations were prepared following the same procedure as in the mixture design experiments, including retort processing at 121°C for 41 min (Valdez, 2023), with consistent ingredient proportions and processing conditions. Each formulation was prepared in triplicate. Sensory evaluation was conducted using a 9-point hedonic scale, with panelists assessing appearance, taste,

spiciness and overall acceptability. Then the observed sensory scores were compared with the predicted values from the mixture design models to verify the accuracy and reliability of the optimization.

Statistical analysis

All statistical analyses were performed using Minitab Version 8. An RSM approach using an extreme-vertices design was used to optimize the formulation of RTE halal chevon sinina. One-way analysis of variance at a significance level of $\alpha = 0.05$ was applied to detect significant differences among the samples in terms of appearance, taste, spiciness and overall acceptability. Additionally, a one-sample t test at $\alpha = 0.05$ was used to compare the predicted overall acceptability with the observed overall acceptability of the two optimized formulations.

Results and Discussion

Response optimization

Across the nine formulations, mean hedonic ratings for appearance ranged from 6.11 to 7.19, for taste from 5.74 to 7.10 and for spiciness from 5.91 to 7.06, while overall acceptability scores varied from 5.42 to 7.44 (Table 3). Formulation 2 obtained the highest mean score for appearance (7.19), while Formulation 4 achieved the highest mean scores for taste (7.10) and spiciness (7.06). Despite these numerical differences, appearance, taste and spiciness did not differ significantly among formulations. In contrast, overall acceptability varied significantly, with Formulation 4 receiving the highest mean score (7.44), suggesting that its ingredient proportions yielded the most favorable and well-balanced sensory profile.

Table 3 Sensory attributes of RTE chevon sinina in retort pouch

Formulation number	Appearance	Taste	Spiciness	Overall acceptability
1	6.11 ± 2.34	6.52 ± 2.25	6.30 ± 1.75	5.42 ± 2.23 ^c
2	7.19 ± 1.50	6.96 ± 1.53	6.83 ± 1.23	7.32 ± 1.35 ^{ab}
3	6.48 ± 1.20	6.56 ± 1.40	6.64 ± 1.66	6.06 ± 1.39 ^{bc}
4	7.15 ± 0.99	7.10 ± 1.30	7.06 ± 1.39	7.44 ± 1.25 ^a
5	6.70 ± 0.93	6.36 ± 1.15	6.75 ± 1.07	6.88 ± 0.97 ^{ab}
6	6.92 ± 1.26	5.74 ± 1.18	5.91 ± 1.15	6.14 ± 0.79 ^{bc}
7	6.63 ± 1.21	6.28 ± 0.96	6.18 ± 1.42	6.57 ± 1.31 ^{abc}
8	6.71 ± 1.30	6.50 ± 1.14	6.54 ± 1.32	6.46 ± 1.14 ^{abc}
9	7.07 ± 1.44	6.20 ± 1.50	6.80 ± 1.06	6.86 ± 0.96 ^{ab}

a,b,c = mean ± SD values in same column with the same letter are not significantly different at $p > 0.05$, according to Tukey's test.

Table 4 presents the quadratic Scheffé mixture models developed for each sensory attribute, showing that the proportion of tomato puree (X_1), palapa (X_2) and chili powder (X_3) accounted for most of the variability in panel responses. All models had high values for the coefficient of determination ($R^2 > 0.90$) for appearance ($R^2 = 0.9373$; adjusted $R^2 = 0.8745$), taste ($R^2 = 0.9406$; adjusted $R^2 = 0.8812$), spiciness ($R^2 = 0.9155$; adjusted $R^2 = 0.8311$) and overall acceptability ($R^2 = 0.9466$; adjusted $R^2 = 0.8891$), indicating that the fitted equations described the sensory data with good precision. These values suggested that random error and unexplained variation were relatively low and that the polynomial terms captured the main and interaction effects of the three components on product liking. Similar findings have been reported in the development of a prebiotic beef snack using a D-optimal mixture design (Dadkhah et al., 2025), where quadratic models for flavor, odor, color, texture and overall acceptability produced R^2 values close to 1, indicating strong agreement between the experimental and predicted scores. Likewise, the models confirmed the suitability of mixture RSM for simultaneously optimizing formulation and sensory acceptability.

Furthermore, the analysis of variance of the mixture models showed that for appearance, most explained variability was due to the linear blending of the three components, whereas quadratic effects were not significant (Supplementary Table S1). However, for taste and spiciness, the quadratic component was highly significant, driven mainly by the tomato puree and chili powder interaction, indicating strong non-linear blending along this edge of the mixture simplex (Supplementary Tables S2–S3). For overall acceptability, the regression model remained significant, but neither interaction term reached significance at $\alpha = 0.05$, suggesting that consumer liking was primarily governed by the linear effects of the component proportions rather than by curvature in the mixture space (Supplementary Table S4).

Appearance

The mixture contour plot for appearance (Fig. 1) shows that higher acceptability scores (≥ 7.2) were associated with

higher amounts of palapa and chili powder and a lower amount of tomato puree within the constrained region. This trend was reflected in Formulation 2 (Table 3), which obtained the highest appearance score (7.19) and consisted of 34.75% tomato puree, 62.5% palapa and 2.75% chili powder.

The positive influence of chili powder on appearance could be attributed to its rich content of red-pigmented carotenoids, such as capsanthin, capsorubin, zeaxanthin and cryptoxanthin, which impart orange-to-red hues in food products (Villa-Rivera and Ochoa-Alejo, 2020). Red food colors have been shown to enhance food craving, eating motivation and hedonic response compared with other colors (Bozdağ and Akkurt, 2025); often, red-colored samples receive the highest acceptance scores and positive affective descriptors (Silva et al., 2025).

Palapa may have further enhanced the appearance of the chevon sinina as it contains turmeric and toasted coconut, with turmeric contributing yellow pigments due to curcumin, the principal curcuminoid responsible for the characteristic yellow coloration of turmeric rhizomes (Nguyen et al., 2024). The combined presence of red carotenoids from the chili powder and the yellow curcumin from turmeric likely produced bright orange-to-red-orange hues, which would explain the high appearance acceptability observed in the optimized formulations (Fig. 2).

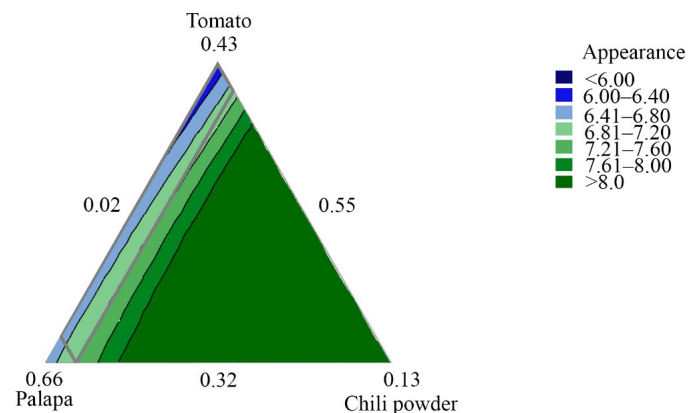


Fig. 1 Contour plot of appearance as influenced by tomato puree, palapa and chili powder proportions

Table 4 Quadratic Scheffé mixture models for sensory attributes of RTE chevon sinina as influenced by tomato puree (X_1), palapa (X_2) and chili powder (X_3)

Dependent variable (Y)	Predicted model	R^2 value	Adjusted R^2
Appearance	$Y = -21.0X_1 + 1.01X_2 - 5.3X_3 + 52.5X_1X_2 + 258X_1X_3$	0.9373	0.8745
Taste	$Y = 7.5X_1 - 16.48X_2 + 656X_3 + 59.8X_1X_2 - 1737X_1X_3$	0.9406	0.8812
Spiciness	$Y = -42.7X_1 - 32.51X_2 + 581X_3 + 181.3X_1X_2 - 1387X_1X_3$	0.9155	0.8311
Overall Acceptability	$Y = -60.9X_1 - 19.6X_2 + 255X_3 + 169.6X_1X_2 - 333X_1X_3$	0.9466	0.8891



Fig. 2 Chevon sinina, a traditional Muslim goat stew simmered in coconut milk and seasoned with palapa, a toasted coconut-based spice blend with chili and aromatics

Conversely, the upper area of the simplex with higher tomato proportions tended to fall within lower appearance-score bands (< 6.8), suggesting that tomato-dominant formulations produced less desirable visual characteristics such as paler color or more watery sauce consistency. Thermal processing studies on tomato-based sauces have shown that retort and other high-temperature treatments can degrade heat-sensitive nutrients and alter viscosity, leading to phase separation and a thinner appearance that consumers find less attractive in sauce-based foods (Giannakourou and Taoukis, 2021; Dhuey et al., 2021).

Taste

The mixture contour plot for taste acceptability (Fig. 3) shows that only a small portion of the constrained region achieved scores within the range 6.8–7.2. The least-liked formulations were those with a high tomato content, particularly when combined with low palapa levels. This trend was reflected in Formulation 6 (Table 3), which had a taste acceptability score of 5.74. In contrast, formulations with high palapa and chili powder and a low tomato content tended to receive the

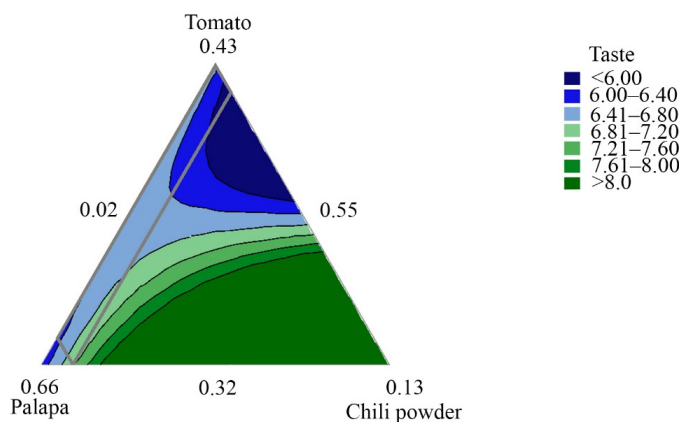


Fig. 3 Contour plot of taste as influenced by tomato puree, palapa and chili powder proportions

highest acceptability scores, as shown by Formulation 4, which contained 32% tomato puree, 65% palapa and 3% chili powder.

From a sensory perspective, this result aligned with consumer expectations for sinina as a traditional Muslim stew of beef or goat cooked in coconut milk and generously seasoned with palapa and chilies. In this context, the aromatic, spice-forward flavors of palapa and a noticeable but balanced chili heat operated as key identity cues, consistent with how spiciness functions as a culturally shaped sensory signal in many cuisines (Spence, 2018; Jeong and Lee, 2021). Recent work on precooked stewed beef has shown that tomato additions can substantially reshape the flavor profile. For example, Liu et al. (2025) reported that tomato not only suppressed a warmed-over flavor (WOF) by inhibiting lipid oxidation but also produced a strong “flavor endowment” effect via tomato-derived 2-isobutylthiazole, whose contribution increased more than fourfold as the tomato concentration rose, masking WOF and intensifying tomato-like notes. In tomato-rich matrices, such dominant tomato aromas can overshadow other key flavor drivers, analogous to the way a high tomato content in chevon sinina may dilute or mask the spice notes of palapa and chili, leading to a less intense and less authentic flavor profile.

Spiciness

The mixture contour plot for spiciness (Fig. 4) shows that the region associated with higher acceptability scores (6.8–7.2) was located where the palapa and chili powder were relatively high and tomato was kept at low to moderate levels. This trend was exemplified by Formulation 2, which had a spiciness score of 6.83 and contained 34.75% tomato puree, 62.5% palapa and 2.75% chili powder.

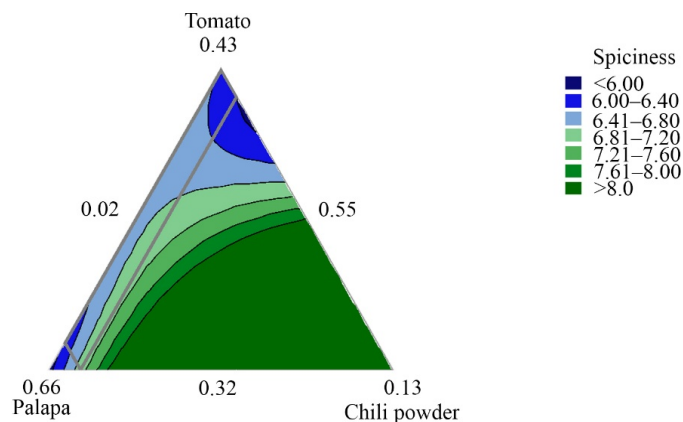


Fig. 4 Contour plot of spiciness as influenced by tomato puree, palapa and chili powder proportions

The increase in spiciness acceptability could be plausibly linked to the chili level, because very low concentrations (around 2% or less) may fall below the detection or preference threshold for many consumers, especially when embedded in a rich sauce matrix. Studies on pungency perception show that capsaicin intensity depended strongly on both the concentration and the surrounding food components, with fats, proteins and sugars moderating the perceived burn and often requiring higher chili levels to reach “ideal” spiciness in mixed dishes (Schneider et al., 2014). Furthermore, consumer research indicated that many Asian consumers habitually consume chili and tend to prefer mild-to-moderate but perceptible pungency rather than extreme heat in everyday foods, particularly dishes eaten with rice, where a lingering but balanced burn is desired (Siebert et al., 2022; Guzmán and Bosland, 2017). These findings were consistent with the 2–3% chili range (identified in the current study) being sufficient to provide a noticeable yet acceptable level of spiciness while preserving the characteristic flavor profile of chevon sinina.

Overall acceptability

The contour plot for overall acceptability (Fig. 5) shows that formulations with a high tomato content but low amounts of palapa and chili powder tended to receive the lowest scores (6.0–6.4). This trend was illustrated by Formulation 1, which contained 43% tomato puree, 55% palapa and 2% chili powder.

In contrast, the highest overall acceptability scores (7.2–7.6) were observed in formulations with high amounts of palapa and chili powder but a low tomato content. This pattern

was exemplified by Formulation 2, which had 34.75% tomato puree, 62.5% palapa and 2.75% chili powder and achieved an overall acceptability score of 7.32, as well as by Formulation 4, containing 32% tomato puree, 65% palapa and 3% chili powder. Based on these results, higher levels of palapa and chili powder, combined with moderate tomato puree content, contributed to a more favorable and well-balanced sensory profile for chevon sinina.

Superimposed contour analysis

The superimposed contour plot of appearance, taste, spiciness and overall acceptability (Fig. 6) reveals that formulations achieving high sensory scores for appearance, taste and spiciness (6.4–7.2), along with an overall acceptability score exceeding 7, were concentrated in regions characterized by high palapa and chili powder contents and low to moderate tomato puree levels. This pattern demonstrated that increasing the amounts of palapa and chili powder, while moderating the tomato puree content, enhanced the flavor intensity and spiciness without compromising visual appeal, resulting in a balanced sensory profile with high overall acceptability.

Next, the superimposed contour plot was used to generate optimal formulations for the halal chevon sinina, with two global solutions being considered. The first solution was set to achieve a target overall acceptability score of 7, while the second solution aimed for a target score of 7 across all four sensory attributes. These criteria yielded two global solutions with predicted scores of 7.0 and 7.13, respectively (Table 5).

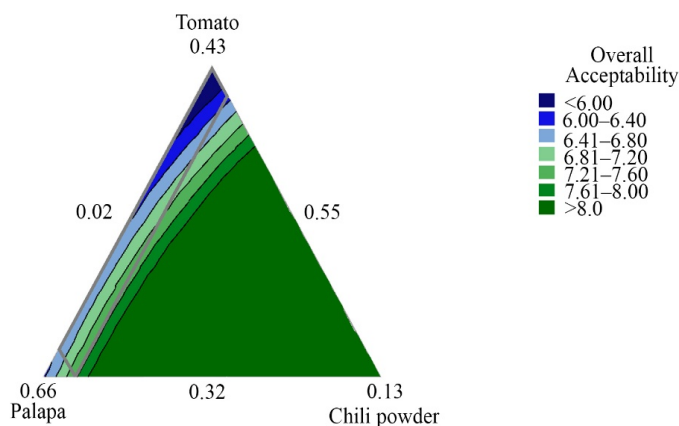


Fig. 5 Contour plot of overall acceptability as influenced by tomato puree, palapa and chili powder proportions

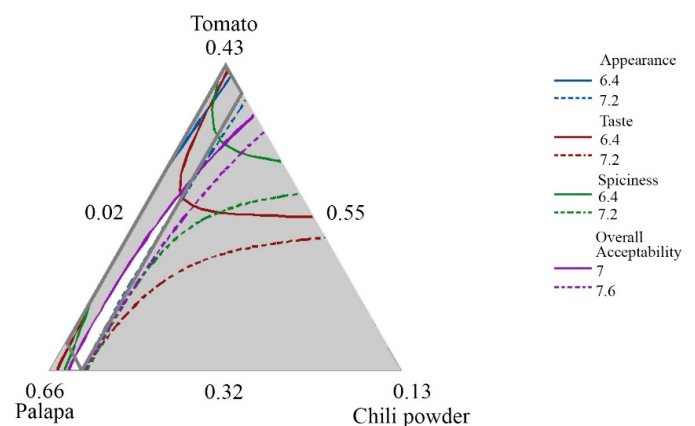


Fig. 6 Superimposed plot of appearance, taste, spiciness and overall acceptability as influenced by tomato puree, palapa and chili powder proportions

Table 5 Mean ± SD sensory scores of the two optimized formulations (global solutions) and their predicted overall acceptability

Global solution	Appearance	Taste	Spiciness	Overall acceptability	Predicted overall acceptability
1	7.56 ± 1.18	7.60 ± 1.28	7.66 ± 1.29	7.68 ± 1.25	7.0
2	7.48 ± 1.15	7.56 ± 1.20	7.50 ± 1.22	7.76 ± 1.04	7.13

Validation experiment

The validation experiment showed that the overall acceptability of both the global solutions was significantly higher than their predicted values at $\alpha = 0.05$, based on a one-sample t test. As shown in Table 5, Global Solution 1 (GS1) had an overall acceptability of 7.68 compared with the predicted 7.0, while Global Solution 2 (GS2) scored 7.76 versus the predicted 7.13. These results indicated that consumers rated both formulations between "like moderately" (7) and "like very much" (8), showing that the optimized formulations were well-received.

Notably, the results of the validation experiment suggested that the optimal range for formulating halal chevon sinina was 32.4–37.5% for tomato puree, 59.8–64.9% for palapa and 2.7% for chili powder. Both global solutions achieved overall sensory ratings above 7 for appearance, taste, spiciness and overall acceptability. Specifically, GS1 had mean sensory scores of 7.56 (appearance), 7.60 (taste), 7.66 (spiciness) and 7.68 (overall acceptability), while GS2 had scores of 7.48, 7.56, 7.50 and 7.76, respectively.

Conclusion

The study optimized the proportions of tomato puree, palapa and chili powder in RTE chevon sinina using an extreme vertices mixture design constrained to 32–43% tomato puree, 55–65% palapa and 2–3% chili powder. Sensory responses for appearance, taste, spiciness and overall acceptability were well described by the fitted quadratic Scheffé mixture models, which had high coefficients of determination (> 0.90) and thus indicated that variability in panel scores was largely attributable to the three formulation components rather than random error. Validation of the response-surface optimization yielded two global solutions: GS1 (37.5% tomato puree, 59.8% palapa, 2.7% chili powder) and GS2 (32.4% tomato puree, 64.9% palapa, 2.7% chili powder), both of which achieved high hedonic ratings (overall acceptability 7.68 and 7.50, respectively), confirming the predictive adequacy of the models. These results defined an optimal formulation window of approximately 32.4–37.5% tomato puree, 59.8–64.9%

palapa and 2.7% chili powder for highly acceptable RTE chevon sinina and demonstrated that an extreme vertices mixture design provided a robust, resource-efficient approach for formulation optimization within constrained ingredient spaces. The strong consumer acceptance of the optimized products further highlighted the potential of the traditional Muslim dish sinina to be developed into a marketable RTE chevon product.

Conflict of Interest

The authors declare that there are no known financial or personal conflicts of interest that could have influenced the work reported in this manuscript

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