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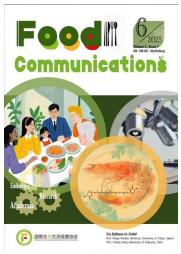

Review

Music Aesthetics and Food Education: A Scoping Review of Interdisciplinary Connections

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ABSTRACT

Based on the multi-sensory integration theory, the regulatory mechanism of music aesthetics parameters on eating behavior and their application value in food education were clarified through the interdisciplinary research methods of food physics, acoustic engineering, and cognitive psychology. The sound wave vibrations at specific frequencies can change the activity of salivary amylase, and there is a significant correlation between music rhythm and food texture perception. A "sound-taste-touch" synergistic intervention model is proposed, providing a theoretical basis for the development of intelligent food education systems.

Food sensory science aims to evaluate and analyze various characteristics of food through human senses, and it is much more important in the field of food science. Currently, the ISO11036 Texture Analysis Standard (ISO 11036, 2020) globally provides a unified method and specification for the quantitative research of food texture. Texture is an important attribute of food, including aspects such as hardness, viscosity, and elasticity, which directly affect taste experience and acceptance of food for the consumers. The ASTM E1879 Sensory Evaluation Standard (ASTM E1879, 2022) covers multiple sensory dimensions such as vision, smell, taste, and touch from a broader perspective, providing a scientific process and index system for comprehensively evaluating food sensory quality. For example, when conducting a sensory evaluation of a new food product, according to these standards, evaluators can carefully score and describe its color, aroma, taste, and texture, providing data support for product research and development and improvement.

Music acoustic parameters are the key elements for understanding music aesthetics. The fundamental frequency (20-4000 Hz) determines the pitch of music, and different pitch combinations form a rich variety of melodies. The rhythm pace (60-140 BPM) gives music the rhythm and dynamics. Fast-paced music usually stimulates vitality, while slow-paced music brings relaxation and tranquility (Wang, 2018). The harmonic structure refers to a series of overtones above the fundamental frequency, which together shape the timbre of music, giving different musical instruments or voices unique sound characteristics. For example, the harmonic structure of the violin makes its timbre bright and melodious, while the cello has a deep and mellow timbre due to its unique harmonics. The changes and combinations of these music

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acoustic parameters can trigger different emotional resonances and psychological reactions in people.

The development of the neuro-cognitive mechanism (Spence, 2021) provides a theoretical basis for interdisciplinary multi-sensory evaluation. Studies via functional magnetic resonance imaging (fMRI) show that the prefrontal cortex plays a core role in multimodal integration (Blood, 2001). When people receive multiple sensory information from hearing (music), taste, touch, etc. simultaneously, the prefrontal cortex is responsible for integrating and processing this information, thus forming a comprehensive perception of food and the eating environment. For example, when enjoying delicious food, the rhythm and melody of the background music interact with the taste and texture of the food. Through the integration of the prefrontal cortex, it affects overall experience and evaluation of the food to the people who are eating (Spence, 2011). This multimodal integration mechanism provides an important neurobiological basis for exploring the synergistic relationship between music aesthetics and food education.

I. The Formation of Inter-discipline in Food Science

With the rapid development of new technologies in various fields, the food research field has faced unprecedented opportunities for interdisciplinary development. Firstly, the interaction between sound waves and food physical properties has been applied in the food research and development field. Sound waves show unique application potential in the food processing field, especially in their impact on protein conformation. Ultrasonic-assisted processing technology uses the high-frequency vibration of ultrasonic waves to break the interactions between protein molecules, thereby changing their conformation. Research results show that under appropriate ultrasonic conditions, the secondary and tertiary structures of proteins change, affecting their functional properties such as solubility, emulsification, and gelation (Sneh, et al., 2022; Zheng, et al., 2024). For example, when preparing soy-protein-based foods, ultrasonic treatment can improve the solubility of soy protein and enhance the texture and taste of the product. The research on the interaction between sound waves and food physical properties provides new ideas and methods for the innovation of food processing technology.

Secondly, the development of the electronic tongue/nose and sound-vibration coupling detection system provides a reliable technical means for studying food flavors. Electronic tongues and noses are new detection technologies that simulate human taste and smell, capable of quickly and accurately analyzing the chemical composition and flavor characteristics of food (Ming, 2024). Combining the electronic tongue/nose with the sound-vibration coupling detection system enables a more comprehensive and in-depth analysis of food. When food is subjected to sound wave vibrations, its internal chemical composition and structure change, which is reflected in the flavor and taste of the food. Through the electronic tongue/nose and sound-vibration coupling detection system, these changes can be monitored in real-time, providing more accurate data support for studying the impact of music on food quality. For example, when studying the impact of music on the quality of wine, this system can simultaneously detect the changes in the chemical composition and flavor characteristics of wine under the action of sound waves, thus help deeply understand the mechanism of the impact of music on the wine aging process.

In addition, the sound field modeling plus virtual reality (VR) dining environments also provides new opportunities for modern food education (Xie et al., 2017; Xie et al., 2021; Lu, 2024). VR technology makes it possible to create immersive dining experiences, and sound field modeling technology is the key to achieving this experience. Through precise sound field modeling, various real-life sound scenes can be simulated in the VR dining environment, such as the background music in a restaurant, the clinking of tableware, and conversations of human beings. These sounds, combined with the visual elements in the virtual environment, can greatly enhance the sense of immersion and reality for the users. For example, in a VR scene simulating an outdoor picnic, by playing natural sound effects such as bird songs, wind sounds, and the rustling of leaves, users can more vividly experience the atmosphere of the picnic, thereby affecting their perception and evaluation of food. This sound field modeling technology for VR dining environments provides a new platform and means for food education and food marketing.

II. The Scientific Impact of Music Parameters on Eating Behavior

The impact of music parameters on eating behavior is widely known (North, 1996), scientific research on this phenomenon has been new hot-point. Current research shows the follows.

(I) The Regulation of Sound Wave Vibrations on Food Physical Properties

Numerous experimental studies have shown that sound wave frequency has a significant impact on food physical properties. Under the action of low-frequency sound waves, the melting temperature of chocolate decreases (Chen, 2020). This is because the vibrations of low-frequency sound waves can intensify the molecular movement inside chocolate, weakening the intermolecular forces and thus reducing the melting point of chocolate. This phenomenon has great value in food processing and storage. For example, the processing technology of chocolate can be adjusted by controlling the sound wave frequency, allowing it to be molded and packaged under milder conditions. High-frequency sound waves, on the other hand, can increase the breaking force of crispy foods. The action of high-frequency sound waves makes the internal microstructure of crispy foods more compact, enhancing the

mechanical strength of the food and thus increasing its breaking force. This is of great significance for maintaining the taste and quality stability of crispy foods. In food production, high-frequency sound waves can be used to optimize the production process of crispy foods and extend their shelf life.

The resonance phenomenon also has unique applications in the food field. Taking wine decanting as an example, by optimizing the sound field and using appropriate sound waves, the polymerization of tannins can be accelerated. Tannins in wine are important components that affect its taste and quality (Li, et al., 2005). Appropriate tannin polymerization can make the taste of wine more mellow and smooth. Under the action of sound waves, the tannin molecules in wine resonate, increasing the frequency of molecular collisions and thus accelerating the tannin polymerization reaction. This method of optimizing the wine decanting process using the resonance phenomenon can not only improve the quality of wine but also shorten the decanting time, bringing convenience to wine consumption and tasting.

(II) The Intervention of Music Elements in Sensory Evaluation

In the rhythm synchronization double-blind controlled experiment, researchers found that music rhythm has a significant impact on the eating behavior and sensory evaluation of subjects. Fast-paced music increases the eating speed of the tested subjects. Fast-paced music can stimulate the physiological reactions of human beings, accelerating the heart rate and breathing frequency, causing people to unconsciously eat faster. Slow-paced music, on the other hand, enhances the perception of flavor complexity. Slow-paced music creates a relaxed and soothing atmosphere, allowing subjects to focus more on savoring the flavor of food, thus enhancing the perception of flavor complexity (Xu et al., 2021). These experimental results show that music rhythm can be used as an effective means of regulating emotions (Liu, 2019), thereby regulating eating behavior and sensory experiences of the people (Zellner, et al., 2015).

On the other hand, there is an interesting mapping relationship between the harmonic structure of music and taste. Researchers have found that major chords can enhance the sensitivity to sweetness (Crisinel, 2011). The harmonious and bright timbre characteristics of major chords are consistent with the pleasant and sweet feeling brought by sweetness, thus psychologically enhancing the sensitivity to sweetness (Reinoso, 2015). Dissonant intervals, however, increase the bitterness threshold. The tense and unstable feeling brought by dissonant intervals distracts the attention from bitterness to a certain extent, thus increasing the bitterness threshold. This mapping relationship between the harmonic structure and taste provides new ideas for food flavor design and matching. For example, foods with unique flavors can be developed according to the harmonic characteristics of music.

III. The Application of Engineering Technology in Music-based Food Education

Understanding the positive impact of music on food education, relevant engineering technologies have been well-applied in the food field.

(I) Acoustic Regulation in Food Processing

Sound waves at specific frequencies can promote the metabolic activity of yeast (Aggiro, et al., 2012), which provides a theoretical basis for the application of music fermentation technology. Researchers reported that the sonic vibrations of music can stimulate the physiological activities of yeast cells, promote their respiration and fermentation processes, thus generating more carbon dioxide gas and causing the bread to expand in volume (Wang, 2020). It is conceivable that in the future, playing the sound waves of Beethoven's "Pastoral Symphony" during the bread-making process may not only increase the volume of the bread, but also add an artistic atmosphere to the bread processing, improving production efficiency and the added value of products.

Currently, frozen foods are widely accepted. The thawing process of frozen foods is an important part of food processing. Traditional thawing methods often have problems such as long thawing times and severe juice loss. The development of sound-field-assisted thawing equipment provides a new way to solve these problems. Researchers found that under - 40°C freezing conditions, after applying a magnetic field, the time for the sample to pass through the maximum ice-crystal formation zone and the total weight loss are significantly reduced, with the optimal values were reduced by 15.3% and 13.1% respectively compared to the control group (Leng, 2023). The application of this sound-field-assisted thawing equipment can not only improve the quality of frozen foods but also save energy and reduce resource waste in the food processing process.

(II) Intelligent Tableware System Design

The sound-vibration-feedback chopsticks are an innovative intelligent tableware that produces corresponding musical scales based on the gripping force. When a user holds the chopsticks, the sensors inside the chopsticks generate sound wave vibrations of different frequencies according to the change in the gripping force, thus emitting corresponding musical scales. This design can assist in controlling the eating rhythm. For example, when the user eats too fast, the sound emitted by the chopsticks becomes rapid, reminding the user to slow down. This technology has been patented (Bi, 2021), providing an interesting tool for cultivating healthy eating habits.

The bone-conduction dinner plate guides the number of chewing times by playing specific-frequency vibrations. The vibration device inside the dinner plate can generate vibrations of specific frequencies, which are transmitted to the human

auditory system through bone conduction (Zhou et al., 2022). Different frequency vibrations can correspond to different chewing rhythms. For example, lower-frequency vibrations can guide the user to chew slowly and thoroughly, while higher-frequency vibrations can remind the user to speed up the chewing. The design of this bone-conduction dinner plate helps to improve the digestion and absorption efficiency of food and promote physical health.

(III) Virtual Reality Food Education Platform

In the VR food education platform, the soundscape-taste synesthesia training module uses the synesthesia relationship between sound and taste to strengthen the perception of food flavors for people (Reinoso, et al., 2022). For example, the sweet and fresh taste of vegetables is enhanced by the timbre of the harp. The soft and crisp timbre of the harp has a certain psychological connection with the sweet and fresh taste of vegetables. By presenting the timbre of the harp and the visual image of vegetables simultaneously in the virtual reality environment, users can more deeply feel the sweet and fresh taste of vegetables when tasting them. This synesthesia training module can help people develop a keen perception of various food flavors, improving the quality and enjoyment of eating.

The music-dynamic recipe generation algorithm based on personal heart-rate variability matching personalized meal-accompanying music is another important innovation of the virtual reality food education platform. The heart-rate variability of each one reflects the changes in their physiological and psychological states. By monitoring the heart-rate variability, the algorithm can match the most suitable meal- accompanying music for the user according to their real-time state. For example, when the user is in a tense state, the algorithm can recommend soothing music to help the user relax and better enjoy the food, while when the user in an excited state, the algorithm can recommend fast-paced music to enhance the dining pleasure. This personalized music-dynamic recipe generation algorithm provides a more customized food education experience for users.

IV. The Practical Paths of Music Aesthetics in Food Education

(I) Correcting Eating Behaviors of Children

The picky eating behavior of children is a great problem faced by many parents. Music rhythm can be used as an effective intervention method. Research has found that playing lively rhythms can reduce rejection rate of vegetables of the children (Li et al., 2020; Chen et al., 2021). Lively rhythms can attract their attention and change their attitude towards vegetables. When eating vegetables, children are more likely to accept the taste and texture of vegetables when following the rhythm of the music. This music -rhythm intervention method can not only help children develop good eating habits but also increase their interest and enthusiasm for food through the fun of music.

Through harmony training, children's taste discrimination ability can be effectively improved. Harmony training can cultivate children's sensitivity and perception of sounds, and the improvement of this perception ability can also be transferred to the taste field (Hetherington, 2018). For example, give chance to the children to participate in chorus activities to learn to distinguish different harmony combinations, and then guide them to distinguish the tastes of different foods during meals. After a period of training, their ability to distinguish food tastes will be significantly improved, allowing them to better enjoy the unique flavors of various foods.

(II) Diet Management for Special Populations

Patients with disease of Alzheimer often suffer from cognitive and memory impairments, affecting their normal eating behavior. The music-memory-awakening eating system uses the awakening effect of music on memory to help patients regain their interest in and memory of food (Chen et al., 2014; Särkämö, et al. 2008). By playing music familiar to the patients, it can evoke their memories of past wonderful dining times, thus increasing their enthusiasm for eating. For example, playing songs they preferred when they were young for the patients, with the accompaniment of music, patients are more likely to accept food and complete the eating process better. This music-memory-awakening eating system provides a new way to improve the quality of life of Alzheimer patients.

The research result of the subconscious association between pitch and taste attributes (Crisinel, 2010) is applied to diabetes diet education to innovate the pitch- glycemic index association teaching method. Different foods have different glycemic indexes. By associating the glycemic index of foods with the pitch of music, diabetic patients can better understand and remember the characteristics of foods. For example, high-glycemic-index foods are associated with high-pitched music, and low-glycemic -index foods are associated with low-pitched music. In this way, when patients hear music of different pitches, they can associate it with the corresponding glycemic index of foods, enabling them to choose foods more scientifically and control their blood sugar levels.

(III) Future Foods and Sustainable Development

With the increasing attention to sustainable development, artificial meat, as a new source of protein, has gradually known to people. However, many people have a sense of rejection towards artificial meat, believing that its taste and texture are not as good as traditional meat. Through environmental soundscape design, the rejection of artificial meat can be effectively reduced. For example, when eating artificial meat, playing sounds related to the natural environment, such as bird songs and the sound of flowing water, can create a natural and healthy atmosphere, making people more psychologically accepting of the taste and texture of artificial meat. This

environmental soundscape design provides a new marketing and educational means for the promotion of future foods, especially sustainable diets.

On the other hand, food waste is a serious problem of our society. Developing a food-waste early-warning sound-effect system can effectively reduce food waste. This system monitors the remaining amount of food through sensors. When the remaining amount of food exceeds a certain threshold, the system will emit specific sound effects to remind people to save food. For example, when there is a large amount of food left on the plate, the system will emit a gentle reminder sound to remind the user to try to finish the food. When the remaining amount of food reaches the level of waste, the system will emit a more intense alarm sound. This food-waste early-warning sound-effect system can cultivate awareness of conservation and promote the formation of a sustainable diet culture.

V. Conclusions and Prospects

In this study, through an interdisciplinary approach, the synergy mechanism between music aesthetics and food education were deeply explored, suggesting that music aesthetics can influence eating behavior through dual paths of physical vibration and neural regulation, providing a new dimension for food engineering technology innovation. In terms of physical vibration, acoustic wave frequencies, resonances, etc., affect food physical properties such as melting temperature and breaking force. In terms of neural regulation, the rhythm, harmonic structure, etc., of music are closely related to sensory evaluation, thus influencing the eating behavior and perception of food.

Future research is further needed in several aspects. Firstly, it is necessary to deeply clarify the interaction mechanism between sound waves and food components. Although some phenomena have been observed, further research is still required on its molecular mechanisms and chemical reaction processes. Secondly, establish a cross-modal database to integrate music acoustic parameters, food physical property parameters, sensory evaluation data, and neurocognitive data, etc., to provide comprehensive data support for subsequent research. At the same time, with the continuous development of technology, attention should be paid to technological ethics issues. For example, in the application of smart tableware and virtual reality food education platforms, how to ensure user privacy and data security, as well as how to avoid excessive interference of technology on users.

In terms of practical applications, it is recommended to incorporate music intervention into the national food education system. Through policy guidance, promote the concept and methods of integrating music aesthetics and food education to various levels such as schools, families, and communities, to cultivate healthy eating concepts and habits. In addition, based on the results of this research, develop the third-generation intelligent kitchen system, integrating technologies such as music regulation, smart tableware, and virtual reality into kitchen equipment to provide users with a more intelligent and personalized cooking and dining experience.

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