



# Modulation of the Sensory Profile of Canned *Sardinella lemuru* in Balado Sauce by Pre-Cooking Techniques

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## Abstract:

Pre-cooking is an initial cooking stage in the processing of canned *Sardinella lemuru* (CSL) before the addition of sauce and sterilization, playing an essential role in determining product quality and sensory profile. This technique can influence attributes such as color, aroma, taste, and texture, making it a strategic effort for companies to maintain consistent quality, enhance consumer acceptance, and strengthen product competitiveness. This study aimed to evaluate consumer preference and the sensory profile of CSL in *balado* sauce using steaming (CSLS) and frying (CSLF) pre-cooking techniques at PT ICR. The samples used were meat from two types of canned *Sardinella lemuru* in *balado* sauce produced by PT ICR. The methods applied included a hedonic test to assess consumer preference and the Check-All-That-Apply (CATA) method to identify sensory attributes. Seven Quality Control staff participated in a Focus Group Discussion (FGD), while 30 production staff served as panelists for the hedonic and CATA tests. Hedonic data were analyzed using the Independent Sample T-Test with SPSS version 26, and CATA data were processed with XLSTAT 2021. Results showed that differences in pre-cooking techniques significantly affected taste and aroma ( $p < 0.05$ ) but had no significant effect on appearance and texture ( $p > 0.05$ ). The FGD identified 19 sensory attributes, including dark grey, cream, brownish yellow, light orange, dark brown, oily, garlic-like, fishy, metallic, salty, sweet, bitter, sour, umami, soft, dense, coarse, watery, and crumble. The ideal sensory profile was described as having umami and salty taste, fishy and oily aroma, dense yet tender texture, and brownish yellow color. Attributes influencing preference included cream color, watery, and crumble texture, while dark grey color was identified as a "Must Not Have" attribute that requires careful attention.

Keywords: Check-all-that-apply; Focus Group Discussion; Sensory Profile; Sensory Wheels; Consumer Preference

## 1. Introduction

The fish canning industry plays an important role in providing safe, nutritious, and shelf-stable seafood products to consumers worldwide. In Indonesia, *Sardinella lemuru* is one of the economically important pelagic fish species widely utilized as raw material for canned fish products due to its high nutritional value, availability, and affordability. As consumer demand for ready-to-eat seafood products continues to increase, product quality is no longer evaluated solely based on safety and nutritional content but also on sensory attributes that influence consumer acceptance. Sensory characteristics such as appearance, aroma, taste, and texture are recognized as major determinants of consumer preference and purchasing decisions for processed fish products (Utari *et al.*, 2024). Therefore, understanding factors affecting sensory quality is essential for improving the competitiveness of canned seafood products.

Among the various processing stages involved in fish canning, pre-cooking is considered one of the most critical operations affecting the final quality of the product. Pre-cooking promotes moisture reduction, facilitates product handling before canning, and induces physicochemical changes that influence sensory characteristics such as flavor, color, and texture (Morsy, 2016). Steaming and frying are among the most commonly applied pre-cooking techniques in the seafood processing industry (Nawaz et al., 2021; Sun et al., 2020). Previous studies have shown that steaming tends to preserve moisture content, volatile aroma compounds, and the natural characteristics of fish due to its relatively mild heat transfer mechanism (Wang et al., 2020; Liu et al., 2025). In contrast, frying promotes Maillard reactions, caramelization, and lipid oxidation, resulting in enhanced color development and more complex flavor formation (Chang et al., 2020). These differences suggest that pre-cooking methods may substantially influence consumer perception of canned fish products.

Several studies have investigated the effects of cooking methods on the sensory and physicochemical properties of fish and fish-based products (Hassoun et al., 2022; Nopiyanti et al., 2023; Mazarel et al., 2025). However, most available studies focus on fresh fish, fish fillets, or fish-based snacks, whereas studies addressing the influence of pre-cooking techniques on canned fish products remain limited. More importantly, no study has specifically compared steaming and frying as pre-cooking methods for canned *Sardinella lemuru* products formulated with *balado* sauce. This represents an important research gap because the interaction between thermal processing conditions and seasoning components may alter flavor development, texture formation, and overall sensory perception. Consequently, scientific information regarding the most suitable pre-cooking technique for producing highly acceptable canned *Sardinella lemuru* products is still lacking.

In addition to the limited information regarding pre-cooking methods, sensory evaluation studies on seafood products frequently rely solely on hedonic testing to measure consumer acceptance. Although hedonic testing provides valuable information regarding preference, it does not adequately explain which sensory attributes contribute to liking or disliking. Recent studies have highlighted the importance of rapid sensory profiling techniques such as Check-All-That-Apply (CATA) because they provide a more comprehensive understanding of the relationship between sensory characteristics and consumer perception (Adawiyah et al., 2024). Furthermore, the integration of CATA with multivariate analyses and penalty analysis enables the identification of sensory attributes that drive consumer liking and supports the development of products that better align with market expectations (Saputra et al., 2023).

Therefore, this study aimed to evaluate the effects of steaming and frying pre-cooking techniques on the sensory quality and consumer acceptance of canned *Sardinella lemuru* in *balado* sauce. A consumer-oriented sensory approach combining hedonic testing, CATA, correspondence analysis, principal component analysis, and penalty analysis was employed to characterize sensory profiles and identify the sensory attributes associated with consumer preference. The findings of this study are expected to provide scientific evidence for selecting appropriate pre-cooking techniques and contribute to the development of canned fish products with improved sensory quality, higher consumer acceptance, and enhanced industrial competitiveness.

## 2. Material and Method

### Materials

Commercial canned *Sardinella lemuru* (CSL) in *balado* sauce was obtained from PT ICR, Bali, Indonesia. Two product variants differing only in the pre-cooking technique applied prior to canning were evaluated i.e steaming pre-cooking (CSLS) and frying pre-cooking (CSLF). Both products were manufactured using the same fish species, formulation, canning process, and sterilization conditions, with the pre-cooking method being the primary variable. equipment used for sensory evaluation included a set of eating utensils consisting of plates, spoons, and forks with uniform color, shape, and size to minimize visual bias among panelists. Sensory assessment forms were prepared for evaluations, and stationery was provided for recording panelists' responses.

### Research design

This study employed a comparative experimental design to evaluate the effect of different pre-cooking techniques on the sensory quality of CSL in *balado* sauce. Two commercially produced samples differing in pre-cooking method, namely steaming (CSLS) and frying (CSLF), were evaluated. Consumer acceptance and sensory characteristics of the products were assessed using hedonic and Check-All-That-Apply (CATA) tests,

followed by statistical analyses to determine differences in sensory perception and identify attributes associated with consumer preference.

### Time and location of the study

This study was conducted from May to July 2025 at PT ICR, Bali, Indonesia. The sensory evaluations, including the Focus Group Discussion (FGD), hedonic test, and Check-All-That-Apply (CATA) test, were carried out at the company's sensory evaluation facility using trained quality control personnel and production staff as panelists.

### Preparation of CSL samples

In this research, only the meat of *Sardinella lemuru* was used while the *balado* sauce was removed to eliminate potential interference from sauce-related sensory attributes and to ensure that the evaluation focused solely on the effects of the pre-cooking methods on the fish. Each sample was served in a uniform portion size of approximately 20 g and placed on identical white plates with the same shape and dimensions to minimize visual bias. The samples were equilibrated and served at room temperature ( $27 \pm 2^\circ\text{C}$ ), reflecting the typical consumption temperature of canned fish products during sensory assessment. Each plate was labeled with a randomized three-digit code and presented to panelists following a balanced serving order. Water was provided as a palate cleanser between sample evaluations.

### Sensory evaluation of CSL samples

The sensory evaluation was conducted in three stages (Adawiyah *et al.*, 2019), consisting of a Focus Group Discussion (FGD), a hedonic rating test, and a Check-All-That-Apply (CATA) test. The FGD involved seven trained quality control personnel from PT ICR to identify and define sensory attributes of CSL processed using different pre-cooking techniques. During the discussion, panelists generated descriptive terms related to appearance, aroma, taste, and texture characteristics of the samples. The selected attributes were subsequently organized into a sensory wheel and used as the attribute list for the CATA questionnaire.

The hedonic rating test was conducted with 30 untrained panelists consisting of production staff from PT ICR. Approximately 20 g of fish sample was served on identical white plates and coded with randomized three-digit numbers. Only the fish meat was evaluated, while the *balado* sauce was removed to ensure that the assessment focused on the sensory characteristics of the fish. Samples were served at room temperature ( $27 \pm 2^\circ\text{C}$ ), and water was provided as a palate cleanser between evaluations. Panelists evaluated appearance, aroma, taste, texture, and overall acceptance using a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) (Meilgaard *et al.*, 2006).

The CATA test was conducted with the same 30 untrained panelists. Based on the attribute list generated during the FGD session, panelists were instructed to select all sensory attributes that they perceived in each sample. The CATA data were analyzed using XLSTAT 2021 software, including Cochran's Q test to identify discriminating attributes between samples, Correspondence Analysis (CA) and Principal Component Analysis (PCA) to visualize relationships among samples and sensory attributes, and Penalty Analysis to identify sensory drivers of consumer liking (Adawiyah *et al.*, 2024).

### Data analysis

The hedonic data obtained from the sensory evaluation were analyzed using an Independent Samples *t*-test with SPSS version 26 to determine significant differences between samples at a 95% confidence level ( $p < 0.05$ ). Meanwhile, the CATA data were analyzed using XLSTAT 2021 software. Cochran's Q test was applied to identify sensory attributes that significantly discriminated the samples, while Correspondence Analysis (CA) and Principal Component Analysis (PCA) were used to visualize the relationships between samples, sensory attributes, and consumer liking. In addition, Penalty Analysis was performed to determine sensory attributes that positively or negatively influenced consumer acceptance and to identify the sensory drivers of liking for CSL samples.

### 3. Results and Discussion

#### Hedonic rating test

The results of the hedonic evaluation of CSL in *balado* sauce are presented in Figure 1. Statistical analysis showed that differences in pre-cooking techniques did not significantly affect ( $p < 0.05$ ) appearance, taste, aroma, and texture attributes, indicating that both steaming and frying methods produced relatively similar sensory perceptions for these attributes. However, a significant difference ( $p < 0.05$ ) was observed in the overall acceptance attribute, suggesting that the pre-cooking method influenced the overall consumer preference toward the products.

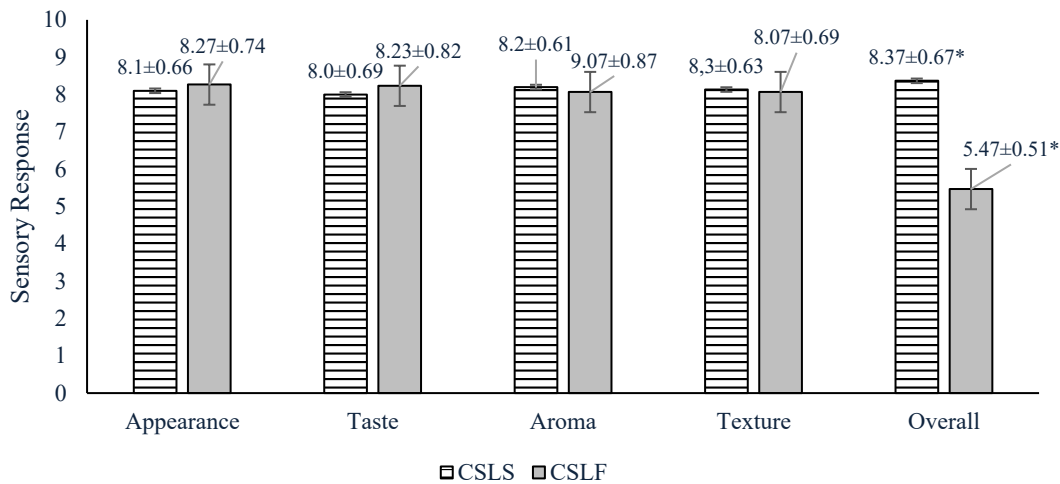


**Figure 1.** Result of hedonic rating test on CSLS (≡) and CSLF (■)

CSLS showed the highest overall acceptance score (8.37) and was significantly different from the CSLF sample (5.47). The higher overall liking of CSLS may be related to the gentle heat transfer mechanism during steaming, which preserves volatile aroma compounds, minimizes moisture loss, and promotes gradual protein denaturation (Liu, 2024). This condition results in better retention of natural fish aroma and produces a moist and tender texture that contributes positively to consumer acceptance. In addition, the aroma and texture scores of CSLS tended to be higher than those of CSLF, indicating that steaming was more effective in maintaining the desirable sensory quality of the fish. Previous studies have also reported that steaming can preserve volatile compounds and maintain water-holding capacity in fish products, thereby improving aroma perception and texture acceptability (Liu *et al.*, 2025).

Meanwhile, the CSLF demonstrated slightly higher scores in appearance and taste attributes, although the differences were not statistically significant. The enhanced appearance of CSLF may be associated with non-enzymatic browning reactions, such as Maillard reactions and caramelization, which generate attractive golden-brown pigmentation during frying (Chen *et al.*, 2025). Furthermore, high-temperature frying promotes the formation of volatile flavor compounds through lipid oxidation and Maillard reactions, leading to a richer flavor profile and stronger taste perception (Chang *et al.*, 2020). However, excessive heat exposure during frying may reduce moisture content and alter the natural sensory characteristics of fish, which could explain the lower overall acceptance score observed in CSLF. These findings indicate that steaming was more effective in preserving favorable sensory characteristics and improving consumer acceptance of CSL in *balado* sauce.

#### Sensory wheels characterization of CSLS and CSLF

Sensory wheel analysis was used to visualize the sensory profile of CSLS and CSLF based on panelists' perceptions across four categories: color, aroma, taste, and texture (Figure 2). This approach provides an overview of the dominant attributes and facilitates comparison between products. Overall, both samples showed a similar general sensory profile, indicating that they belonged to the same product category. However, differences were observed in the relative intensity of several attributes, suggesting that panelists were able to distinguish the products through specific sensory characteristics.

In the color category, CSLS was mainly characterized by cream and brownish yellow, while CSLF showed stronger brownish yellow and light orange attributes. The higher cream intensity in CSLS indicates a brighter and cleaner appearance, whereas CSLF tended to exhibit a darker yellow–orange profile. Visual appearance is one of the earliest quality indicators in seafood products and strongly influences consumer expectations and acceptance (Wang *et al.*, 2023). Therefore, the brighter appearance of CSLS may provide a more favorable visual perception than CSLF.

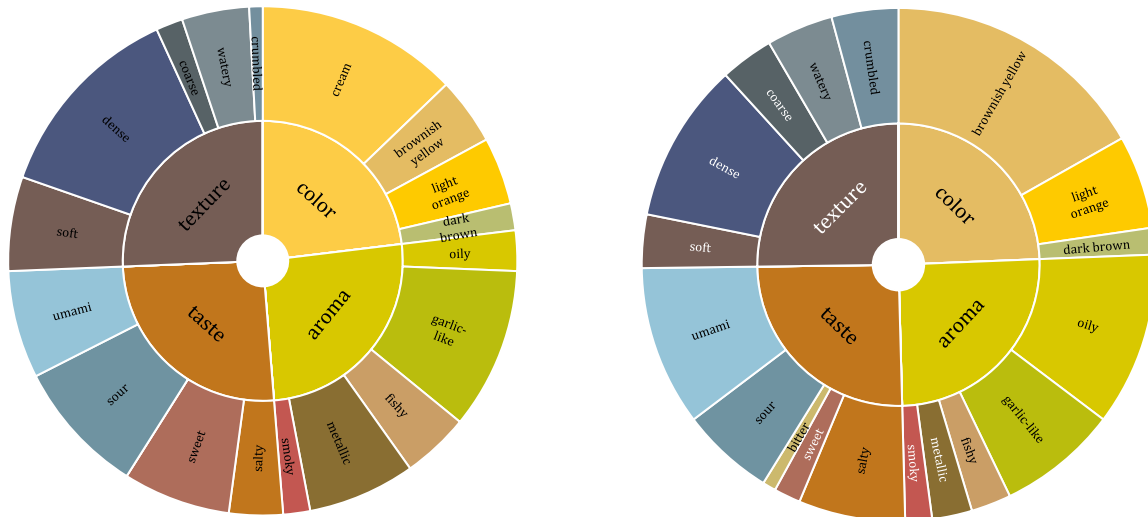


**Figure 2.** Sensory wheels to characterize the sensory profile categories of CSLS (left) and CSLF (right)

For the aroma profile, both products were dominated by garlic-like and oily notes, indicating that seasoning and lipid-derived aroma contributed strongly to the sensory characteristics. Fishy aroma was also detected in both samples but appeared slightly more pronounced in CSLF. In fish-based products, lipid oxidation and volatile compounds contribute significantly to oily and fishy aroma perception, which may affect acceptance depending on intensity (Rani *et al.*, 2023). This suggests that aroma differences between both products were present, although not highly contrasting.

In the taste category, umami and sourness were dominant in both samples, indicating that savory and acidic taste contributed substantially to product flavor. CSLS showed a relatively balanced taste profile, whereas CSLF exhibited stronger taste intensity. Umami is an important contributor to seafood palatability due to naturally occurring glutamate and nucleotides (Wang *et al.*, 2020).

In terms of texture, both samples were mainly described as dense, but secondary differences were evident. CSLS was associated with a softer texture, while CSLF showed stronger coarse and crumbled characteristics. Texture is an important determinant of seafood quality, as consumers generally prefer products with a compact yet tender structure. The softer texture observed in CSLS may therefore contribute positively to acceptance.

Overall, the sensory wheel demonstrated that both products shared a comparable sensory structure, but differed in the intensity of several attributes. CSLS was characterized by cream color, balanced taste, and softer texture, whereas CSLF showed stronger brownish-yellow appearance, oily aroma, and coarser texture. These findings indicate that the main sensory differences were associated with appearance and texture, which may influence consumer perception and acceptance. The sensory wheel therefore provides an initial descriptive overview that supports further interpretation using CATA and consumer liking analysis.

### Check-all-that-apply test

The sensory profile evaluation of CSLS and CSLF using the CATA method consisted of Cochran's Q test, correspondence analysis, principal coordinate analysis, and penalty analysis. The results of Cochran's Q

test (Table 1) showed that among all evaluated attributes, only *cream* ( $p < 0.0001$ ) and *light orange* ( $p = 0.018$ ) were significantly different between CSLS and CSLF at the 5% significance level. These findings indicate that panelists were able to clearly distinguish both products primarily through differences in visual appearance. Visual appearance is recognized as one of the first quality indicators affecting consumer expectations and acceptance, particularly in seafood products where color is closely associated with freshness and processing conditions (Cheng *et al.*, 2015). Differences in cream and light orange coloration may therefore reflect changes occurring during processing, including thermal treatment and pigment development, which were more noticeable than variations in aroma, taste, or texture.

**Table 1.** Cochran's Q test for the sensory attributes of CSLS and CSLF

| Attributes      | <i>p</i> -values |
|-----------------|------------------|
| Dark Gray       | 0.052            |
| Cream           | <0.0001          |
| Brownish Yellow | 0.366            |
| Light Orange    | 0.018            |
| Dark Brown      | 0.074            |
| Oily            | 0.157            |
| Garlic-like     | 0.221            |
| Fishy           | 0.083            |
| Metallic        | 0.132            |
| Salty           | 0.527            |
| Sweet           | 0.157            |
| Bitter          | 0.166            |
| Sour            | 0.467            |
| Umami           | 0.180            |
| Soft            | 0.206            |
| Dense           | 1.000            |
| Coarse          | 0.134            |
| Watery          | 1.000            |
| Crumble         | 0.617            |

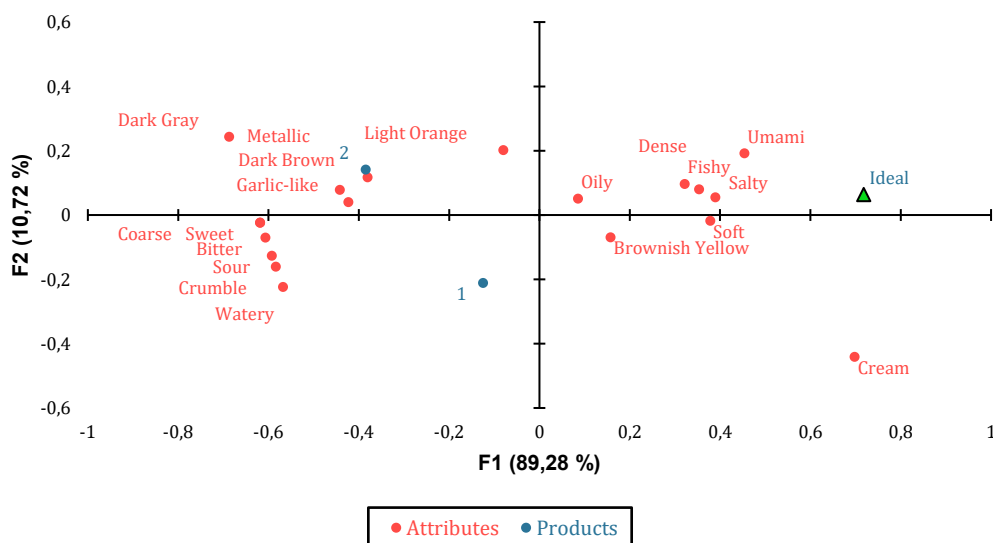


**Figure 3.** Sensory profile representation of CSL using correspondence analysis

Correspondence analysis was used to illustrate the relationship between the ideal product and the tested products through a biplot showing both products and sensory attributes in the same dimensional space (Adawiyah *et al.*, 2019). Based on the analysis (Figure 3), the ideal product was mainly characterized by cream color, umami taste, soft texture, and dense texture. These attributes were positioned close to the ideal point, indicating that panelists considered them as the most desirable sensory characteristics. In contrast, attributes such as dark gray, dark brown, metallic, crumble, and watery were located farther from the ideal point, suggesting that these attributes were less preferred and did not represent the expected ideal product profile.

Based on the correspondence plot, CSLS was positioned in the same quadrant and closer to the ideal product compared with CSLF, indicating that CSLS had sensory characteristics more closely aligned with panelists' expectations of the ideal product. Meanwhile, CSLF was located farther from the ideal point and was associated with less favorable attributes, particularly darker appearance and less desirable textural characteristics. These results indicate that among the tested samples, CSLS was the closest to the ideal sensory profile according to panelists, while CSLF showed lower similarity with the ideal product. This finding is consistent with the CATA and overall liking results, which showed that panelists preferred CSLS over CSLF.

Principal component analysis was conducted to visualize the relationship between sensory attributes and panelists' preference by mapping the liking point together with the evaluated sensory descriptors in the same dimensional space. Based on the analysis (Figure 4), cream color was located closest to the liking point, indicating that this attribute had the strongest positive association with consumer acceptance. This suggests that panelists preferred samples with a lighter cream appearance. In addition to cream color, attributes such as soft texture and watery texture were positioned on the positive side of the first dimension, indicating a relatively close relationship with liking, although their contribution was weaker than cream color.

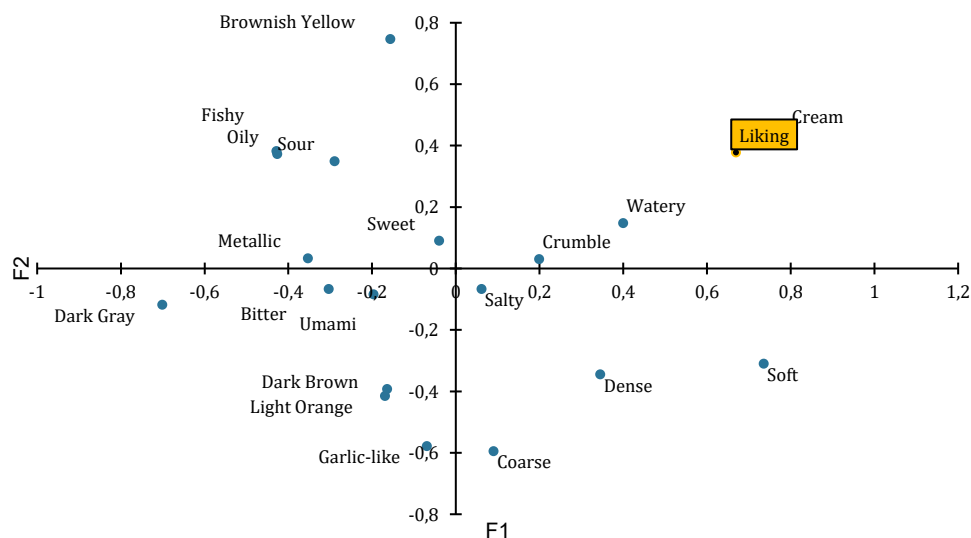


**Figure 4.** Correlation map of CSL sensory attributes and liking using principal component analysis

In contrast, several attributes including dark gray, dark brown, metallic, bitter, garlic-like, and coarse texture were located farther from the liking point, indicating a weaker relationship with consumer preference. These attributes tended to be positioned on the opposite side of the liking vector, suggesting that they were less desirable according to panelists. Similar findings have been reported in sensory studies showing that visual appearance and texture are among the most important factors affecting acceptance of seafood products, while darker color and strong off-flavor characteristics are generally associated with lower consumer preference (Cheng *et al.*, 2015). The present results therefore indicate that panelists tended to prefer products with a brighter appearance and more favorable texture characteristics.

Consumer perception of sensory quality may vary depending on product familiarity, cultural background, and consumption habits. However, visual appearance generally becomes one of the earliest indicators influencing product acceptance before tasting begins (Cheng *et al.*, 2015). In the present study, the positive association between cream color and liking indicates that appearance played an important role in

shaping panelists' preferences. Overall, the principal component analysis confirmed the results of CATA and correspondence analysis, demonstrating that cream color was the sensory attribute most strongly associated with consumer liking, while darker appearance and several less favorable flavor-related attributes tended to reduce acceptance.

Penalty analysis is one of the analytical approaches derived from the CATA method and is used to identify how much the overall liking score may increase or decrease due to deviations between the sensory profile of the tested products and the ideal product perceived by panelists (Adawiyah *et al.*, 2019). This analysis helps determine sensory attributes that potentially contribute positively or negatively to consumer acceptance. This analysis is useful for identifying which attributes should be prioritized during product development because it combines both attribute frequency and the impact of each attribute on liking score. A cut-off value of 20% was used to determine the practical importance of each attribute, where attributes with frequencies above this threshold were considered relevant to panelists' evaluations.

Based on the analysis (Figure 5), cream color was identified as the only must-have attribute. This indicates that cream appearance was considered an important positive sensory characteristic and contributed to higher liking scores when present in the product. This finding is consistent with the sensory wheel, CATA, and correspondence analysis results, which also showed that cream color was strongly associated with panelists' preference and positioned close to the ideal product. The positive relationship between cream color and liking suggests that visual appearance was one of the key sensory factors affecting acceptance.

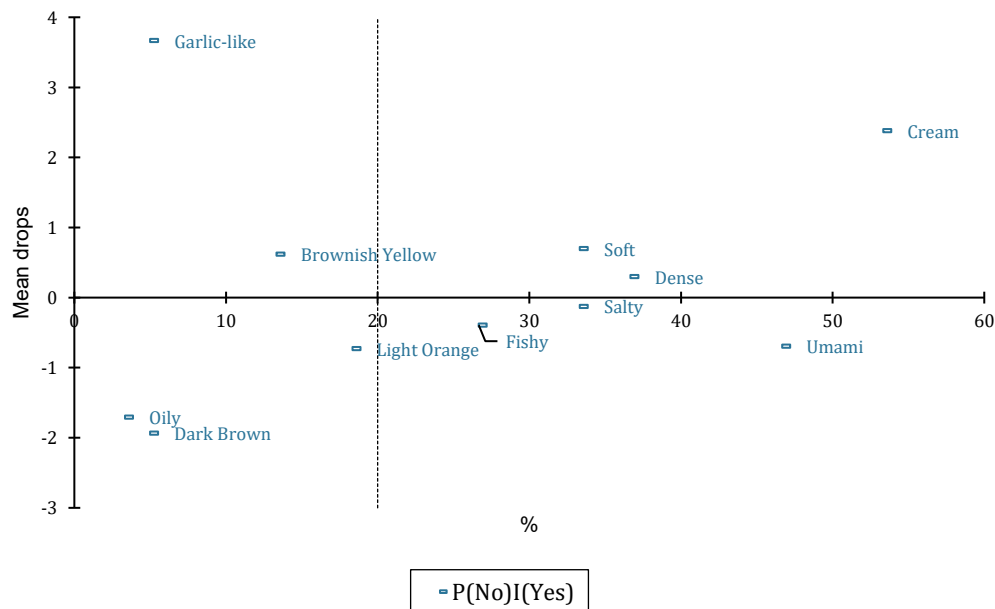


**Figure 5.** Penalty analysis for *must have*, *nice to have*, *dan must not have* in CSL

Several attributes, including fishy, salty, umami, soft, and dense, were categorized as does not influence, indicating that the presence or absence of these attributes did not substantially change panelists' liking scores. Meanwhile, light orange, dark brown, garlic-like, metallic, sweet, bitter, sour, coarse, watery, and crumble were classified as does not harm, suggesting that although these attributes were perceived by panelists, they did not significantly reduce acceptance and may still be tolerated within the sensory profile of the product. No attributes were categorized as nice to have, indicating that no additional attribute showed a clear positive contribution beyond cream color.

In contrast, dark gray was identified as the only must-not-have attribute. This indicates that the presence of dark gray coloration was associated with decreased liking scores and should therefore be avoided in product development. The result suggests that darker appearance was perceived less favorably by panelists and may reduce visual attractiveness. Overall, the penalty analysis confirms that visual appearance was the most influential sensory dimension affecting consumer preference, with cream color positively contributing to acceptance and dark gray appearance negatively affecting liking. These findings indicate that maintaining a

lighter cream appearance while minimizing dark coloration may improve consumer acceptance and support the development of products with sensory characteristics closer to the ideal profile perceived by panelists.

#### 4. Conclusion

Pre-cooking techniques (steaming and frying) applied to canned *Sardinella lemuru* (CSL) in balado sauce did not significantly affect individual sensory attributes, including appearance, taste, aroma, and texture. However, they modulated the overall sensory perception and significantly influenced consumer acceptance of canned *Sardinella lemuru* in balado sauce. Steaming was superior in preserving the natural aroma and providing a tender texture, thereby aligning more closely with the ideal consumer profile. In contrast, frying, despite enhancing appearance and the sweet-salty taste, was less consistent with consumer preferences. Therefore, steaming is recommended as the preferred pre-cooking method for producing CSL in balado sauce to achieve higher consumer acceptance. For industrial applications, it is recommended to optimize the steaming process and implement stricter visual quality control measures to ensure that the product remains aligned with consumer expectations.

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