

*A Kaleidoscope of Colors:  
Exploring the Vibrant Palette of Taiwan's Fermented Food Culture*

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The Kyoto Conference on Arts, Media & Culture 2023  
Official Conference Proceedings

**Abstract**

Numerous countries have launched cultural color surveys to emphasize the significance of intangible cultural assets, focusing on local landscapes and human environments. These surveys aim to establish norms that promote historically grounded research, bolstering the identification and cultural value of distinct colors. However, there remains a limited scope of research on the color aspects of cultural experiences, specifically the role of color in daily food practices, necessitating a more comprehensive exploration of cultural appearances. There is an urgent need for a systematic method that ensures accurate recording and presentation of representative cultural colors. This research project was aimed at being completed within two years. Its objective was to review relevant literature on Taiwanese terroir and fermentation culture, investigate the color memories associated with fermented foods, and establish a comprehensive database of cultural colors. During the study, color deduction data showcasing continuous color changes were collected from the raw materials to the maturation stage of 32 fermented foods. Additionally, spectrum data for these fermented foods was meticulously collected and analyzed. Furthermore, 200 questionnaires were gathered and analyzed to delve into the Taiwanese understanding of color associations related to fermented food's smell, taste, and emotional memory. These collective efforts will ultimately contribute to the comprehensive documentation of the cultural colors intrinsic to Taiwan's terroir-fermented foods.

Keywords: Fermented Food, Color Association, Cultural Colors

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## **Introduction**

Countries worldwide have initiated cultural color surveys of local geographical and cultural landscapes to demonstrate their appreciation for intangible cultural heritage. They have also established corresponding guidelines to encourage the exploration of historical contexts and implied meanings, thereby enhancing the distinctive identity and cultural value of these unique facets. However, most extensive cultural color research primarily focuses on visual design, landscapes, architectural spaces, and historical artifacts. Conversely, color-related research concerning aspects of everyday life, such as clothing, food, housing, and transportation, still needs to be explored and attention to complete the mosaic of cultural life. Furthermore, there is an urgent need to develop systematic methods for acquiring and analyzing color data to enable the precise documentation and presentation of these representative cultural color datasets.

This project spans two years and commences with a review and analysis of literature related to Taiwan's fermentation culture. The objectives include:

- (1) Color measurement of 32 commonly fermented foods in Taiwan entails a detailed record of the color evolution of these fermented foods at various stages, from raw materials to maturity.
- (2) To survey color associations related to the aromas, flavors, and emotional memories of fermented foods among the Taiwanese population.

Finally, the research aims to consolidate the recorded spectral color interpretations of local fermented foods and dietary memory color data to construct a unique Taiwanese fermentation culture color database emblematic of the region's distinctive cultural characteristics.

## **Literature Review**

### ***Fermentation Culture***

In times when agriculture, transportation, and food industries were less developed, preserving food freshness was a vital concern. The concept of preserving food emerged, with fermentation being one method. Fermentation relies on natural bacteria like lactic acid and acetic acid bacteria, yeast, and molds to break down food, creating unique flavors and enhancing nutrients. Different regions have their fermented specialties, such as Korean kimchi, Japanese Natto, or Italian cheese, shaped by local environments and traditions. These foods rotate with the seasons, creating cherished memories and cultural imprints in our hearts.

### ***Color Association***

From the perspective of color psychology, our perception, preferences, and cognition of colors are not solely influenced by the physical and psychological characteristics of colors themselves. They are also affected by the environment we are in and our experiences. These experiences, perceptions, and impressions of specific colors are embedded in our subconscious and can resurface in our minds when triggered. This phenomenon of generating various concepts triggered by color experiences is known as color association.

Essentially, color association involves using current colors to evoke memories of past colors. Colors not only have the power to influence mood and emotions but also guide individuals to associate specific meanings with them (Kauppinen-Räsänen & Luomala, 2010).

In the realm of research concerning the association between scent and color, the cross-modal association between color and olfaction/taste has long been a topic of interest for designers and scholars (Adams & Doucé, 2017; Spence, 2011, 2018, 2020). In terms of color and memory associations, colors are powerful information channels within the human cognitive system, significantly enhancing memory, associations, and memory retrieval (Wichmann et al., 2002).

Kaya and Epps (2004) suggest that while the concept of arousal can encompass physical, psychological, physiological, and emotional awakening, emotional arousal has received more attention in memory research than other types of arousal. If associated with pleasant experiences, it tends to preserve long-term memories better and possesses a higher emotional arousing capacity.

### ***Olfaction, Flavors, and Food Memory***

The sensation of olfaction plays a crucial role in our everyday lives, concurrently influencing our emotions, psychology, and physical well-being (Morrot, 2001). Since the human olfactory system bypasses the thalamus and connects directly to various emotional centers within the brain, emotional responses to odors are notably immediate and swift. Consequently, numerous studies have observed that scents can unconsciously affect individuals, whether eliciting emotional responses (Vernet-Maury et al., 1999) or evoking past contextual memories (Chu & Downes, 2000). Simultaneously, olfaction can potently trigger emotions, serving as an effective means to evoke memories (Krusemark et al., 2003).

Sorokowska et al. (2019) contends that although all senses, including vision, olfaction, taste, or audition, can stimulate event-related memories, olfaction stands out as the swiftest in eliciting emotional responses and tends to leave the most enduring perceptual memories among the five senses.

Numerous studies have also demonstrated that odors can subconsciously influence humans, irrespective of whether they trigger emotional responses (Herz, 1998; Vernet-Maury et al., 1999; Morrot, 2001) or recall past situations (Chu & Downes, 2000). Furthermore, the sensory experience of taste, facilitated by the interaction of olfaction and gustation, is recognized for its strong association with memory. The finding is attributed to the heightened memorability of a particular spatiotemporal context when both olfaction and gustation are engaged. With its distinctive ability, Olfaction can unlock previously forgotten but vivid and emotionally charged memories. This phenomenon is commonly referred to as the Proust effect. Over time, the richness of food experiences becomes a critical factor in enhancing cultural and experiential memory (Montgomery, 2012).

### **Research Methods**

In the first year of this study, we collect data related to Taiwan's local food culture and fermented foods and analyze the literature on cultural colors, aromas, flavors, and emotional memory triggers. Expert consultations guided the explicit collection of 36 datasets of fermented food production. During this year, we collaboratively produced 12 fermented items. We employ a color colorimeter for regular color measurements (Fig.1) capturing the color evolution at various fermentation stages, from raw materials to maturity. Simultaneously, we gathered semantic terms associated with aroma and flavor conveyance to conduct a color

association survey among the Taiwanese population regarding the aromas, flavors, and emotional memories of fermented foods.

In the second year, based on expert recommendations, we focus on adjusting the previously conducted fermented food color questionnaire. (Fig.2) We design a digital color questionnaire app for tablets and perform color calibration using professional color management software (Fig.3). We surveyed 200 participants to explore color associations with fermented food memories. Concurrently, we continue collaborative production and periodic color measurements for the planned 24 fermented items. After classifying and archiving color data, we create a comprehensive color profile for the 36 fermented foods, depicting their color evolution from raw materials to maturity. To establish a distinctive color profile of fermented foods within the context of Taiwan's cultural characteristics, stored in the Taiwan Fermentation Culture Color Database (Fig.4). Finally, we employ CIE Lab color space distribution to analyze the relationships between actual colors, aromas, flavors, and emotionally associated colors of fermented foods over time. The study delves into color perception, associations, and memory theories, facilitating a thorough discussion of the aroma and flavor memory associated with color survey findings and concluding with the research's final insights.



Figure 1: Regularly Conduct color measurements and record them using a color colorimeter

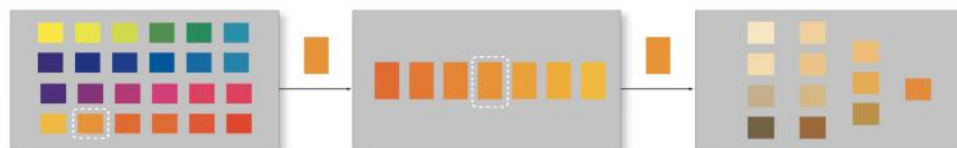


Figure 2: Olfactory and Gustatory Memory Color Association Questionnaire Design



Figure 3: Color Questionnaire APP on iPad

Sample	main ingredient	Color Interpretation Diagram (Precise color will be indicated using the LAB (CIELAB) color space)	Required Maturation Time					
fermented wax gourd	Wax gourd	L*76 a*5 b*54	Approximately 10-14 days	Pickled mustard green	Mustard greens	L*76 a*9 b*66	Approximately 21 days	
	Soybean meal	L*64 a*12 b*24		Salt + soup	L*92 a*9 b*19			
	Salt + soup	L*91 a*8 b*30		Red Yeast Rice (Fuzhou)	Glutinous rice	L*81 a*15 b*68	Approximately 30 days	
Sour Cabbage	Napa cabbage	L*89 a*5 b*24	Red yeast rice	L*27 a*40 b*52				
	Salt + Water + soup	L*96 a*1 b*15	White yeast + Distilled water	L*55 a*71 b*43				
Watermelon pickles	Small watermelon	L*90 a*-7 b*45	Approximately 7 days	Red Yeast Rice (Hakka)	Round glutinous rice	L*67 a*66 b*42	Approximately 10-15 days	
	Salt	L*98 a*-8 b*24		Red yeast rice	L*28 a*46 b*53			
Acid beans	Snake beans + Salt	L*78 a*4 b*52	At least 14 days	Pickled Bamboo Shoots	20% alcohol rice wine + Fine salt	L*54 a*54 b*46		
	Salt	L*92 a*-1 b*44			Bamboo shoots	L*76 a*9 b*66	Approximately 90 days	
Sour Bamboo Shoot	Bamboo shoots	L*93 a*-7 b*40	Approximately 7 days		Soybean koji	L*48 a*18 b*42		
	Salt	L*94 a*1 b*35		Salt + Sugar + Rice wine	L*92 a*10 b*19			
Tofu Cheese (Fermented bean curd)	Air dry Tofu cubes	L*68 a*11 b*39	Approximately 60-90 days	fermented soybeans	Soybeans	L*58 a*39 b*70	Approximately 15 days	
	Rice koji	L*69 a*17 b*41		Salt + soup	L*54 a*11 b*31			
	Sugar + Rice wine + Distilled water	L*72 a*19 b*57		Dried Pickled Mustard Greens	Mustard greens	L*44 a*23 b*43	Approximately 30 days	
		Dried Tangerine Peel	Orange peel	L*69 a*11 b*56	At least 1-2 years			

Figure 4: Fermented Food Color Interpretation Diagram

### Current Research Progress and Findings

As the research is ongoing, let us briefly summarize the findings, focusing on the color associations with smell, taste, and memory of tofu cheese and pickled cabbage.

#### Tofu Cheese

Regarding the smell of tofu cheese, most respondents described it positively, with over 60% finding it "fragrant" and "rich." About half perceived it as having a "fermented aroma," and around one-third mentioned it as "sweet." Some respondents used negative descriptors like "moldy," "foul," "rotten," or "sour." Overall, the positive descriptors "fragrant," "rich," "fermented aroma," and "sweet" covered the perceptions of nearly all respondents, accounting for 95.5% of the total.

Regarding color associations with the smell of "tofu cheese," most respondents associated it with shades of red and yellow. In the red range, seven people mentioned "fragrant," and four mentioned "fermented aroma." In the yellow range, nine people described it as "rich," six associated it with a "fermented aroma," five found it "fragrant," and four perceived it as "sweet." While the selected descriptors showed overall similarity, there were subtle differences between the red and yellow ranges.

Regarding the taste of tofu cheese, about 40% of respondents described it positively, with terms like "sweet," "umami," "rich," and "glutinous." Combining these descriptors accounted for 86.4% of respondents who enjoyed the taste.

While respondents selected different colors, most color icons in the chart are located in the upper-right section of the color wheel, predominantly in shades of red to yellow. Within this region are 19 color icons, representing 86.4% of the respondents who tasted tofu cheese (fig.5-8).

In summary, respondents generally associated the taste of tofu cheese with descriptors like "sweet," "umami," "rich," and "glutinous," and these descriptors corresponded to a range of warm colors, including soft and bright tones as well as saturated and intense shades of red and yellow.

In the tofu cheese memory color space map, the distribution of icons appears more scattered compared to the olfactory and gustatory aspects. It can be broadly categorized into three main areas: the red-tone area, the yellow-tone area, and the other-tone area. Most colors in this space are vivid colors situated closer to high saturation and high brightness on the color wheel.

Although slight differences exist in the spatial distribution of colors, the general direction of respondents' descriptions aligns. They frequently mentioned favorable terms related to the sensory experience of tasting dishes, such as "appetizing," "stimulating appetite," "complements rice," "sweet," "aftertaste," "delicious," and "fragrant aroma." From this, we can infer that tofu cheese, with its distinctive flavor and aroma, stimulates the taste buds of respondents and leaves a lasting impression. Saturated orange-red tones and soft, bright yellow tones in the color space primarily represent the sensory memories associated with this. Based on the above findings, the following conclusions can be drawn:

- (1) **Smell Associations:** When it came to the smell of tofu cheese, participants described it as "fragrant," "intense," and "fermented." These smell associations were predominantly positive, indicating that the aroma of tofu cheese evoked pleasant memories.
- (2) **Taste Associations:** Respondents associated tofu cheese with flavors such as "sweet," "savory," "rich," and "glutinous." These taste perceptions were often linked with positive emotions and experiences.
- (3) **Memory-Color Associations:** The color associations related to the taste, smell, and memory of tofu cheese tended to be in the warm color spectrum, including shades of red and yellow. These colors were associated with terms like "appetizing," "aromatic," and "stimulating."






Ingredients	Production Method			Completion
				
Air dry Tofu cubes, Rice koji, Sugar, Rice wine, Distilled water	Air dry Tofu cubes are blanched in boiling water, drained, and set aside. Mix rice wine, sugar, and water evenly for later use.	Using chopsticks, place tofu embryos in a glass jar, arranging them in a single layer with a spoonful of rice bean paste between each layer. Pour the sugar and wine mixture in two separate pours.	After spraying the lid with alcohol, seal the jar and store for two weeks to one month before consuming.	In summer, it takes about 2 months, and in winter, 3 months to complete. After storing for one year, the color deepens, resulting in aged tofu.

Figure 5: The Production Method of Tofu Cheese (Fermented bean curd)

The study indicates that taste, smell, and memory associations with tofu cheese are primarily positive and often linked with warm and vibrant colors, reflecting this food item's sensory and emotional aspects.



Figure 6: Olfactory, Gustatory, Memory Color Association of Tofu Cheese



## Pickled Cabbage

According to the data, six individuals (2.67% of the respondents) chose "pickled cabbage" as their favorite fermented food. The participants' descriptions of the smell of pickled cabbage can be categorized into positive, neutral, and negative. Among the positive descriptions, Most participants described the smell of pickled cabbage as 'sour' and 'sweet and sour.' Half of them also mentioned 'fragrant' and 'fresh.' Therefore, among those who chose pickled cabbage as their favorite fermented food, all of them found the 'sour' flavor to be the most prominent, followed by 'sweet and sour,' and then 'fragrant' and 'fresh' flavors.






Ingredients	Production Method			Completion
				
Napa Cabbage, Salt, Water	Water Soak and rinse quickly	then drain Apply salt to the cut surfaces (2% of cabbage weight)	Cover with a lid and place in a cool, room-temperature area	The fermentation process takes a total of ten days to complete.

Figure 7: The Production Method of Pickled Cabbage

Regarding the association of colors with the smell of pickled cabbage, two respondents chose [Light Yellowish Green (lt yG,125)], followed by [Light Grayish Purple (ltg pR,2)], [Orange Yellow (lt rY,77)], [Deep Yellowish Green (dp YG,119)], and [Pink Yellowish Green (p yG,121)], each chosen by one respondent. From the color space diagram above, we can observe that most icons are located in the yellow to yellowish green area, slightly towards the lower right side of the color wheel. The predominant color in this area is a bright and soft shade of yellowish green.



Figure 8: Olfactory, Gustatory, Memory Color Association of Pickled Cabbage

In conclusion, based on the respondents' descriptions of the smell of pickled cabbage, it can be inferred that there is a specific relationship between the descriptors "sour, sweet and sour, fresh, fragrant" and the bright and soft shades of yellow to yellowish green.

Regarding the taste of pickled cabbage, in positive descriptions, four respondents (66.7%) thought it was sour, and four respondents (66.7%) thought it was sweet and sour. Additionally, three respondents (50%) found it to be delicious, two respondents (33.3%) found it to have a sweet aftertaste, two respondents (33.3%) found it to be salty, and two respondents (33.3%) found it to be mellow. Finally, one respondent (16.7%) thought it was sweet, refreshing, sticky, sour, spicy, salty and fresh. Based on the above information, more

than 60% of the respondents believed that the taste of pickled cabbage is "sour" and "sweet and sour." Half of the respondents found it delicious, with a sweet aftertaste.

Firstly, regarding the olfactory (smell) color associations with pickled cabbage, most respondents perceived it as a smell of "sourness, sweet and sour," and associated it with bright and soft yellow to yellow-green hues.

Moving on to the taste color associations with pickled cabbage, respondents generally described its taste as "sour, sweet, and sour." They associated it primarily with orange-yellow tones, followed by yellow-green hues.

Lastly, in terms of the memory color associations with pickled cabbage, respondents had the strongest impression of "pickled cabbage and pork hot pot," mentioning words such as "sour and fragrant, fresh and sweet, appetizing, warm." The corresponding color associations were mainly in the range of orange-yellow to orange-red hues.

In conclusion, respondents tended to associate pickled cabbage with "sourness, sweet and sour, sour fragrance" regarding smell, taste, and memory. However, the color associations with smell leaned more towards yellow-green tones than taste associations. We found that memory associations were influenced by personal recollections, leading to a preference for orange-yellow to orange-red hues.

Regarding the association of colors with the taste of pickled cabbage, respondents chose [Light Purple-Red (lt pR,5)], [Light Orange (lt O,53)], [Bright Orange (b O,57)], [Orange Yellow (lt rY,77)], [Light Yellowish Green (lt yG,125)], and [Light Blueish Green (lt bG,149)]. From the chart above, we can observe that most color icons are distributed on the right side of the color wheel, predominating orange-yellow and yellow-green hues. Based on the above findings, the following conclusions can be drawn:

- (1) **Smell Associations:** Most respondents associated the smell of pickled cabbage with bright and soft yellow to yellow-green hues. Specific color choices included Light Yellowish Green, Light Grayish Purple, Orange Yellow, Deep Yellowish Green, and Pink yellowish Green.
- (2) **Taste Associations:** Respondents primarily associated the taste of pickled cabbage with orange-yellow tones, followed by yellow-green hues. Color choices included Light Purple-Red, Light Orange, Bright Orange, Orange Yellow, Light Yellowish Green, and Light Blueish Green.
- (3) **Memory-Color Associations:** Respondents associated pickled cabbage with the mnemonic color associations of "pickled cabbage and pork hot pot." They described it as "sour and fragrant, fresh and sweet, appetizing, warm." The corresponding color associations were mainly in the range of orange-yellow to orange-red hues.

## Discussion and Conclusion

This study surveyed the taste, smell, and mnemonic color associations of fermented foods that respondents liked or consumed frequently. A total of 245 respondents were interviewed, and after excluding 20 invalid questionnaires, data from 225 respondents were collected.

Based on the collected information, the top ten most frequently consumed or preferred fermented foods by the respondents were stinky tofu (26.2%), miso (19.1%), fermented bean



curd (9.7%), soy sauce (6.6%), dried radish (6.6%), followed by doubanjiang (3.5%), plum vinegar (3.5%), red yeast rice (2.6%), cucumber (2.6%), and pickled cabbage (2.6%).

During the study, we found that the respondents' mnemonic color associations were greatly influenced by sensory stimulation. As a result, the color space maps of smell, taste, and memory often exhibited similar distribution patterns. However, compared to taste and smell, mnemonic color associations usually had higher lightness and chroma levels. For example, the above image shows the smell, taste, and memory color space maps of stinky tofu. From the horizontally juxtaposed charts, we can observe that the smell and taste color markers of stinky tofu are evenly distributed on the inner and outer sides of the color wheel, leaning towards orange-yellow tones overall. On the other hand, the memory color markers are noticeably closer to the color wheel, indicating a preference for vibrant and bright reddish-orange tones.

We can also infer that the more concentrated the distribution of color markers is, the more consistent the respondents' mnemonic color associations are with the item. There is also a higher correlation between specific taste, smell, and memory descriptions. It is worth noting that even if there is a connection between taste, smell, memory descriptions, and specific colors, that color cannot universally represent that particular sensation. For example, both miso and soy sauce have a description of "fragrant," but their color markers are distributed in different positions. Therefore, the collected color impressions in this study only apply to fermented foods related to them.

In addition, the items that respondents or their family members have made before were most commonly dried radish, fermented bean curd, and pickled small eggplant. The items that respondents liked or consumed most frequently were stinky tofu, miso, and fermented bean curd. The survey results for these two categories of items were significantly different. This difference is due to the flourishing development of the modern food manufacturing industry and the wide variety of fermented products available. Nowadays, people can easily purchase stable, transportable, and preservable ready-made fermented products in supermarkets or stores. Therefore, homemade fermented foods are different from the most popular fermented foods. Based on the above, whether the convenience of obtaining fermented foods and the decrease in people's participation in making fermented foods will affect the taste, smell, and mnemonic color associations of fermented foods remains to be observed.

At the same time, this study was concentrated in northern Taiwan. Although Taiwan is small and densely populated, there may still be regional differences in culture and customs. We suggest that future researchers visit various regions and explore the Hakka areas where fermentation culture thrives to obtain more comprehensive research information.

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