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ABSTRACTING & INDEXING

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The Association Between Social Media Addiction, Eating Attitudes, and Life Satisfaction in Adolescents

Aliye Özenoğlu[1,*]

[1] *Ondokuz Mayıs University, Faculty of Health Sciences, Department of Nutrition and Dietetics, 55139, Samsun, Turkiye*

Abstract

In today's increasingly digitalized world, social media have become indispensable to daily life, providing easy access to vast information. However, concerns arise about uncontrolled and unconscious use of social media, especially among younger generations. Social media, which adolescents turn to meet their various psychosocial needs, such as emotions, thoughts, and experiences, are believed to influence their food choices, nutritional habits, exercise routines, sleep patterns, and, ultimately, their overall health. Specifically, nutritional habits of teenagers are affected by a broad range of psychosocial and environmental factors. Since adolescence attributes an increased importance to physical appearance, the ideal body image portrayed on social media enhances teenagers' vulnerability to body dissatisfaction. It makes them prone to developing eating disorders. Available research indicates that social media addiction is associated with an increase in eating disorders and a decrease in life satisfaction, which, in turn, can result in deteriorating social relationships, social withdrawal, and an inability to take adequate responsibility for one's health and nutrition, thus further perpetuating social media addiction. In this context, educational interventions aimed at families', children's, and adolescents' awareness about conscious social media use could be crucial steps to improve public health and safeguard the well-being of future generations.

Keywords: Adolescents, Social Media Addiction, Eating Attitudes, Life Satisfaction.

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1. Introduction

Social interaction is an inherent need of human nature. Throughout history, different methods have been used to fulfill this necessity. The advent of the internet and the new digital era gave rise to social media, where communication has undergone significant changes. Initially used to obtain information, the internet has evolved into a platform employed for various purposes, leading to a continuous increase in the number of users. According to a recent estimate by the Turkish Statistical Institute (TÜİK), the percentage of households with internet access in 2023 amounted to 95.5%, while internet usage among individuals aged 16-74 increased from 85.0% in 2022 to 87.1% in 2023. The same report demonstrated that the rate of internet usage in 2023 was 90.9% for males and 83.3% for females (TÜİK, 2023). Today, the internet and social media, as products of rapidly advancing communication technologies, have become an indispensable part of our daily lives. The increased use of social media applications—including but not limited to TikTok, WhatsApp, Twitter, Facebook, YouTube, Netflix, and Instagram—has led to a rise in social media addiction, especially among adolescents (Aktan, 2018). For obvious reasons, this situation has raised concerns in various segments of society, particularly among parents.

As a critical period characterized by rapid biopsychosocial changes, adolescence is crucial for the development of healthy lifestyle behaviors. Striving to adapt to these rapid changes, adolescents frequently share their emotions, thoughts, and experiences with other users through social media platforms. While, when used appropriately, social media can provide various benefits, their improper use can lead to numerous negative consequences. Among scholars, there is a broad consensus that social media, which adolescents turn to in order to meet various psychosocial needs, exert a strong impact on their food choices, nutritional habits, exercise routines, sleep patterns, and ultimately, their overall health (Pedrouzo & Krynski, 2023; Boniel-Nissim et al., 2023).

* Corresponding Author: Aliye Özenoğlu
Email: aozenoglu@yahoo.com
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Concurrently, adolescents are considered to be a vulnerable group that is prone to developing problematic social media use or social media addiction. Specifically, available evidence suggests that internet addiction in adolescents can lead to reduced exercise levels, problems in interpersonal relationships, disruptions in nutritional and sleep patterns, various psychological imbalances, as well as various health issues (Korkmaz et al., 2023; Özmen & Kocakaya, 2024).

Reflecting the realities of the new digital era, the list of previously known behavioral addictions was complemented by Internet addiction (IA) and social media addiction (SMA). Both IA and SMA exhibit characteristics of common symptoms associated with substance addiction (e.g., salivation, mood changes, desensitization, withdrawal symptoms, conflict, and relapse) after a period of absence from the internet or social media (Derevensky et al., 2019). With the rapid increase in internet usage, IA and SMA rates have dramatically increased worldwide. Already in 2015, the World Health Organization (WHO, 2015) identified IA as a significant public health issue affecting a large number of people. Adolescence is broadly understood as a transitional period from childhood to adulthood, during which new attitudes and behaviors are formed, particularly in health and nutrition. This life phase is characterized by rapid physical, psychological, metabolic, and social changes (Heslin & McNulty, 2023). Since growth and development continue during this period, a crucial aspect is meeting energy and nutrient requirements (Carroll et al., 2024; Neri et al., 2024). Psychosocial and environmental factors play a critical role in adolescents' food choices (Davison et al., 2023; Smith et al., 2023; Erkul and Özenoğlu, 2023). Another important aspect is that, during adolescence, the ideal body image promoted by social media heightens the importance of physical appearance. This emphasis makes adolescents vulnerable to body dissatisfaction and teenagers, who are already trying to adapt to various changes, may develop body image disturbances. These disturbances can compel teenagers to restrict food intake or engage in excessive exercise to control their bodies. Overall, the portrayal of the perfect body on social media creates a fertile ground for the development of eating disorders in vulnerable individuals (Jarman et al., 2023; Mahon & Hevey, 2023).

From a broader perspective, depicting women as thin and attractive, and men as muscular in the media can generate in individuals negative perceptions of their own bodies and cause changes in eating attitudes and food choices (Gül & Yılmaz Akyüz, 2019). Affected by fashion trends, vulnerable individuals engage in diets and exercise to appear slimmer, and even make what are termed aesthetic adjustments to their bodies to improve their appearance. Users regularly exposed to ideal bodies on social media are more affected by these trends and may begin to dislike or feel dissatisfied with their own bodies. Conversely, social media content that focuses on recipes, healthy eating, and healthy living can lead to stress and unhealthy eating behaviors in sensitive individuals. It is well known that, in today's stressful living conditions, the interest in food, particularly hedonistic eating for pleasure, has increased as a result of social media posts. Via advertising on television and social media, food businesses have made food more desirable and consumable (Kılıçlar et al., 2021). This phenomenon can be explained through neuromarketing, which affects people's perceptions, attitudes, and behaviors towards food, ultimately affecting their nutritional status and health.

Life satisfaction is generally defined as an individual's evaluation of their life based on a set of criteria (Diener & Lucas, 1999; Pavot & Diener, 1993). Young individuals with higher life satisfaction are generally expected to have healthier interpersonal relationships and mental well-being (Türkel & Dilmaç, 2019). Obviously, the challenges that young people have to cope with throughout their lives can negatively affect mental health and, in turn, lead to a decrease in life satisfaction. Adolescence is a central period of life when the conflicts caused by these challenges are experienced most intensely. The rapid cycles of psychosocial, hormonal, and metabolic functions characteristic of adolescence make it difficult for young people to effectively adapt to their environment and changes and can negatively impact their life satisfaction. A low level of life satisfaction can create a vicious cycle, leading to increased social withdrawal, loneliness, mental health issues, deterioration in self-care and nutritional habits, all of which cause health issues.

Overall, previous research identified many factors predicting high life satisfaction among younger cohorts. For instance, in a study on university students, Akcan et al. (2023) found that students with good financial status, moderate academic success, strong friendships, mothers with primary education, literate fathers, those living in dormitories, those residing in districts, and those participating in social activities reported having higher life satisfaction scores (Akcan, Karakut, & Bucak, 2023). Furthermore, another study

that explored the relationship between depression, anxiety, stress, emotional appetite, and life satisfaction among university students revealed that changes in students' emotional states affected both their life satisfaction and emotional appetite, with lower life satisfaction and emotional appetite observed during negative emotional states (Hamurcu & Arslan, 2022). In another relevant study, focused on the effects of social media addiction on the life satisfaction of Generation Z, Bayramoğlu and Gültekin (2023) found that the most frequently used social media applications were WhatsApp, Instagram, and YouTube, and it was reported that increased time spent on social media was strongly associated with decreased life satisfaction.

Importantly, previous research documented that the relationship between social media use, eating attitudes, and life satisfaction is reciprocal. However, available evidence regarding these associations in adolescents, who are at a heightened risk of social media addiction, remains scarce. To fill this gap in the literature, in the present study, we conduct a comprehensive overview of existing research on the relationship between social media addiction (SMA), eating attitudes, and life satisfaction in adolescents. In this review, relevant articles were systematically obtained from various academic databases, including PubMed, Scopus, and Google Scholar. The searches were conducted relevant keywords such as "social media addiction," "eating attitudes," and "life satisfaction." Articles were selected based on their relevance to adolescent populations and the focus on social media's psychosocial effects. The selected studies were then analyzed to identify patterns, inconsistencies, and gaps within the literature so as to lay down the foundation for the development of the conceptual framework of this study.

2. Social Media Addiction and Theoretical Framework

Addiction is generally defined as an individual's overwhelming and uncontrollable desire for a person or object, leading to a state of dependency on that person or object (Karakuş et al., 2021). Along with substance addictions as in the case of smoking, alcohol, and caffeine, there are also behavioral addictions like internet and social media addiction. Behavioral addiction can be described as engaging in a particular behavior more frequently and regularly than normal, which leads to adverse psychological, social, and physical consequences for the individual. Beyond causing addiction, the addictive substances can also cause changes in the brain, particularly in the reward system and executive function areas (Kaya et al., 2019). Accordingly, frequent manifestations of substance abuse include psychiatric problems such as intoxication, dementia, withdrawal delirium, psychotic disorders, mood disorders, sleep disorders, anxiety disorders, and sexual dysfunction (Güleç, 2015).

Today, the internet has become a basic necessity for people, akin to basic human needs for food, shelter, or communication. The increasing accessibility and affordability of the internet, combined with the pleasure derived from time spent online, have contributed to a rise in the amount of time people usually spend surfing online. However, available evidence suggests that uncontrolled increases in internet use can lead to negative consequences such as internet addiction, reluctance to engage in physical activities, procrastination, avoidance of social environments, and, eventually, isolation to the point of becoming asocial (Anlı, 2018; Büyükgebiz Koca & Tunca, 2020).

Social media are broadly understood as internet-based channels allowing users to interact either synchronously or asynchronously, where users derive value from the content they create and from interactions with others (Carr & Hayes, 2015). While social media have many positive effects that facilitate daily life, their uncontrolled and unconscious use can negatively affect users' physical and mental health (Sümen & Evgin, 2021), including the development of such issues as anxiety, depression, eating disorders, and sleep disorders. In addition, social media addiction was reported to be associated with paranoid thoughts, phobic anxiety, anger, and aggression (Bilgin, 2018).

Most adolescents use social media applications, either passively or actively, on a daily basis. Uncontrolled and unconscious use of social media can lead to disruptions in teenagers' lifestyle habits and result in academic failure. In addition, such usage can cause mental health issues like anxiety, depression, anxiety disorders, and body image disturbances due to problems in interacting with their social environment (Yiğitcan, 2021). For instance, Günay (2017) found that university students spend on average 3±1.9 hours per day on social media; furthermore, the authors also reported that the students who had poor adaptation to university life spent more time on social media and struggled to maintain a balance between real life and social media. Similarly, in another study on the relationship between social media addiction (SMA) and communication skills among Education Faculty students, İliş and Gülbahçe (2019) found a significant

negative relationship between SMA and communication skills.

With regard to the factors making individuals more prone to the development of SMA, in a study on the effects of various variables on social media addiction among university students Demir and Kumcağız (2019) found that SMA did not differ by gender (see also TÜİK, 2023 for a similar conclusion); however, students with higher academic success were found to have lower levels of SMA. Moreover, the students who spent more time on social media had higher addiction levels. The aforementioned study also revealed that the students who reported being harmed by social media had significantly higher levels of SMA than those who did not report any harm.

Similarly to people with substance use disorders, individuals addicted to social media recognize the harm that excessive social media use causes to their personal relationships, lifestyle habits, physical and mental health, and academic performance. However, despite this awareness, they continue to engage in such behaviors. This highlights the need for more effective interventions capable of preventing the development of addiction and addressing the disruptions in various areas of life caused by social media addiction.

To date, several theories—including Social Cognitive Theory, Cognitive Dissonance Theory, and Social Comparison Theory—have been proposed that explain the relationship between social media addiction, eating attitudes, and life satisfaction. These theories can contribute to understanding the psychosocial impacts of social media on adolescents and help to explain the negative effects of social media addiction on eating attitudes and life satisfaction.

To start with, Social Cognitive Theory posits that individuals learn behaviors through observation (Bandura, 2001). Individuals with social media addiction may adopt behaviors they observe in the content they frequently encounter on social media platforms that idealize the consumption of unhealthy foods. Adolescents, in particular, may be inclined to model the unhealthy eating behaviors of social media influencers and celebrities, integrating these behaviors into their own lives. This provides a robust framework for explaining how social media addiction reinforces unhealthy eating attitudes.

Furthermore, Cognitive Dissonance Theory also holds a significant place in the theoretical framework of this study. According to this theory, individuals experience internal discomfort when they engage in behaviors conflicting with their beliefs or values, which leads them to change either their beliefs or behaviors to alleviate this discomfort (Festinger, 1957). Accordingly, it individuals who are continuously exposed to ideal body images on social media are expected to alter their eating habits to resolve this dissonance. Considering social media as an "environmental stressor" allows for a deeper understanding of its impact on adolescents' psychological well-being and eating attitudes.

Finally, another essential theoretical basis to explain the relationship between social media addiction and life satisfaction is Social Comparison Theory. This theory posits that individuals evaluate themselves through a comparison with others—a process that can significantly affect individuals' self-esteem and life satisfaction (Festinger, 1954). Social media exposes individuals to idealized lifestyles and body images, potentially leading to negative comparisons. Adolescents, in particular, may feel inadequate when comparing their own lives to the seemingly perfect lives displayed on social media platforms, which may lead to a decrease in their life satisfaction.

3. Social Media Addiction and Eating Attitudes

There is a broad scholarly consensus that healthy lifestyle habits are acquired during childhood and adolescence. The habits formed during this period are key determinants of future health. However, adolescence is particularly risky in terms of the development of unhealthy nutrition-related attitudes and behaviors, as, during this stage, the influence of the social environment and peer pressure is more prominent. Increased independence from the family and the growing habit of eating out with peers can lead to changes in food choices, frequently resulting in a shift from healthy eating habits. The consumption of processed foods that are high in fat, sugar, and calories but low in vitamins, minerals, and fiber may increase the risk of obesity and related diseases.

Among the key factors that affect eating attitudes are gender, age, and body mass index (BMI), along with various biological, developmental, cultural, environmental, psychological, and familial factors. Due to the pressure to achieve the ideal body image promoted by the media, unhealthy and restrictive dieting practices are more commonly observed during adolescence. In a study investigating factors influencing eating attitudes among university students (Kadıoğlu & Ergün, 2015), female students were found to have significantly higher Eating Attitudes Test (EAT)

scores as compared to male students. The percentage of students with EAT scores above 30 was 7.1% in the 18-19 age group, 10.9% in the 20-21 age group, and 17.6% in the 22-24 age group (Kadıoğlu & Ergün, 2015). In addition, the risk of eating disorders was found to be twice as high in overweight/obese students as compared to those of normal weight, while it was 2.9 times lower in underweight students as compared to those of normal weight (Kadıoğlu & Ergün, 2015).

Furthermore, in a study on the relationship between social media addiction and healthy eating attitudes among university students, Gürsoy and Atmaca (2021) established that, with an increase of social media addiction increased, healthy eating attitudes deteriorated. Likewise, investigating the impact of social media use on eating attitudes and nutritional habits in women, Yıldırım (2022) found that 81.3% of participants had high levels of social media addiction (SMA), with younger individuals showing higher SMA scores. The authors also documented that, with an increase of severity of eating disorders, social media addiction also aggravated. Overall, numerous previous studies documented that the increase in social media usage duration and frequency is proportional to the rise in addiction levels, which is associated with negative eating attitudes and depression (e.g., Topaktaş & Çetin, 2023; Balcı & Baloğlu, 2018).

Furthermore, the persuasive marketing of unhealthy foods on social media was reported to have a strong impact on triggering children's desire for instant energy intake (Powell & Pring, 2024). In a systematic review on the physiological and social mechanisms underlying social media's impact on the nutrition of children and adolescents, Sina et al. (2022) found that social media are associated with skipping breakfast, increased consumption of unhealthy snacks and sugary drinks, and lower consumption of fruits and vegetables in all age groups. The aforementioned review also showed that, as compared to healthy digital food images, exposure to unhealthy foods resulted in increased brain responses related to reward and attention in children and adolescents.

Food has both sensory and physiological effects on humans. The human brain filters the chemical flavors found in foods, taking into account some while archiving others for a later evaluation. Subsequently, information related to the appearance, texture, smell, taste, sound, and color of foods is transmitted to the brain through sensory receptors for further processing. In this way, the brain determines which foods will be consumed, as well as when, where, and in what quantities (Özenoğlu, 2017).

While the energy content of macronutrients plays a role in homeostatic satiety, it is not a decisive factor in sensory-specific satiety, which ultimately determines the variety and quantity of foods consumed (Cankül & Uslu, 2020; Tokat & Yılmaz, 2023). This knowledge provides valuable insights for producers' development and marketing efforts based on consumer preferences. With the advent of social media use, neuromarketing, which bridges neuroscience and consumer behavior, has come to exert a strong impact on food choices, eating attitudes, and the corresponding behaviors (Gedik, 2020). For instance, using functional magnetic resonance imaging (fMRI), Koenigs and Tranel (2008) examined brain responses when the study participants were unaware of the brand they were consuming, followed by measuring their brain activity when they were informed about the brands. The results revealed that when the drinks were consumed without knowledge of the brand, higher activation was observed in the brain's ventromedial prefrontal cortex (reward centers), whereas when the brand names were known, higher activation occurred in the hippocampus and dorsolateral prefrontal cortex, i.e. areas associated with memory and emotion. This finding, referred to as the Pepsi Paradox (Koenigs & Tranel, 2008), indicates that consumer preferences are influenced more by memories and emotions related to the brand than by the actual taste of the product (Bakardjieva & Kimmel, 2017). Although this paradox was not confirmed in subsequent studies (Van Doorn & Miloyan, 2018), increasing research in the field of nutritional psychiatry confirms that emotions and past experiences play a crucial role in food choices (Özenoğlu, 2020).

Neuroimaging studies can provide insights into how much consumers like and engage with an advertisement, which can help create well-designed new products. This can play a key role in developing effective advertising strategies for food businesses (Gedik, 2020). Moreover, exposure to food images on social media can stimulate digestive secretions via the autonomic nervous system, preparing individuals to consume the depicted food. However, repeated exposure to such experiences is likely to contribute to unhealthy eating habits and the development of obesity.

As demonstrated in several previous studies, social media addiction may affect not only food preferences, but also eating attitudes and behaviors, generating a broad spectrum of eating disorders from anorexia to obesity. According to Social Cognitive Theory, individuals learn through observation, and social media offer idealized models, especially for young

people, that may lead them to imitate behaviors such as unhealthy food consumption. This can trigger individuals with social media addiction to adopt unhealthy eating habits. Furthermore, from the perspective of Cognitive Dissonance Theory, individuals exposed to certain elements on social media may eventually experience discomfort or a shift in perspective regarding previously learned notions of unhealthy eating behaviors. This continuous exposure can eventually result in reduced life satisfaction, as individuals either struggle with or re-evaluate these conflicting beliefs.

4. Social Media Addiction and Life Satisfaction

Life satisfaction is generally defined as individual's satisfaction with their present, past, and anticipated future, coupled with their desire to improve their life (Diener et al., 1999). To date, numerous previous studies documented a strong negative relationship between social media use and life satisfaction. Accordingly, with an increase of life satisfaction, social media use decreases (Cavga, 2019; Yalçın Çınar & Mutlu, 2019; Türkel & Dilmaç, 2019).

In a study conducted to determine the effect of perceived social support, an important tool for social support, particularly for adolescents, on life satisfaction, Balcı and Kaya (2021) found that perceived social support has a significant and positive effect on life satisfaction.

Another relevant concept to discuss here is the fear of missing out (FoMO), which is known to be related to an individual's inability to meet their psychological needs, which in turn influences their participation in social media. In an investigation on the relationship between internet addiction, self-esteem, life satisfaction, and FoMO among university students, Sağar and Özçelik (2022) found internet addiction to be positively associated with FoMO, decreased attention and hyperactivity, and neurotic personality traits, while being negatively associated with life satisfaction, self-esteem, and a sense of responsibility. Another relevant study found that emotion regulation and life satisfaction were significant predictors of social media addiction (Sağar & Özçelik, 2022).

Furthermore, in a study examining the relationship between social media use disorder (SMUD) and life satisfaction, Doyaroğlu and Noyan (2023) identified that an increase in the number of social media applications browsed and the time spent on social media was strongly associated with higher SMUD scores. Interestingly, males in this study had higher SMUD scores compared to females. Furthermore, the analysis of the relationship between life satisfaction and SMUD scores revealed that an increase in SMUD scores was significantly associated with a decrease in life satisfaction scores. Moreover, the conflict sub-dimension of SMUD was found to be a significant negative predictor of life satisfaction.

In another pertinent study on the relationship between hedonic smartphone addiction, stress, and life satisfaction, Vujic & Szabo (2022) found that female gender, hedonic smartphone use, and perceived life stress were strong predictors of smartphone addiction. Similarly, Öncü and Erel's (2024) investigation of the factors associated with internet addiction (IA) and social media addiction (SMA) among medical students showed that high life satisfaction, engaging in physical activity at least twice a week, and using the internet for communication purposes were independent protective factors against internet addiction.

Among adolescents, seeking social support is a significant motivation for social media use, with perceived social support being a key factor influencing life satisfaction. For individuals with social media addiction, the constant observation of others' lives, as posited by the Social Comparison Theory, can generate the feelings of inadequacy due to comparisons with others, which, in turn, may diminish life satisfaction. In addition, social media's impact can be examined through Cognitive Dissonance Theory. If the influence aligns with the expectations set by social media, it may lead to negative changes in eating attitudes or even contribute to eating disorders; conversely, if individuals resist this dissonance, a decline in life satisfaction cam nevertheless be observed. Other relevant factors include high levels of life stress, difficulty coping with stress, irregular physical activity, and unhealthy eating habits all of which negatively impact both physical and mental health and can ultimately reduce life satisfaction. Accordingly, while healthy lifestyle habits are positively linked to life satisfaction, internet and social media addiction have a strong link both an unhealthy lifestyle and lower life satisfaction.

5. Eating Attitudes and Life Satisfaction

Adolescence is a critical life stage during which significant changes in eating behaviors and food preferences occur. Without proper guidance, adolescents may develop poor eating habits and face an increased risk of eating disorders. Several previous

studies demonstrated that university students exhibit high levels of restrictive eating behaviors (Tang et al., 2020; Young et al., 2021). Similarly, there is evidence to suggest that restrictive eating can predict the severity of eating disorders and is an important factor in their development (Laessle & Hilterscheid, 2019). Individuals engaged in restrictive eating tend to reduce their energy intake to maintain or lose weight. This leads them to prefer low-calorie foods, such as vegetables and fruits, while restricting the consumption of higher-calorie foods like grains, tubers, and various types of meat. Consequently, excessive restrictive eating may lead to inadequate energy intake. Conversely, individuals who practice restrictive eating are known to be frequently more prone to episodes of overeating. This phenomenon, known as the disinhibition effect, can result in symptoms of eating disorders such as bulimia nervosa and binge eating, as well as obesity (Wood et al., 2020; Bayrak et al., 2020). Restrictive eating, which is frequently accompanied by prolonged dieting and overeating, can elicit strong negative emotions such as stress, depression, and anxiety, all of which adversely affect both physical and psychosocial health (Joseph et al., 2018).

Overall, social norms that equate thinness with beauty play a critical role during adolescence, a period when body image becomes increasingly important. Aesthetic ideals imposed by social media can make adolescents, who are particularly vulnerable to external influences, more susceptible to body dissatisfaction, which may, in turn, lead to unhealthy dieting practices. For instance, in a Chinese study on the relationship between restrictive eating, body image, and dietary intake among university students, Yong et al. (2021) observed the prevalence of high-level restrictive eating in 52.8% study participants. Furthermore, the authors also found that the students who were dissatisfied with their bodies or overestimated their body weight exhibited a greater tendency toward restrictive eating ($p < 0.05$). In addition, those with a high tendency for restrictive eating were more likely to frequently consume fruits and eggs, while they were less likely to consume meat, sugar-sweetened beverages, and fast food. Additionally, high levels of restrictive eating were identified as a risk factor for reduced dietary diversity.

6. The Impact of Social Media on Nutritional Deficiencies

As discussed in previous sections, the addictive use of social media can trigger a process that negatively affects individuals' eating attitudes and life satisfaction, ultimately leading to nutritional deficiencies. Figure 1, presented as a conceptual aid, synthesizes existing knowledge to highlight potential pathways among these constructs. Rather than proposing a novel theoretical model, the diagram organizes and visualizes the relationships between social media addiction, eating attitudes, life satisfaction, and nutritional deficiencies. Within this framework, social media addiction may lead individuals to engage in social comparison, pursue idealized body standards, and adopt unhealthy eating habits, all of which contribute to nutritional deficiencies.

The relationships depicted in Figure 1 are drawn from the existing literature and are presented as a conceptual framework to visualize potential pathways. Social media addiction can negatively impact individuals' eating attitudes and life satisfaction, both of which are critical mediators in the development of nutritional deficiencies. Specifically, social media addiction may lead to unhealthy eating behaviors by

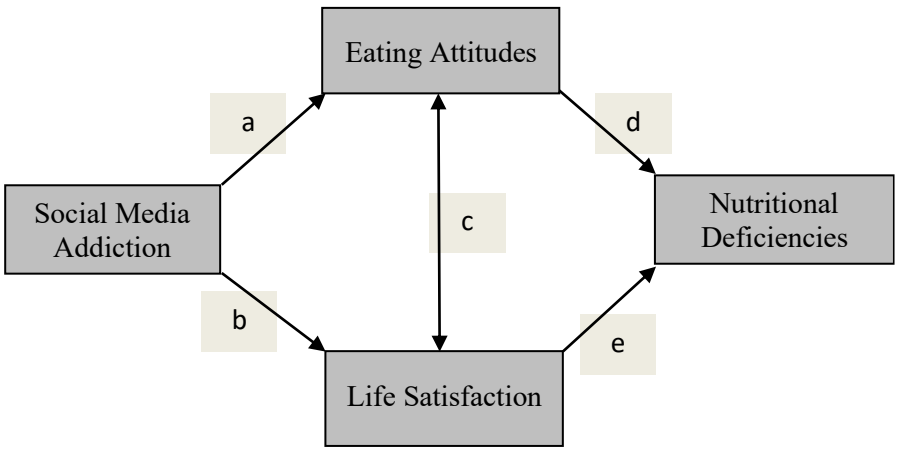

Figure 1. The Impact of Social Media on Nutritional Deficiencies

fostering negative eating attitudes, such as skipping meals or restrictive dieting. Similarly, social comparisons can diminish life satisfaction, where individuals feel inadequate when exposed to idealized lives on social media. Furthermore, a bidirectional relationship exists between life satisfaction and eating attitudes: decreased life satisfaction may worsen eating behaviors, while poor eating attitudes may further lower life satisfaction. Over time, these disruptions in eating patterns and emotional well-being can make individuals more susceptible to nutritional deficiencies. Social media addiction fosters social comparisons and unrealistic body image goals, leading to negative eating attitudes and diminished life satisfaction. These factors, in turn, may increase the risk of developing unhealthy eating habits and nutritional deficiencies.

7. Conclusion and Recommendations

While eating is an activity that engages all our senses, the degree of pleasure derived from it is subjective and varies across different individuals. The dishes we watch being prepared, the plates we see, restaurants that stand out with their designs and concepts, the aromas of foods we enjoy, and various other elements evoke different emotions in each of us. Triggering the act of eating, these sensory stimuli lead individuals on a journey to explore new tastes, flavors, and foods. Through these sensory cues, food images frequently encountered on social media may increase the desire for consumption and contribute to the development of obesity. Conversely, messages related to the ideal body image on social media may act as triggers for eating disorders, particularly in vulnerable individuals.

Having become an integral part of modern life, social media are now widely used across all age groups and cultures. Of note, however, while conscious use of social media can positively contribute to life, uncontrolled and excessive use, especially among children and adolescents, can give rise to significant psychosocial and health issues. Previous research convincingly demonstrates that social media addiction increases susceptibility to eating disorders and is associated with declines in life satisfaction. This, in turn, leads to deterioration in social relationships, withdrawal, and a lack of responsibility towards nutrition and health, ultimately driving individuals back into social media addiction. In this context, raising awareness through educational programs, campaigns, and policies aimed at promoting conscious social media use among families, children, and adolescents could be crucial steps for safeguarding the health of society and future generations.

Most importantly, in order to mitigate the negative effects of social media addiction, it is crucial to organize educational programs and awareness campaigns aimed at promoting responsible social media use across all age groups, especially among children and adolescents. Policymakers and healthcare professionals may also find it beneficial to take relevant steps to protect public health by considering the impact of social media on eating behaviors and life satisfaction. Such initiatives to enhance digital media literacy would be particularly helpful for individuals in terms of a more critical re-evaluation of social media content and maintaining healthy eating habits.

Declaration of Competing Interest

The author declares that they have no financial or non-financial competing interests.

Author's Contributions

A. Özenoğlu (0000-0003-3101-7342): *Definition, Conceptualization, Literature collection, Critical review, Review methodology, Writing, and Editing*.

References

Akcan, K., Karakut, Ş., & Bucak, F. K. (2023). Sağlık Meslek Yüksekokulu Öğrencilerinin Sosyal Medya Bağımlılığının Yalnızlık ve Depresyon ile İlişkisi. *Genel Sağlık Bilimleri Dergisi, 5*(2), 178-189.

Aktan, E. (2018). Üniversite öğrencilerinin sosyal medya bağımlılık düzeylerinin çeşitli değişkenlere göre incelenmesi. *Erciyes İletişim Dergisi, 5*(4), 405-421.

Anlı, G. (2018). İnternet Bağımlılığı: Sosyal ve Duygusal Yalnızlık. *Uluslararası Bilimsel Araştırmalar Dergisi, 3*(2), 389-397. https://doi.org/10.21733/ibad.414862

Bakardjieva, E., & Kimmel, A. J. (2017). Neuromarketing research practices: Attitudes, ethics, and behavioral intentions. *Ethics & Behavior, 27*(3), 179–200. https://doi.org/10.1080/10508422.2016.1162719

Balcı, Ş., & Baloğlu, E. (2018). Sosyal medya bağımlılığı ile depresyon arasındaki ilişki: Üniversite gençliği üzerine bir saha araştırması. *Galatasaray Üniversitesi İletişim Dergisi, 29*, 209-234.

Balcı, Ş., & Kaya, E. (2021). Sosyal Medyada Algılanan Sosyal Desteğin, Yaşam Doyumu Üzerindeki Etkinliği: Üniversite Gençliği Araştırması. *Akdeniz Üniversitesi İletişim Fakültesi Dergisi, 36,* 47-71. https://doi.org/10.31123/akil.988521

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual review of psychology, 52*(1), 1-26.

Bayrak, E., Serter, R., Işıklı, S. (2020). Duygusal, Dışsal Ve Kısıtlayıcı Yeme Bozukluklarının Metabolik Sendrom Gelişimi Üzerine Etkisi. *Ankara Eğt. Arş. Hast. Derg., 53*(1): 36-43

Bayramoğlu, G., & Gültekin, F. (2023). Z Kuşağının Sosyal Medya Bağımlılığının Yaşam Doyumu Üzerine Etkisi. *Turkuaz*

Uluslararası Sosyo-Ekonomik Stratejik Araştırmalar Dergisi, 5(1), 27-53.

Bilgin, M. (2018). Ergenlerde Sosyal Medya Bağımlılığı ve Psikolojik Bozukluklar Arasındaki İlişki. *The Journal of International Scientific Researches, 3*(3), 237-247. https://doi.org/10.23834/isrjournal.452045

Boniel-Nissim, M., Tynjälä, J., Gobiņa, I., Furstova, J., van den Eijnden, R. J., Marino, C., Klanšček, H. J., Klavina-Makrecka, S., Villeruša, A., & Lahti, H. (2023). Adolescent use of social media and associations with sleep patterns across 18 European and North American countries. *Sleep Health, 9*(3), 314-321.

Büyükgebiz Koca, E., & Tunca, M.Z. (2020). İnternet ve Sosyal Medya Bağımlılığının Öğrenciler Üzerindeki Etkilerine Dair Bir Araştırma. *Alanya Akademik Bakış, 4*(1), 77-103.

Cankül D. & Uslu N. (2020). Nörogastronomi ve Duyusal Algılama. *Turizm ve İşletmecilik Dergisi, 1* (1), 64-74

Carr, C. T., ve Hayes, R. A. (2015). Social media: Defining, developing, and divining. *Atlantic Journal of Communication, 23*(1), 46-65.

Carroll, C., Booth, A., & Cuevas, D. C. (2024). What matters to adolescents with obesity, and their caregivers, when considering bariatric surgery or weight loss devices? A qualitative evidence synthesis. *Obesity Reviews, 25*(2), e13654.

Cavga, Z. (2019). *Lise öğrencilerinin aile yaşam doyumu, psikolojik dayanıklılığı ve sosyal medya kullanım bozukluğu arasındaki ilişkinin incelenmesi.* [Unpublished Master's Thesis]. İstanbul Sabahattin Zaim University, İstanbul.

Davison, J., Bunting, B., & Stewart-Knox, B. (2023). The mediating effect of food choice upon associations between adolescent health-related quality of life and physical activity, social media use and abstinence from alcohol. *Health and Quality of Life Outcomes, 21*(1), 46.

Demir, Y., & Kumcağız, H. (2019). Üniversite Öğrencilerinin Sosyal Medya Bağımlılığının Farklı Değişkenler Açısından İncelenmesi. *Turkish Psychological Counseling and Guidance Journal, 9*(52), 23-42.

Derevensky, J. L., Hayman, V., & Lynette, G. (2019). Behavioral addictions: Excessive gambling, gaming, internet, and smartphone use among children and adolescents. *Pediatric Clinics of North America, 66*(6), 1163–1182. https://doi.org/10.1016/j.pcl.2019.08.008

Diener, E., & Lucas, R. E. (1999). Personality and subjective well-being. In D. Kahneman, E. Diener, & N. Schwarz (Eds.), *Well-being: The foundations of hedonic psychology* (pp. 213–229). Russell Sage Foundation.

Diener, E., Suh, E. M., Lucas, R. E. & Smith, H. L. (1999). Subjective Well-Being: Three Decades of Progress. *Psychological Bulletin, 125*(2), 276-302.

Doyaroğlu, Ş., & Noyan, C. O. (2023). Sosyal Medya Kullanımı Ve Yaşam Doyum Düzeyi Arasındakı İlişkinin İncelenmesi. *Current Addiction Research, 7*(2), 5-17. https://doi.org/10.32739/car.2023.7.2.217

Erkul, C., & Ozenoglu, A. (2023). Psychosocial Stressors Affecting Food Choices. *International Journal of Gastronomy Research, 2*(2), 62–69. https://doi.org/10.56479/ipeak.2023.12191

Festinger, L. (1954). A Theory of Social Comparison Processes. Human Relations, 7(2), 117– 140.

Festinger, L. (1957). A theory of cognitive dissonance. Stanford University Press.

Gedik, Y. (2020). Nöropazarlama Ve Nöropazarlama Araçları: Teorik Bir Çerçeve. Ankara *Üniversitesi Sosyal Bilimler Dergisi, 11*(2), 251 – 267.

Gül, A., & Yılmaz Akyüz, E. (2019). Sosyal Medya Kullanımı: Yeme Bozukluğu Nedeni Olabilir Mi?. *Sağlık Profesyonelleri Araştırma Dergisi, 1*(1), 28-32.

Güleç, G., Köşger, F., & Eşsizoğlu, A. (2015). DSM-5'te alkol ve madde kullanım bozuklukları. *Psikiyatride Güncel Yaklaşımlar, 7*(4), 448-460.

Günay, M. (2017). *Sağlıkla İlgili Fakültelerde Eğitim Görenlerin Sosyal Medya Bağımlılık Düzeyi* [Unpublished Master's Thesis]. Trakya Üniversitesi Sağlık Bilimleri Enstitüsü, Edirne.

Gürsoy Coşkun, G., & Atmaca Demir, B. (2021). Lisans Öğrencilerinin Sosyal Medya Bağımlılığı ile Sağlıklı Beslenmeye İlişkin Tutumlarının Değerlendirilmesi – İstanbul'da Bir Üniversite Örneği. *Fenerbahçe Üniversitesi Sağlık Bilimleri Dergisi, 1*(3), 195-205.

Hamurcu, P., & Arslan, M. (2022). The Relationship Between Mood, Life Satisfaction and Emotional Appetite: A Study on University Students. *Gevher Nesibe Journal Of Medıcal And Health Scıences, 7*(17), 119–130. https://doi.org/10.46648/gnj.367

Heslin, A. M., & McNulty, B. (2023). Adolescent nutrition and health: Characteristics, risk factors and opportunities of an overlooked life stage. *Proceedings of the Nutrition Society, 82*(2), 142-156.

İliş, A., & Gülbahçe, A. (2019). Sosyal Medya Bağımlılığı İle İletişim Becerileri Arasındaki Yordayıcı İlişkinin İncelenmesi. *Ekev Akademi Dergisi, 78*, 45-60.

Jarman, H. K., Fuller-Tyszkiewicz, M., McLean, S. A., Rodgers, R. F., Slater, A., Gordon, C. S., & Paxton, S. J. (2023). Who's most at risk of poor body image? Identifying subgroups of adolescent social media users over the course of a year. *Computers in Human Behavior, 147*, 107823.

Joseph P.V., Davidson H.R., Boulineaux C.M., Fourie N.H., Franks A.T., Abey S.K., & Henderson W.A. (2018). Eating Behavior, Stress, and Adiposity: Discordance Between Perception and Physiology. *Biol. Res. Nurs. 20*, 531–540. https://doi.org/10.1177/1099800418779460.

Kadıoğlu, M., & Ergün, A. (2015). Üniversite Öğrencilerinin Yeme Tutumu, Öz-Etkililik ve Etkileyen Faktörler. *Clinical and Experimental Health Sciences, 5*(2), 96-104. https://doi.org/10.5455/musbed.20150309011008

Karakuş, B. N., Özdengül, F., Solak Görmüş, Z. I., & Şen, A. (2021). Bağımlılık Fizyopatolojisi. *KTO Karatay Üniversitesi Sağlık Bilimleri Dergisi, 2*(3): 158-166

Kaya, E., Akpınar, D., & Akpınar, H. (2019). Bağımlılığın patofizyolojisi. *Muğla Sıtkı Kocaman Üniversitesi Tıp Dergisi, 6*(3), 166-170.

Kılıçlar, A., Bozkurt, İ., Sarıkaya, G. S., & Şahin, A. (2021). Sosyal Medyanın X ve Z Kuşağı Üzerindeki Yemek Yeme Davranışına Etkisi. *Journal of Tourism and Gastronomy Studies, 9*(1), 531-552.

Koenigs, M. & Tranel, T. (2008). Prefrontal cortex damage abolishes brand-cued changes in cola preference. *Social Cognitive & Affective Neuroscience, 3,* 1-6

Korkmaz, Z., Çiçek, İlhan, Yıldırım, M., & Ünsal, F. (2023). Sosyal Medya Bağımlılığı ve Uyku Kalitesi Arasındaki İlişki: Sanal Dünyanın Ergenler Üzerindeki Etkisi. *Yaşadıkça Eğitim, 37*(3), 844–856. https://doi.org/10.33308/26674874.2023373654

Laessle, R., & Hilterscheid, E. (2019). Stress-Induced Release of Eating-Related Hormones in Young Women Classified as Restrained and Unrestrained Eaters. *Neuropsychobiology, 78*, 27–30. https://doi.org/10.1159/000498866.

Linh, T.T., Giang, N.T.H, & Khanh Ha, T.T. (2021). When are children satisfied with life? An initiative qualitative study

from Vietnamese children sample. *Sci Prog. 104*(4), 368504211067655. https://doi.org/10.1177/00368504211067655.

Mahon, C., & Hevey, D. (2023). Pilot trial of a self-compassion intervention to address adolescents' social media-related body image concerns. *Clinical child psychology and psychiatry, 28*(1), 307-322.

Neri, L. d. C. L., Guglielmetti, M., Fiorini, S., Quintiero, F., Tagliabue, A., & Ferraris, C. (2024). Nutritional counseling in childhood and adolescence: a systematic review. *Frontiers in Nutrition, 11*, 1270048.

Öncü, S., & Erel, Ö. (2024). Tıp Fakültesi Öğrencilerinin İnternet ve Sosyal Medya Bağımlılığı. *TED, 23*(70):49-60.

Özenoğlu, A. (2020). Beslenme Psikiyatrisi. In Özenoğlu, A. (Ed). *Beslenme ve diyetetiğin psikososyal boyutu.* Nobel Akademik Yayıncılık, 2. Basım. Ankara.

Özmen, S., & Kocakaya, K. (2024). Sağlık Yönetimi Öğrencilerinde Sosyal Medya Bağımlılığının Karanlık Kişilik Özellikleri Üzerine Etkisi. *Iğdır Üniversitesi Sosyal Bilimler Dergisi* (35), 146-159. https://doi.org/10.54600/igdirsosbilder.1314855

Pavot, W., & Diener, E. (1993). Review of the Satisfaction With Life Scale. *Psychological Assessment, 5*(2), 164–172. https://doi.org/10.1037/1040-3590.5.2.164

Pedrouzo, S. B., & Krynski, L. (2023). Hyperconnected: children and adolescents on social media. The TikTok phenomenon. Archivos Argentinos de Pediatria, e202202674-e202202674.

Powell, J., & Pring, T. (2024). The impact of social media influencers on health outcomes: Systematic review. *Soc Sci Med. 340,* 116472. https://doi.org/10.1016/j.socscimed.2023.116472.

Sağar, M. E., & Özçelik, T. (2022). Ergenlerde Duygu Düzenleme Ve Yaşam Doyumunun Sosyal Medya Bağımlılığı Üzerindeki Yordayıcı Rolü. *Kırıkkale Üniversitesi Sosyal Bilimler Dergisi, 12*(2), 493-511.

Sina, E., Boakye, D., Christianson, L., Ahrens, W., & Hebestreit, A. (2022). Social Media and Children's and Adolescents' Diets: A Systematic Review of the Underlying Social and Physiological Mechanisms. *Adv Nutr. 13*(3):913-937. https://doi.org/10.1093/advances/nmac018.

Smith, A. C., Ahuvia, I., Ito, S., & Schleider, J. L. (2023). Project Body Neutrality: Piloting a digital single-session intervention for adolescent body image and depression. *International Journal of Eating Disorders, 56*(8), 1554-1569.

Sümen, A., & Evgin, D. (2021). Social Media Addiction in High School Students: A Cross-Sectional Study Examining Its Relationship with Sleep Quality and Psychological Problems. *Child Ind Res 14,* 2265–2283.

Tang C., Cooper M., Wang S., Song J., & He J. (2020). The relationship between body weight and dietary restraint is explained by body dissatisfaction and body image inflexibility among young adults in China. *Eat. Weight Disord.* (Suppl. 2):3. https://doi.org/10.1007/s40519-020-01032-0.

Tokat, P., & Yilmaz, I. (2022). Neurogastronomy: Factors Affecting the Taste Perception of Food. *International Journal of Gastronomy Research, 2*(1), 1–10. https://doi.org/10.56479/ayed.2022.10261

Topaktaş, B., & Çetin, M. (2023). Ebelik ve Hemşirelik Öğrencilerinde Sosyal Medya Bağımlılık Düzeylerinin Beslenme Alışkanlıkları Üzerine Etkisi. *Hitit Med J., 5*(1): 19-24. https://doi.org/10.52827/hititmedj.1161788

TÜİK (2023). *Hanehalkı bilişim teknolojileri (BT) kullanım araştırması. https://data.tuik.gov.tr/Bulten/Index?p=Hanehalki-Bilisim-Teknolojileri-(BT)-Kullanim-Arastirmasi-2023-49407*

Türkel, Z., & Dilmaç, B. (2019). Ergenlerde Sosyal Medya Kullanımı, Yalnızlık Ve Yaşam Doyumu Arasındaki Yordayıcı İlişkiler. Necmettin Erbakan Üniversitesi Ereğli Eğitim Fakültesi Dergisi, 1(1), 57-70.

Van Doorn, G., & *Miloyan*, B. (*2018*). The Pepsi Paradox: A review. *Food Quality and Preference, 65,* 194–197.

Vujić, A, & Szabo, A. (2022). Hedonic use, stress, and life satisfaction as predictors of smartphone addiction. *Addict Behav Rep. 15*, 100411. https://doi.org/10.1016/j.abrep.2022.100411.

Wood, K.L., Barrack, M.T., Gray, V.B., Cotter, J.A., Van Loan, M.D., Rauh, M.J., McGowan, R., & Nichols, J.F. (2020). Cognitive dietary restraint score is associated with lower energy, carbohydrate, fat, and grain intake among female adolescent endurance runners. *Eat. Behav. 40:101460.* https://doi.org/10.1016/j.eatbeh.2020.101460.

World Health Organization. (2015). *Public health implications of excessive use of the internet, computers, smartphones and similar electronic devices: meeting report*. Main Meeting Hall, Foundation for Promotion of Cancer Research, National Cancer Research Centre, Tokyo, Japan, 27-29 August 2014. World Health Organization. https://iris.who.int/handle/10665/184264

Yalçın Çınar, Ç., & Mutlu, E. (2019). İnternet Bağımlılığının Benlik Saygısı, Dikkat, Gelişmeleri Kaçırma Korkusu, Yaşam Doyumu ve Kişilik Özellikleri ile İlişkisi. *Bağımlılık Dergisi, 20*(3), 133-142.

Yiğitcan, A. (2021). *İnternet bağımlılığı, beden imajı ve yeme bozukluğu arasındaki ilişki.* [Ubpublished master's thesis]. İstanbul Gelişim University.

Yıldırım, Z. (2022). *Kadınlarda Sosyal Medya Kullanımının Yeme Tutumu Ve Davranışı Üzerine Etkisi.* [Ubpublished Master's Thesis]. Necmettin Erbakan University.

Yong C, Liu H, Yang Q, Luo J, Ouyang Y, Sun M, Xi Y, Xiang C, Lin Q. (2021). The Relationship between Restrained Eating, Body Image, and Dietary Intake among University Students in China: A Cross-Sectional Study. *Nutrients, 13*(3), 990. https://doi.org/10.3390/nu13030990.

Yong, C., Liu, H., Yang, Q., Luo, J., Ouyang, Y., Sun, M., Xi, Y., Xiang, C., & Lin, Q. (2021). The Relationship between Restrained Eating, Body Image, and Dietary Intake among University Students in China: A Cross-Sectional Study. *Nutrients, 13*(3):990. https://doi.org/10.3390/nu13030990.

The Effect of Job Stress on Diet Quality and Emotional Eating Among Hospital Employees

Aliye Özenoğlu[1,*] and Cahit Erkul[2]

[1] *Ondokuz Mayıs University, Faculty of Health Sciences, Department of Nutrition and Dietetics, 55139, Samsun, Turkiye*
[2] *Near East University, Faculty of Health Sciences, Department of Nutrition and Dietetics, 99138, Nicosia, TRNC*

Abstract

Hospital employees are considered one of the high-stress occupational groups due to their challenging working conditions and their responsibility for human health. Emotional eating, which describes the tendency to overeat in response to negative emotions, is expected to be more prevalent among hospital employees because of stressful working conditions. It is likely that emotional eating, alongside stressful working conditions, may negatively impact diet quality. This study aimed to investigate the effect of job stress on diet quality and emotional eating among hospital employees. In this study, 272 volunteers participated, consisting of 112 men and 160 women, with an average age of 34.26±11.50 years. According to the Mediterranean Diet Quality Index (KID-MED), only 24.6% of the participants had optimal diet quality. In comparison, 28.3% were categorized as non-emotional eaters based on their Emotional Eating Scale (EES) scores. A positive and significant correlation was found between Body Mass Index (BMI) and EES scores ($p<0.001$). Participants who worked exclusively during the day had significantly lower job stress and EES scores than other participants ($p<0.05$), while their KID-MED scores were significantly higher ($p<0.001$). As workload increases, the role of evolutionary survival mechanisms in decreasing KID-MED scores becomes evident, suggesting that higher levels and intensity of stress lead to a predominance of homeostatic eating. Our findings support the negative impact of job stress on emotional eating and diet quality among healthcare workers.

Keywords: Diet quality, Emotional eating, Hospital employees, Job stress.

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1. Introduction

Emotions and eating are both natural and recurrent aspects of daily life. “Emotional eating” refers to consuming energy-dense and highly palatable foods in response to negative emotions. The responses to emotional eating vary among individuals. Although the exact causes of these individual differences are not fully understood, various mechanisms such as adverse childhood experiences, learning history, chronic stress, hypothalamic-pituitary-adrenal axis functioning, and cortisol secretion are believed to play a role (Konttinen, 2020).

Workplace stress is defined as a type of stress that arises from the conditions of the workplace, the nature of the job, or individual characteristics such as personality, skills, and knowledge. It also includes external factors that challenge a person’s abilities, resources, knowledge, and physical, psychological, and professional capacity, often leading to negative outcomes (Yücel, 2022).

It has been emphasized that one of the most significant causes of stress is work and that job-related stress can manifest among hospital employees. Stress factors in the workplace for healthcare workers include verbal and physical abuse from patients, bullying/mobbing by colleagues or managers, the risk of lawsuits due to provided services, insufficient resources, fear of increased violence during visiting hours, low managerial support, role conflicts with other professional groups, heavy workload, low job control, patient expectations, the need to suppress negative emotional responses, shift work, and increasing administrative workload (Çamkerten et al., 2020).

During episodes of stress-induced eating, both emotional eating and binge eating can occur simultaneously. An anxious mood can also trigger feelings of hunger. Awareness of one’s emotions and thoughts is the first step to addressing this issue. It is

* Corresponding Author: Aliye Özenoğlu
Email: aozenoglu@yahoo.com
https://doi.org/10.56479/ijgr-42

well-established that the lack of awareness regarding emotional eating is a fundamental cause of unbalanced relationships with food (Arslan & Aydemir, 2019).

Although the connection between stress and emotional eating is well-established, there is limited research focusing on the underlying mechanisms that mediate this relationship. Notably, there has been little investigation into the impact of job stress on emotional eating behavior among high-stress occupational groups, such as hospital employees. Exposure to stress may increase the preference for comfort foods, particularly those rich in carbohydrates, which in turn may lead to a deterioration in diet quality. Therefore, this study aims to investigate the effect of job stress on emotional eating and diet quality among hospital employees.

2. Material and Methods

The study population consisted of 970 hospital staff working at İstinye University Medical Park Gaziosmanpaşa Hospital. The sample size was calculated using a power analysis formula in the G Power program, with a power of 0.95 and a significance level of 0.05, resulting in a required sample size of 74 participants.

A total of 272 volunteers participated in the study, including 112 men (41.2%) and 160 women (58.8%), with an average age of 34.26±11.50 years. Data collection tools included a personal information form, the Emotional Eating Scale (EES), the Job Stress Scale, and the Mediterranean Diet Quality Index (KID-MED).

2.1. Personal Information Form

The researcher developed this form using relevant literature. The form consists of 12 questions about socio-demographic information such as age, educational level, marital status, health status, and alcohol or tobacco use.

2.2. Emotional Eating Scale

The Emotional Eating Scale (EES) was originally developed by Garaulet et al. (2012), and its Turkish validity and reliability were established by Arslantaş et al. (2019). The scale aims to assess individuals' emotional eating behaviors and consists of 10 items and 3 subscales (disinhibition, type of food, and guilt). Responses are recorded on a 4-point Likert scale ("0" Never, "1" Sometimes, "2" Usually, and "3" Always). The scale scores range from a minimum of "0" to a maximum of "30." Higher scores indicate higher levels of emotional eating behavior. Garaulet et al. (2012) reported that scores between "0-5" indicate non-emotional eaters, "6-10" indicate low emotional eaters, "11-20" indicate emotional eaters, and "21-30" indicate highly emotional eaters.

2.3. Job Stress Scale

This Likert-type scale evaluates job stress, including workload, job control, social support, decision latitude, skill use, and job stress. Reported Cronbach's alpha coefficients for the workload, control, and social support subscales range from 0.51 to 0.72. The validity and reliability of a model-based version of this scale for Turkiye were established by Demiral et al. (2007). The questionnaire consists of 17 questions and has three main subscales: 5 questions for workload, 6 for job control, and 6 for social support. Of the 6 questions used to measure job control, 4 pertain to skill use and 2 to decision latitude. Response options for the workload, skill use, and decision latitude subscales range from "often, sometimes, rarely, and never." For social support, the response options are "strongly agree, somewhat agree, somewhat disagree, and strongly disagree." In the evaluation of the scale, responses are coded between 1 and 4, and the total score for each subscale is obtained by summing the scores. High scores indicate high workload, high job control, and high social support. Job stress is assessed as the ratio of workload to job control (Demiral et al., 2007).

2.4. Mediterranean Diet Quality Index (KID-MED)

The Mediterranean Diet Quality-KID-MED scale was originally developed by Serra-Majem et al. (2004) and adapted for Turkiye by Şahingöz et al. (2019). The scale consists of 16 items, 4 of which address negative associations with the Mediterranean diet (e.g., fast food, baked goods, sweets, and skipping breakfast), and 12 of which pertain to positive associations (e.g., consumption of oil, fish, fruits, vegetables, grains, nuts, legumes, pasta or rice, dairy products, and yogurt). Responses are scored as yes (1) and no (2). Items 6, 12, 14, and 16 are scored as -1, while the remaining 12 items are scored as +1. In the interpretation of the scores, a range of 0-3 points indicates poor adherence to the Mediterranean diet, 4-7 points indicate average adherence and 8-12 points indicate good adherence (Serra-Majem et al., 2004).

2.5. Statistical Analysis

IBM SPSS 22 statistical software package was used for data analysis. Descriptive tests such as frequency, percentage, mean, and standard deviation were employed in the analysis, along with independent groups t-tests, one-way ANOVA, and correlation

analysis. All analyses were interpreted at a significance level of 0.05.

2.6. Ethical Approval

The ethical approval for the study was obtained from the İstinye University Social and Humanities Research Ethics Committee with the decision dated 11.03.2022 and numbered 11.

3. Results

A total of 272 participants, including 112 men (41.2%) and 160 women (58.8%), were included in the study. All participants were hospital employees, with the majority (64.3%) having a university degree. Of the participants, 47.4% were married, and 80.1% reported living with their families. The mean age of the participants was 34.26±11.50 years (ranging from 18 to 65 years), and the mean BMI was 24.08±4.41 kg/m². The mean BMI of men (25.70±3.78 kg/m²) was significantly higher than that of women (22.94±4.47 kg/m²) ($p<0.001$, $t=5.484$). A total of 44.1% of participants reported smoking and 46.0% reported consuming alcohol. Moreover, 55.1% of participants worked only during the day, while 44.9% worked in a shift system. Additionally, 37.9% of participants had been working for less than five years, while 17.6% had been working for more than twenty years.

The mean scores obtained from the scales applied to the participants are presented in Table 1. The mean Emotional Eating Scale (EES) score was found to be 9.82±6.45, and the mean Mediterranean Diet Quality Index (KID-MED) score was 5.02±2.75.

The evaluation of the scores obtained from the Mediterranean Diet Quality Index (KID-MED) and the Emotional Eating Scale is presented in Table 2. According to the KID-MED score assessment, 27.6% of all participants were found to have very poor diet quality, 46.3% had diet quality that needed improvement, and 26.6% had optimal diet quality.

When evaluating the Emotional Eating Scale scores, it was found that 28.3% of the participants were categorized as non-emotional eaters, 46.3% as low-level emotional eaters, 32.4% as emotional eaters, and 6.6% as highly emotional eaters.

Table 1. Mean scores of participants from the scales

		Mean	*Std. Dev.*	*Min.*	*Max.*
Emotional Eating Scale		9.82	6.45	0	30
Job Stress Scale Subscales	*Workload*	15.19	2.90	5	20
	Skill usage	13.19	2.16	5	16
	Decision latitude	6.68	1.55	2	8
	Social support	20.64	4.20	9	63
	Job control	19.87	2.99	10	24
	Job stress	0.78	0.19	0.23	1.82
KID-MED		5.02	2.75	2	11

Table 2. Evaluation of KID-MED and emotional eating scale scores

		N	%
KID-MED	Very poor diet quality	75	27.6
	Diet quality needing improvement	126	46.3
	Optimal diet quality	67	24.6
Emotional Eating Scale	Non-emotional eater	77	28.3
	Low-level emotional eater	89	32.7
	Emotional eater	88	32.4
	Highly emotional eater	18	6.6

Table 3. T-Test results for factors affecting emotional eating scale scores

		N	*Emotional Eating Mean Score ±Std. Dev.*	*t*	*p*
Gender	Male	112	9.49±6.45	-0.710	0.478
	Female	160	10.06±6.46		
Smoking	Yes	120	9.63±6.30	-0.450	0.653
	No	152	9.98±6.58		
Alcohol Consumption	Yes	125	9.80±6.51	-0.055	0.956
	No	147	9.84±6.42		
Chronic Illness	Yes	71	10.04±7.10	0.321	0.748
	No	200	9.76±6.23		
Marital Status	Married	129	9.23±5.42	-1.459	0.146
	Not Married	143	10.36±7.23		
Work Schedule	Daytime	150	9.01±5.90	-2.315	**0.021***
	Shift Work	122	10.82±6.96		
Living Situation	With Family/Friends	232	9.71±6.45	-0.717	0.474
	Alone	40	10.50±6.45		

* p<0.05

The results of the analysis regarding the factors affecting the Emotional Eating Scale (EES) score are presented in Table 3. A significant difference was found between the work schedule and EES score. It was observed that participants who worked only during the day had significantly lower EES scores compared to participants with other work schedules (night, mixed, shift work) (p=0.021).

A correlation test was conducted to evaluate whether there was a correlation between the Emotional Eating Scale (EES) score of the participants and certain continuous variables, as well as other scale scores. The results are presented in Table 4. According to the findings, there was a positive and significant correlation between BMI and EES score (p<0.001). In other words, as BMI increased, the Emotional Eating Scale score also increased. A positive and significant correlation was also found between weight and the EES score (p<0.001), indicating that as weight increased, the EES score increased as well. Additionally, there was a converse and statistically significant correlation between the Workload score and the EES score (p=0.036), meaning that as the workload increased, the EES score also decreased. A negative and statistically significant correlation was observed between Decision Latitude and the EES score (p=0.025), showing that as decision latitude increased, the EES score decreased. Finally, there was a negative and statistically significant correlation between Social Support and the EES score (p=0.001), indicating that as social support increased, the EES score decreased.

Table 4. Pearson correlation test results for factors affecting the emotional eating scale score

Group	*Pearson Correlation*	*p*
Age	-0.050	0.407
BMI	0.229	**<0.001***
Weight	0.212	**<0.001***
KID-MED Score	-0.037	0.542
Workload Score	-0.127	**0.036***
Skill Use Score	-0.064	0.296
Decision Latitude Score	-0.136	**0.025***
Social Support Score	-0.192	**0.001***
Job Control Score	-0.116	0.055
Job Stress Score	-0.034	0.577

* p<0.05

Table 5 presents an examination of certain factors affecting the job stress scores, which are subcomponents of the Job Stress Scale. The analysis

Table 5. T-Test results for factors affecting job stress subscale scores

		N	*Job Stress Mean Score ±Std. Dev.*	*t*	*p*
Gender	Male	112	0.78±0.21	0.135	0.893
	Female	160	0.78±0.18		
Smoking	Yes	120	0.80±0.23	2.016	**0.045***
	No	152	0.76±0.16		
Alcohol Consumption	Yes	125	0.76±0.18	-1.362	0.174
	No	147	0.79±0.20		
Chronic Illness	Yes	71	0.80±0.25	1.249	0.213
	No	200	0.77±0.17		
Marital Status	Married	129	0.77±0.20	-0.425	0.671
	Not Married	143	0.78±0.18		
Work Schedule	Daytime	150	0.75±0.21	-2.262	**0.025***
	Shift Work	122	0.81±0.17		
Living Situation	With Family/Friends	232	0.77±0.18	-0.988	0.324
	Alone	40	0.80±0.24		

* $p<0.05$

results indicated that there was no significant relationship between job stress scores and gender, alcohol consumption, the presence of chronic illness, marital status, or living situation ($p>0.05$). However, it was observed that participants who smoked had significantly higher job stress scores compared to non-smokers ($p=0.045$). Additionally, participants who worked only during the day had significantly lower job stress scores than other participants ($p=0.025$).

A positive and statistically significant correlation was found between BMI and Emotional Eating Scale (EES) scores ($r=0.229$, $p<0.05$). This indicates that as BMI increases, the score on the Emotional Eating Scale also increases. However, the correlation between BMI and the scores from the subscales of the Job Stress Scale was not statistically significant. The analysis of factors affecting the KID-MED scores (Table 6) revealed no significant relationship between KID-MED scores and gender, alcohol consumption, or the presence of chronic illness ($p>0.05$). However, participants who smoked had significantly lower KID-MED scores compared to non-smokers ($p=0.013$). Additionally, married participants had significantly higher KID-MED scores compared to unmarried participants ($p=0.037$). Furthermore, participants who worked only during the day had significantly higher KID-MED scores than those with other work schedules ($p<0.001$). Finally, participants who lived alone had significantly lower KID-MED scores compared to those living with family or friends ($p=0.041$).

4. Discussion

Hospital employees work in a stressful environment characterized by a heavy workload, long and sometimes shift-based working hours, and high levels of responsibility. This stress can influence individuals' health behaviors, particularly their nutritional habits. Job stress may restrict healthy food choices and increase emotional eating behaviors. Over time, this can lead to a decline in diet quality and an elevated risk of chronic diseases such as obesity and diabetes. This study aims to examine the effects of job stress on diet quality and emotional eating, with the goal of raising awareness and informing intervention strategies to improve the quality of life for healthcare workers.

According to the Emotional Eating Scale (EES) scores, only 28.3% of the participants were classified as non-emotional eaters, while the rest were determined to be emotional eaters to varying degrees. It was observed that participants who worked only during the day had significantly lower EES scores compared to

Table 6. T-Test results for factors affecting KID-MED scores

		N	*KID-MED Mean Score ±Std. Dev.*	*t*	*p*
Gender	Male	112	4.98±2.82	-0.200	0.842
	Female	160	5.05±2.71		
Smoking	Yes	120	4.56±2.77	-2.492	**0.013***
	No	152	5.39±2.69		
Alcohol Consumption	Yes	125	5.06±2.71	0.187	0.852
	No	147	4.99±2.79		
Chronic Illness	Yes	71	5.56±2.59	1.948	0.052
	No	200	4.83±2.79		
Marital Status	Married	129	5.39±2.76	2.093	**0.037***
	Not Married	143	4.69±2.71		
Work Schedule	Daytime	150	5.56±2.60	3.654	**<0.001***
	Shift Work	122	4.36±2.80		
Living Situation	With Family/Friends	232	5.16±2.72	2.057	**0.041***
	Alone	40	4.20±2.79		

* $p<0.05$

those with other work schedules (night, mixed, shift work) (p=0.021). Similarly, in a study by Akkuş and Mermer (2022), it was found that individuals working in shifts were more likely to lack control over their eating compared to daytime workers, and their emotional eating scores during meals were higher (p<0.05). Another study by Vidafar et al. (2020) showed that among shift workers, poor sleep quality and short sleep duration were associated with increased food cravings, while poor sleep hygiene and quality were linked to a higher appetite for palatable foods (greater hedonic drive). Similarly, in the study conducted by Erden et al., shift work was associated with an increase in emotional eating, consistent with our findings.The findings of the studies confirm that shift work tends to increase emotional eating as well as cause disruptions in sleep quality and patterns.

In our study, although not statistically significant, EES scores were found to be higher in women, and a significant positive correlation was observed between EES scores and both BMI and body weight (p<0.001). Similar to our findings, İbrahimova (2020) and Akpınar (2019) reported no significant association between emotional eating scores and gender. In contrast, Özkan and Bilici (2018) noted that men had significantly higher "Emotional Eating" scores compared to women. In Sağlam's (2021) study, men were found to have higher "Emotional Eating" scores but lower scores in "Eating Control," "Awareness," and "Eating Discipline" compared to women. Additionally, Barak et al. (2021) found that emotional eating scores were higher in women. Our study also revealed a statistically significant difference in BMI between non-emotional eaters and both emotional eaters (p<0.001) and highly emotional eaters (p=0.021), with the highest BMI values observed in the highly emotional eater group. Similar to our findings, studies by Bilici et al. (2019) and Spinosa et al. (2019) also reported a positive correlation between BMI and EES scores. Various studies have shown that emotional eating disorders are more prevalent in obese individuals (43.5%) compared to those of normal weight (33.5%) and underweight (18.4%) (Madali et al., 2021). Furthermore, it was found that emotional eating disorders, independent of depressive symptoms, led to higher increases in BMI only in women (Van Strier et al., 2016). Studies indicate that women are more sensitive to emotional eating and that an increase in emotional eating is accompanied by an increase in BMI. However, in our study, no significant relationship was found between EES scores and gender.

The relationship between stress and eating behavior is well-established, with studies demonstrating that stress leads to changes in food consumption among adults (Hill et al., 2022; Dakanalis et al., 2023). The stress-induced eating response causes an increase in the consumption of energy-dense and highly palatable foods as a coping mechanism. In our study, a negative correlation was found between workload scores and Emotional Eating Scale (EES) scores, indicating that as workload increased, emotional eating decreased. Additionally, the negative and significant correlation between decision latitude scores and EES scores suggests that as decision latitude increased, emotional eating scores decreased. Similarly, the negative and statistically significant correlation between social support scores and EES scores indicates that as social support increased, emotional eating scores decreased. Güneşer and Atalay (2020) also reported that employees with higher levels of job stress had higher emotional eating scores.

In a study comparing the health behaviors of medical students, residents, and senior physicians, it was found that residents had the poorest dietary habits, while students exhibited the best. However, a higher proportion of physicians, compared to students, reported perceiving their health as poorer (Wilf-Miron et al., 2021). The study concluded that the healthy lifestyle of medical students deteriorates as they transition into residency, primarily due to increased emotional stress and workload. In the analysis of factors affecting job stress subscale scores, it was found that participants who worked only during the day had significantly lower job stress scores than other participants, and that smokers had significantly higher job stress scores compared to non-smokers. A similar study also reported that participants who worked only during the day had significantly lower job stress scores than other participants (Güneşer ve Atalay, 2020).

In a study examining the effects of the COVID-19 pandemic on the physical and mental health of healthcare workers in intensive care units, it was found that ¾ of the participants experienced a heavy workload, and the majority showed signs of poor sleep quality, depression, anxiety, and burnout. Additionally, deteriorations in mental health were accompanied by decreases in serum vitamin levels (B12 and D) and an increase in smoking (Duru, 2022). In another study examining the relationship between perceived stress and emotional eating in adults during the COVID period, it was found that individuals with perceived stress were more likely to be emotional eaters and were particularly sensitive to weight gain (Carpio-Arias et al., 2022). Klatzkin et al. (2019) investigated whether perceived life stress or cognitive restraint increased snack consumption under stress, finding that perceived life stress amplified the hyperphagic effects of stress-induced negative affect.

Both the findings of our study and the literature suggest that the impact of intense and prolonged stress on hedonic, emotional, or homeostatic eating behaviors may vary depending on an individual's physiological, psychological, and environmental factors. Heavy workloads can influence individuals' stress-coping strategies, leading them to engage in more hedonic and emotional eating behaviors as a form of self-reward. This behavior is often associated with a search for "escape" or "reward," frequently resulting in increased consumption of unhealthy foods, such as snacks and junk food. Individuals who constantly feel under pressure due to heavy workloads may seek to meet their emotional needs through physiological eating. Moreover, long working hours can limit the time and energy available for preparing healthy meals, pushing individuals towards easily accessible, often nutritionally poor but highly palatable foods. However, while short-term stressors may increase emotional eating, prolonged and intense stress exposure can shift eating behaviors from hedonic cravings to the satisfaction of homeostatic needs. This type of response may vary depending on an individual's coping mechanisms, environmental conditions, and the nature of the stressor (Reichenberger et al., 2020; Pannicke et al., 2021). In "survival-oriented situations" (e.g., war, natural disasters, or famine), people are more likely to prioritize their basic needs. Such stress can lead individuals to adopt a rational approach to eating in order to maintain essential life functions. Energy storage or maintaining physical resilience becomes a priority. Indeed, our study's finding that emotional eating decreases as workload increases supports the notion that stress induced by heavy workloads shifts individuals away from pleasure-oriented eating behaviors and towards meeting their fundamental survival needs.

There was no statistically significant correlation between BMI and scores from the subscales of the Job Stress Scale in our study. However, a study by Özcan and Kızıl (2020) found that staff members' workload scores were negatively correlated with BMI and waist circumference (Özcan and Kızıl, 2020).

In our study, 27.6% of the participants were found to have very poor diet quality according to their KID-MED scores, while 46.3% had diet quality that needed improvement. In a study by Carlos et al. (2020), low

adherence to the Mediterranean diet (15.5%) and significant levels of emotional eating (29%) and anxiety (23.6%) were reported among university students. The correlation between KID-MED scores and Emotional Eating Scale (EES) scores in our study was not statistically significant ($p>0.05$), while smokers had significantly lower KID-MED scores compared to non-smokers ($p=0.013$). A study conducted by Gençalp in 2020 among first aid and emergency care students similarly found that non-smokers had significantly higher KID-MED scores than smokers, supporting our findings (Gençalp, 2020).

Participants who were married had significantly higher KID-MED scores than those who were unmarried ($p=0.037$). However, a study by Ciğerli (2023) found no significant difference in KID-MED scores between married and unmarried individuals in terms of marital status (Ciğerli, 2023).

In our study, participants who worked only during the day had significantly higher KID-MED scores compared to other participants ($p<0.001$). In contrast, a study by Leyva-Vela et al. (2021) among nurses found no significant relationship between shift work and KID-MED scores (Leyva-Vela et al., 2021). Similarly, Radoncic (2023) found that employees working shifts had lower KID-MED scores (Radoncic, 2023).

In our study, participants who lived alone had significantly lower KID-MED scores compared to those living with family or friends ($p=0.041$). This finding highlights the potential impact of social support on nutrition. However, a study by Gümüş and Yardımcı (2020) among university students found no significant relationship between KID-MED scores and the people participants lived with (Gümüş and Yardımcı, 2020).

5. Conclusions

This cross-sectional study, which investigated the relationship between job stress and emotional eating among hospital employees, found that participants working only during the day had lower Emotional Eating Scale (EES) scores compared to other participants, and a positive correlation was observed between BMI and EES scores. No significant relationship was found between KID-MED scores and emotional eating, but it was concluded that increased decision latitude and social support reduced emotional eating behavior. While no significant relationship was found between job stress scores and emotional eating, it was observed that smokers and those working in shifts or mixed schedules experienced higher job stress. Additionally, an increase in job stress was found to be associated with lower KID-MED scores, indicating poorer adherence to the Mediterranean diet.

On the other hand, the significant inverse relationship found between workload and emotional eating scores suggests that as the intensity and duration of stress increase, individuals may regulate their eating behaviors based on an evolutionary logic. This shift indicates a movement away from emotional eating towards meeting homeostatic needs, prioritizing survival, and ultimately settling for what is available.

Factors influencing eating behavior under stress include an individual's coping mechanisms and whether their food choices are driven by emotional or physiological needs. While some individuals are more prone to emotional eating as a way of coping with stress, others may adopt goal-oriented eating and prioritize healthier food choices in managing stress.

These behaviors can vary significantly among individuals. In extreme situations such as war or disasters, some people may fully adopt homeostatic eating behaviors, while others may continue to engage in hedonic or emotional eating. In other words, certain individuals may view eating as a tool for "relaxation" and turn to sugary or high-calorie foods under stress.

In summary, the tendency of individuals under intense stress to shift towards homeostatic eating aligns with an evolutionary rationale, potentially enhancing their adaptability to survival requirements. However, it should be noted that this process is influenced by personal and environmental factors, and behavioral responses can differ significantly across individuals.

Based on our findings and the existing literature, it can be concluded that increases in psychological distress, stress, and depressive symptoms are associated with an increased risk of emotional eating, often accompanied by an increase in BMI. Furthermore, stress negatively impacts diet quality. Developing positive coping mechanisms for managing stress and providing education on healthy eating may help prevent the prevalence of emotional eating. Future studies could focus on better elucidating the underlying mechanisms between mental health conditions such as stress, anxiety, and depression, and their relationships with emotional eating, overweight/obesity, and dietary patterns. Such research would provide valuable insights for designing effective interventions in this area.

Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

A. Özenoğlu (0000-0003-3101-7342): *Conceptualization; original draft; methodology; review and editing*.
C. Erkul (0000-0003-0940-1129): *Resources; methodology; writing, and editing*.

References

Akkuş, Ö. Ö., & Mermer, M. (2022). Vardiyalı çalışan bireylerde hedonik açlık, yeme arzusu ve obezite riski: Kesitsel bir çalışma. *Mersin Üniversitesi Sağlık Bilimleri Dergisi, 15*(2), 370-381.

Akpınar, B. (2019). *Obezite ve diyabette yeme farkındalığı.* [Unpublished Master's thesis]. Okan University.

Arslan, M., & Aydemir, İ. (2019). Relationship between emotional appetite, eating attitudes, sleep quality, and body mass index in healthcare workers: a multi-centre study. *Psychiatry and Clinical Psychopharmacology, 29*(3), 346-353.

Arslantaş, H., Dereboy, F., Yüksel, R., & İnalkaç, S. (2019). Duygusal yeme ölçeği'nin Türkçe çevirisinin geçerlik ve güvenirlik çalışması. *Türk Psikiyatri Dergisi, 30*, 1-10.

Bilici, S., Ayhan, B., Karabudak, E., & Koksal, E. (2020). Factors affecting emotional eating and eating palatable food in adults. *Nutrition Research and Practice, 14*(1), 70-75.

Çamkerten, S., Tatar, A., & Saltukoğlu, G. (2020). Sağlık çalışanlarının stres düzeylerinin incelenmesi. *Sağlık Akademisyenleri Dergisi, 7*(4), 257-265.

Carlos, M., Elena, B., & Teresa, I. M. (2020). Are adherence to the Mediterranean diet, emotional eating, alcohol intake, and anxiety related in university students in Spain?. *Nutrients, 12*(8), 2224.

Carpio-Arias, T. V., Manzano, A. M. S., Sandoval, V., Vinueza-Veloz, A. F., Betancourt, A. R., Ortíz, S. L. B., & Vinueza-Veloz, M. F. (2022). Relationship between perceived stress and emotional eating. A cross sectional study. *Clinical Nutrition ESPEN, 49*, 314-318.

Ciğerli, G. T. T. (2023). *Mudanya'da yaşayan yetişkinlerin beslenme alışkanlıkları, Akdeniz diyet skoru ve antropometrik ölçümler arasındaki ilişki* [Unpublished Master's thesis]. Bursa Uludağ University.

Dakanalis, A., Mentzelou, M., Papadopoulou, S. K., Papandreou, D., Spanoudaki, M., Vasios, G. K., ... & Giaginis, C. (2023). The association of emotional eating with overweight/obesity, depression, anxiety/stress, and dietary patterns: a review of the current clinical evidence. *Nutrients, 15*(5), 1173.

Demiral, Y., Ünal, B., Kılıç, B., Soysal, A., Bilgin, A. C., Uçku, R., & Theorell, T. (2007). İş stresi ölçeğinin İzmir Konak Belediyesi'nde çalışan erkek işçilerde geçerlik ve güvenilirliğinin incelenmesi. *Toplum Hekimliği Bülteni, 26*(1), 11-18.

Duru H. (2022). The Continuing Effect of COVID-19 Pandemic on Physical Well-Being and Mental Health of ICU Healthcare Workers in Turkey: A Single-Centre Cross-Sectional Later-Phase Study. *J Intensive Care Med., 37*(9), 1206-1214. https://www.doi.org/10.1177/08850666211070740.

Elran Barak, R., Shuval, K., Li, Q., Oetjen, R., Drope, J., Yaroch, A. L., ... & Harding, M. (2021). Emotional eating in adults: The role of sociodemographics, lifestyle behaviors, and self-regulation—findings from a US National Study. *International Journal of Environmental Research and Public Health, 18*(4), 1744.

Erden, S. C., Yilmaz, B. K., Kozaci, N., Uygur, A. B., Yigit, Y., Karakus, K., ... & Ersahin, D.A. (2023). The Relationship Between Depression, Anxiety, and Stress Levels and Eating Behavior in Emergency Service Workers. *Cureus, 15*(2), e35504.

Garaulet, M., Canteras, M., Morales, E. (2012). Validation of a questionnaire on emotional eating for use in cases of obesity; the Emotional Eater Questionnaire (EEQ). *Nutr. Hosp., 27,* 645-51.

Gençalp, D. K. (2020). Covid-19 salgını döneminde ilk ve acil yardım öğrencilerinin beslenme alışkanlıkları ve fiziksel aktivite durumlarının değerlendirilmesi. *Paramedik ve Acil Sağlık Hizmetleri Dergisi, 1*(1), 1-15.

Gümüş, A. B., & Yardımcı, H. (2020). Üniversite öğrencilerinin günlük besin ögesi alımlarının Akdeniz diyeti kalite indeksi (KIDMED) ile ilişkisi. *Adıyaman Üniversitesi Sağlık Bilimleri Dergisi, 6*(2), 167-173

Güneşer, R., & Atalay, E. (2020). Ambulans servisi çalışanlarının uyku kalitesi, iş stresi ve beslenme davranışlarının değerlendirilmesi. *Hastane Öncesi Dergisi, 5*(2), 143-156.

Hill, D., Conner, M., Clancy, F., Moss, R., Wilding, S., Bristow, M., & O'Connor, D. B. (2022). Stress and eating behaviours in healthy adults: a systematic review and meta-analysis. *Health Psychology Review, 16*(2), 280-304.

İbrahimova, A. (2020). *Üniversite öğrencilerinin yeme farkındalığına göre aşırı besin isteği, iştah ve beslenme durumlarının değerlendirilmesi.* [Unpublished Master's Thesis] Başkent University.

Klatzkin, R. R., Dasani, R., Warren, M., Cattaneo, C., Nadel, T., Nikodem, C., & Kissileff, H. R. (2019). Negative affect is associated with increased stress-eating for women with high perceived life stress. *Physiology & Behavior, 210,* 112639.

Klingberg, S., Mehlig, K., Johansson, I., Lindahl, B., Winkvist, A., & Lissner, L. (2019). Occupational stress is associated with major long-term weight gain in a Swedish population-based cohort. *International archives of occupational and environmental health, 92*(4), 569-576.

Konttinen, H. (2020). Emotional eating and obesity in adults: the role of depression, sleep and genes. *Proceedings of the Nutrition Society, 79*(3), 283-289.

Leyva-Vela, B., Reche-García, C., Hernández-Morante, J. J., Martínez-Olcina, M., Miralles-Amorós, L., & Martínez-Rodríguez, A. (2021). Mediterranean Diet Adherence and Eating Disorders in Spanish Nurses with Shift Patterns: A Cross-Sectional Study. *Medicina, 57*(6), 576.

Madalı, B., Alkan, Ş. B., Örs, E. D., Ayrancı, M., Taşkın, H., & Kara, H. H. (2021). Emotional eating behaviors during the COVID-19 pandemic: A cross-sectional study. *Clinical nutrition ESPEN, 46,* 264-270.

Özcan, Ç., & Kızıl, M. (2020). İş stres düzeyinin çalışanlarda beslenme durumu, diyet kalitesi ve antropometrik ölçümlere etkisinin değerlendirilmesi. *Beslenme ve Diyet Dergisi, 48*(3), 56-64.

Pannicke, B., Kaiser, T., Reichenberger, J., & Blechert, J. (2021). Networks of stress, affect and eating behaviour: anticipated stress coping predicts goal-congruent eating in young adults. *International Journal of Behavioral Nutrition and Physical Activity, 18*, 1-14.

Radoncic, A. (2023). *Hemşirelerde nöbet tutma durumunun stres, uyku ve beslenme davranışları üzerinde etkisi* [Unpublished Master's thesis]. Trakya University.

Reichenberger J, Schnepper R, Arend A-K, Blechert J. (2020). Emotional eating in healthy individuals and patients with an eating disorder: evidence from psychometric, experimental and naturalistic studies. *Proceedings of the Nutrition Society*, *79*(3), 290-299. https://www.doi.org/10.1017/S0029665120007004

Sağlam, E. (2021). *Yetişkin bireylerin yeme farkındalıkları, uyku kaliteleri ve gece yeme sendromu açısından değerlendirilmesi* [Unpublished Master's Thesis]. Selçuk University.

Şahingöz, S. A., Özgen, L., & Yalçın, E. (2019, October 2-6). Akdeniz Diyet Kalitesi Ölçeğinin (Mediterranean Diet Quality-KIDMED) Geçerlik ve Güvenirlik Çalışması. Proceedings Book of 5 th International Eurasian Congress on Natural Nutrition, Healthy Life & Sport, 1078-1088. Ankara/Turkiye.

Serra-Majem, L., Ribas, L., Ngo, J., Ortega, R. M., García, A., Pérez-Rodrigo, C., & Aranceta, J. (2004). Food, youth and the Mediterranean diet in Spain. Development of KIDMED, Mediterranean Diet Quality Index in children and adolescents. *Public Health Nutrition, 7*(7), 931–935.

Spinosa, J., Christiansen, P., Dickson, J. M., Lorenzetti, V., & Hardman, C. A. (2019). From socioeconomic disadvantage to obesity: the mediating role of psychological distress and emotional eating. *Obesity, 27*(4), 559-564.

van Strien, T., Konttinen, H., Homberg, J. R., Engels, R. C., & Winkens, L. H. (2016). Emotional eating as a mediator between depression and weight gain. *Appetite, 100,* 216-224.

Vidafar, P., Cain, S. W., & Shechter, A. (2020). Relationship between sleep and hedonic appetite in shift workers. *Nutrients, 12*(9), 2835.

Wilf-Miron R, Kagan I, Saban M. (2021). Health behaviors of medical students decline towards residency: how could we maintain and enhance these behaviors throughout their training. *Isr J Health Policy Res., 10*(1), 13. https://www.doi.org/10.1186/s13584-021-00447-z.

Yücel, Y. (2022). İşyeri Stresi. *Çalışma ve Toplum*, *3*(74), 1959-1988.

Consumption Behaviors and Factors Influencing Preferences for Instant Noodles: The Case of Türkiye

Cihat Güner[1,*] Hakan Başdoğan[1], and Abdullah Eriş[1]

[1] *Erisler Gida A.Ş., Research And Devolopment Center, Ali Osman Çelebi Bul., Çorlu No:227, 59850, Tekirdağ, Türkiye*

Abstract

This study aims to examine the instant noodle consumption preferences, packaging expectations, and purchasing tendencies of consumers living in Türkiye, where convenience foods are increasingly popular. The research targeted 3,134 individuals aged between 18 and 44 from socio-economic groups including A, B, C1, and C2, reaching a sample of 700 participants who had purchased instant noodles within 2023. Data were collected through structured and detailed surveys, which were deepened with face-to-face interviews, and analyzed using frequency analysis, cross-tabulations, and other quantitative techniques with SPSS. The findings indicate that most participants prefer instant noodles for their convenience and affordability, with cup noodles being popular for ease of use. Vegetable, barbecue, and seafood flavors rank among the top choices, while there is a growing interest in low-sodium and high-nutrient noodle options. These results both enrich the academic literature and provide valuable insights for manufacturers to tailor product development strategies aligned with market demands.

Keywords: Noodles, Consumption Preferences, Flavor Trends, Market Analysis, Consumer Behavior.

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1. Introduction

Noodles have emerged as a practical and widely consumed food product, appealing to a broad range of consumers worldwide. Traditionally a staple in countries like Japan, South Korea, and China, noodles have rapidly gained popularity in global markets due to their variety of flavors and packaging options (Kim & Park, 2019). In Türkiye, interest in noodles has grown significantly in recent years, particularly among younger consumers (Anderson & Anderson, 2020). The increasing preference for convenient and economical food solutions among individuals with fast-paced lifestyles explains this rising interest (Wang & Chen, 2020).

Packaging types play a crucial role in consumer preferences for instant noodles. Park and Yoo's (2021) study highlighted that convenient packaging, such as cup noodles, significantly enhances consumption frequency. In Türkiye, the high preference for cup noodle packaging reflects the impact of convenience on consumption habits. Moreover, economic factors lead to the preference for single-pack noodles, illustrating the influence of packaging options across different socio-economic groups (Solomon, 2018).

In recent years, the rising trend of healthy living has influenced consumer choices, particularly among young adults who increasingly seek nutritious and functional food products. Growing health awareness has driven demand for low-sodium, nutrient-rich noodle options (Cheng, 2021). In Türkiye, the proliferation of health-conscious attitudes has steered consumers toward healthier products, compelling the food industry to innovate and develop healthier offerings (Yılmaz & Demir, 2021).

Flavor diversity also plays a pivotal role in consumer preferences for noodles. In Türkiye, flavors such as vegetable, barbecue, and seafood resonate with traditional Turkish palates, indicating a preference for familiar taste profiles (Kara & Gürbüz, 2019). Thus, offering diverse flavors that cater to varying taste preferences is a key factor influencing noodle consumption across different consumer groups.

The objective of this study is to provide a comprehensive analysis of the consumption preferences for instant noodles among individuals aged between 18 and44 in Türkiye, focusing on packaging

* Corresponding Author: Cihat Güner
Email: cihat.guner@erislergida.com.tr
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and flavor choices as well as interest in healthier products. Additionally, the study examines how these preferences are shaped by demographic factors such as socio-economic status, age, and gender. Based on data gathered from a large-scale survey of 3.134 individuals, a sample group of 700 respondents who had consumed instant noodles in the past year was identified. Data were collected through face-to-face interviews using a structured questionnaire and analyzed using frequency analysis, cross-tabulations, and correlation methods (Hair et al., 2018; Pallant, 2020). This research aims to provide valuable insights into Türkiye's rapidly growing noodle market and the underlying dynamics of consumer preferences, offering significant contributions to the food industry.

2. Methods

This study is a quantitative research based on a survey model aimed at examining the instant noodle consumption preferences, packaging expectations, and purchasing tendencies of consumers in Türkiye across socio-economic groups. To derive meaningful insights into consumer preferences in Türkiye's rapidly growing instant noodle market, data were collected from participants aged 18–44 in the A, B, C1, and C2 socio-economic groups. The sampling process prioritized reaching these key groups, identified using data from the Turkish Statistical Institute (TÜİK). A total of 3,134 individuals were screened, and a sample of 700 participants who had consumed instant noodles within the past year was selected. The final sampling rate was determined to be 22.3% (Hair et al., 2018). A maximum variation sampling method was employed to ensure an equitable distribution of socio-economic groups (Bryman, 2016).

The scale used in this research was developed based on an extensive literature review of consumer behavior studies. It includes items related to noodle consumption, packaging preferences, flavor preferences, and purchase motivations. The scale items were adapted from examples in previous studies and tailored to reflect the characteristics of Turkish consumers (DeVellis, 2016). Questions were designed in both open- and closed-ended formats to capture diverse aspects of consumer behavior, such as demographic characteristics, consumption and purchase frequencies, packaging preferences, and favorite noodle varieties (Chan & Tan, 2019). Content validity was ensured through expert reviews from researchers specializing in consumer behavior and packaging preferences, and the scale was revised accordingly (Pallant, 2020).

The data collection process was conducted through face-to-face interviews. Participants were selected on a voluntary basis, and anonymity was maintained. To evaluate the reliability of the scale, Cronbach's Alpha was calculated and found to be 0.85, indicating a high level of reliability (Tavakol & Dennick, 2011). A small pilot study was conducted to assess the clarity and applicability of the scale items, and necessary adjustments were made based on the feedback received.

Data analysis was performed using SPSS software. Descriptive analyses, including frequency and percentage distributions, were conducted to summarize demographic variables (Pallant, 2020). Relationships between packaging preferences and variables such as age and gender were examined using cross-tabulations and chi-square tests. Correlational analyses were conducted to explore relationships between variables such as consumption frequency, flavor preference, and packaging choice (Hair et al., 2018). Regression analyses were applied to identify factors influencing purchasing frequency (Park & Yoo, 2021). ANOVA tests were used to determine differences between groups, and non-parametric tests were employed in cases where data did not exhibit normal distribution. The findings reveal significant variations in consumer behavior based on socio-economic status, age, and gender (Bryman, 2016; Solomon, 2018).

3. Results

A total of 3,134 individuals were screened to identify 700 participants who had purchased instant noodles. This corresponds to a consumption penetration rate of 22.3% among the 18 and 44 age group in the A, B, C1, and C2 socio-economic categories. Eight out of ten respondents reported purchasing instant noodles within the past year. In terms of packaging preferences, cup noodles emerged as the most favored type among consumers, with 45% of respondents selecting this option. Single-pack noodles followed at 30%, while the proportion of consumers purchasing both cup and single-pack noodles significantly exceeded the 15% preference rate for 5- or 10-pack noodles ($p < 0.05$). These findings suggest that individual serving sizes are more popular among consumers. When categorized by gender, male consumers predominantly preferred cup noodles, whereas female consumers tended to favor both cup and single-pack noodles. Detailed packaging preferences by gender are presented in Table 1. Analyzing packaging preferences by socio-economic status revealed differences between groups. Consumers in the AB group were more likely to choose cup and

single-pack noodles, while those in the C1, C2 group showed a stronger preference for cup noodles. Additional socio-economic-based preferences are detailed in Table 1. Age-based categorization highlighted that consumers aged 18–29 predominantly preferred cup noodles, those aged 30–39 favored both cup and single-pack noodles, and those aged 40–44 leaned toward 5- or 10-pack formats. Detailed packaging preferences by age group are also presented in Table 1.

An analysis of the frequency of purchasing and consuming cup noodles revealed that the majority of consumers purchase and consume cup noodles once a week. Detailed frequencies of purchasing and consumption behaviors are provided in Table 2. Additionally, when respondents were asked how many packages of cup noodles they typically purchase per shopping trip, the majority indicated that they buy one package. For single-pack noodles, a similar trend was observed, with the majority of consumers purchasing and consuming single-pack noodles once a week. Detailed frequencies for single-pack noodles are presented in Table 3. When asked about the average number of single-pack noodles purchased per shopping trip, most consumers reported buying two packages. The analysis of purchasing days revealed that the vast majority of consumers buy instant noodles during weekdays. Among weekdays, Wednesday was

Table 1. Noodle Packaging Preferences by Participant Categories

	Cup (%)	*Single Pack (%)*	*Both Cup and Single Pack (%)*	*5-Pack or 10-Pack (%)*
Gender				
Male	43.1	23.4	18.3	15.1
Female	39.7	25.4	16.3	18.6
Socio-Economic Status				
AB	38.8	25.6	17.1	18.6
C1C2	42	24.2	17.3	16.5
Age				
18-29	44.7	24	14.8	16.5
30-39	39.1	24	19.4	17.6
40-44	33.3	28.6	17.5	20.6

Table 2. Frequency of Noodle Purchase and Consumption by Participants

	Once every 3 months or less frequently (%)	*Once every 2 months* (%)	*Once a month* (%)	*Once every 15 days* (%)	*Once a week* (%)	*More than once a week* (%)
Noodle Purchase Frequency						
Cup	9.6	13.6	24.3	19.7	27.3	6.1
Single Pack	14.2	9.3	22.5	22.8	27.3	3.8
Noodle Consumption Frequency						
Cup	8.0	12.7	23.6	19.5	29.2	7.1
Single Pack	12.5	10.4	21.1	26.0	26.0	4.2

Table 3. Quantity of Noodles Purchased by Participants in a Single Shopping Trip

	6 or more packs (%)	*5 packs (%)*	*4 packs (%)*	*3 packs (%)*	*2 packs (%)*	*1 pack (%)*
Cup	10.0	10.9	11.2	18.5	19.7	29.7
Single Pack	10.7	20.4	12.1	24.9	22.1	9.7

identified as the most common day for purchasing noodles. Detailed purchasing trends by day are illustrated in Figure 1.

An analysis of the consumption and preference for instant noodle varieties revealed that vegetable-flavored noodles were the most frequently consumed and the most liked by consumers. Among the most frequently consumed varieties, vegetable-flavored noodles ranked first, accounting for 19.1% of consumption. This was followed by chicken flavored noodles at 14.0%, and curry-flavored and spicy tomato-flavored noodles, both at 9.6%.

Similarly, in terms of the most liked varieties, vegetable-flavored noodles were ranked highest, with 21.0% of respondents favoring this flavor. Chicken-flavored noodles followed at 16.7%, and curry-flavored noodles ranked third at 12.1%. These results align with the consumption trends observed, as illustrated in Figure 2.

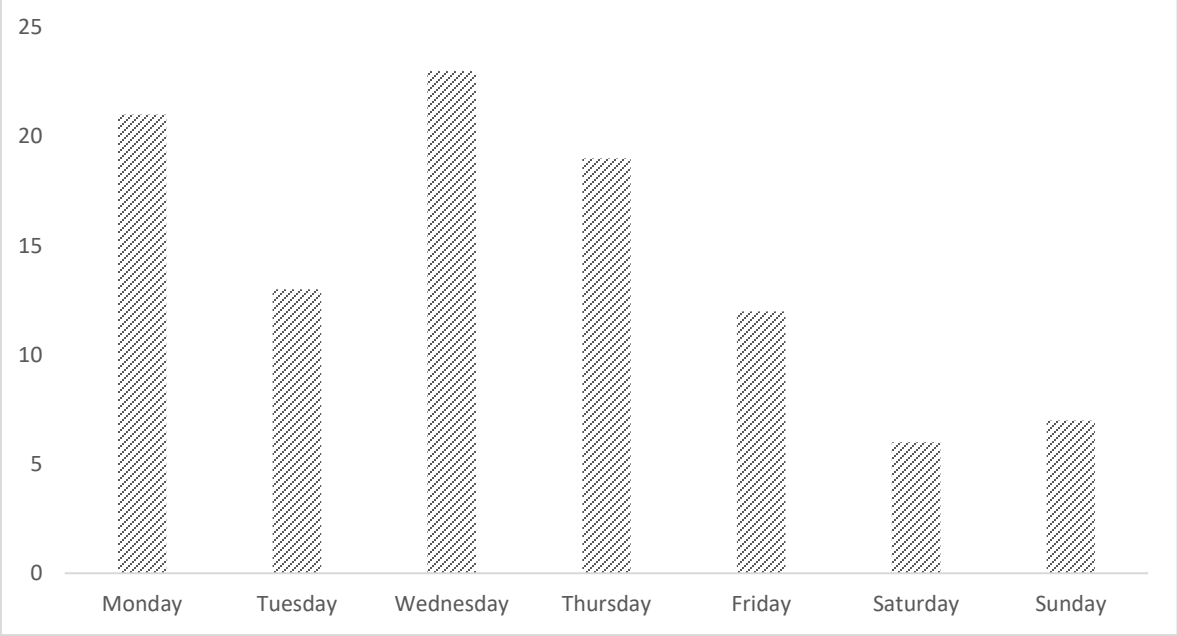

Figure 1. Preferred days for noodle purchases by participants

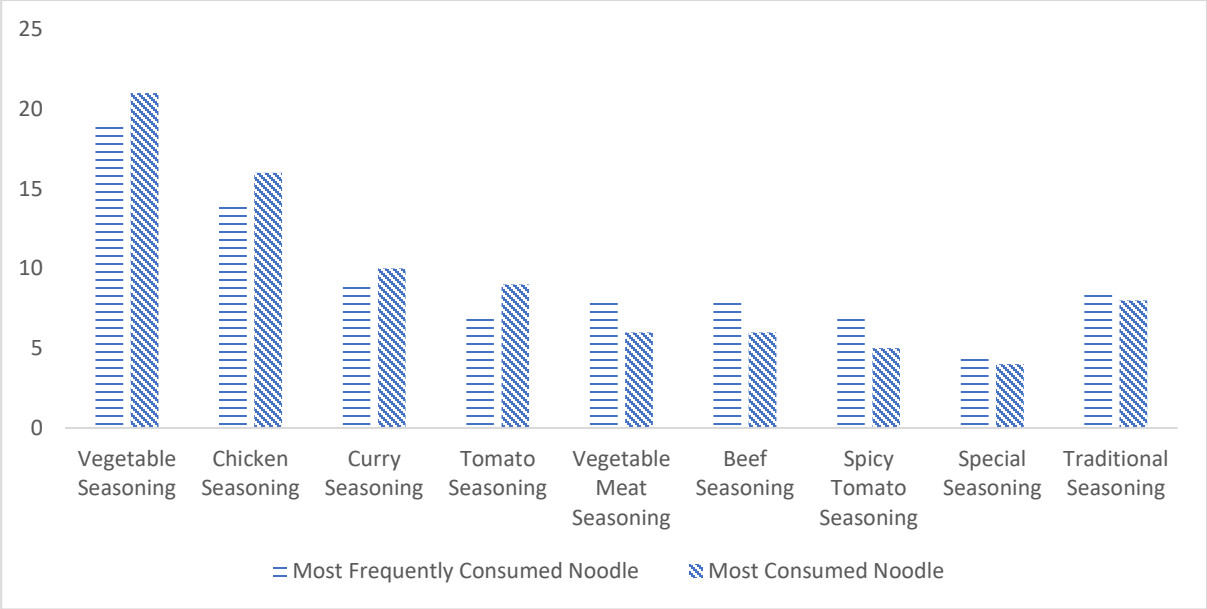

Figure 2. Consumption and preference trends for noodle varieties

Table 4. Most Frequently Consumed Noodle Varieties

	Vegetable Seasoning (%)	*Chicken Seasoning (%)*	*Curry Seasoning (%)*	*Tomato Seasoning (%)*	*Vegetable-Meat Seasoning (%)*	*Beef Seasoning (%)*	*Spicy Tomato Seasoning (%)*	*Special Seasoning (%)*
Gender								
Male	16.6	12.9	9.1	4.9	6.3	5.7	10.3	4.0
Female	16.6	11.4	7.4	8.6	6.9	8.3	6.3	8.3
Age								
18-29	21.8	12.5	10.0	8.1	5.0	6.9	10.6	7.8
30-39	13.7	14.6	10.7	6.0	10.7	10.3	9.9	7.3
40-44	26.9	21.2	1.9	13.5	6.9	5.8	1.9	1.9

Table 5. Most Preferred Instant Noodle Varieties

	Vegetable Seasoning (%)	*Chicken Seasoning (%)*	*Curry Seasoning (%)*	*Tomato Seasoning (%)*	*Vegetable-Meat Seasoning (%)*	*Beef Seasoning (%)*	*Spicy Tomato Seasoning (%)*	*Special Seasoning (%)*
Gender								
Male	16.6	14.3	10.9	7.4	4.9	6.3	6.3	4.6
Female	19.7	14.6	7.1	9.1	6.0	5.4	5.1	5.1
Age								
18-29	22.2	14.7	11.3	9.7	6.9	5.3	6.3	5.9
30-39	18.5	18.9	10.3	7.3	6.4	9.0	7.3	6.4
40-44	25.0	19.2	5.8	19.2	1.9	5.8	5.8	0.3

An analysis of the most frequently consumed instant noodle varieties by gender revealed similar preferences among men and women. Vegetable-flavored noodles were the most frequently consumed variety for both genders. Detailed proportions of other noodle preferences by gender are presented in Table 4. When categorized by age, preferences showed distinct patterns. Consumers aged 18–29 predominantly favored vegetable-flavored noodles, those aged between 30 and 39 preferred chicken-flavored noodles, and those aged 40–44 returned to vegetable-flavored noodles as their top choice. Detailed age-based preferences are also presented in Table 4. In terms of the most liked instant noodle varieties by gender, vegetable-flavored noodles remained the most popular choice among both men and women. Male consumers ranked chicken, curry, tomato, and beef-flavored noodles as their subsequent preferences, while female consumers favored chicken, tomato, curry, and vegetable-meat-flavored noodles after vegetable-flavored noodles. Detailed proportions of these preferences are outlined in Table 5. When analyzed by age, similar trends emerged for the most liked varieties. Vegetable-flavored noodles were the most liked among consumers aged between 18 and 29, chicken-flavored noodles ranked highest for those aged 30–39, and vegetable-flavored noodles were again most popular among the 40–44 age group. Detailed age-based proportions for noodle preferences are provided in Table 5.

An analysis of the consumption patterns of instant noodles revealed that a significant proportion of consumers enhanced their noodles by adding additional ingredients. The most commonly added ingredient was cooked minced meat, followed by white cheese, chicken, mayonnaise, ketchup, tomatoes, eggs, and mustard sauce. Detailed proportions of these additions are presented in Figure 3A. When examining the meal contexts, one in three consumers reported consuming instant noodles as a main meal. Noodles were also frequently consumed between lunch and dinner, as well as during lunch. Other meal preferences are detailed in Figure 3B. In terms of situational contexts, the majority of consumers reported eating instant noodles when they were hungry at work or when no food was available at home, or there was insufficient time to prepare a meal. Other common situations included snacking during the day, staying late at work or the office, and watching TV. Detailed situational preferences are provided in Figure 3C.

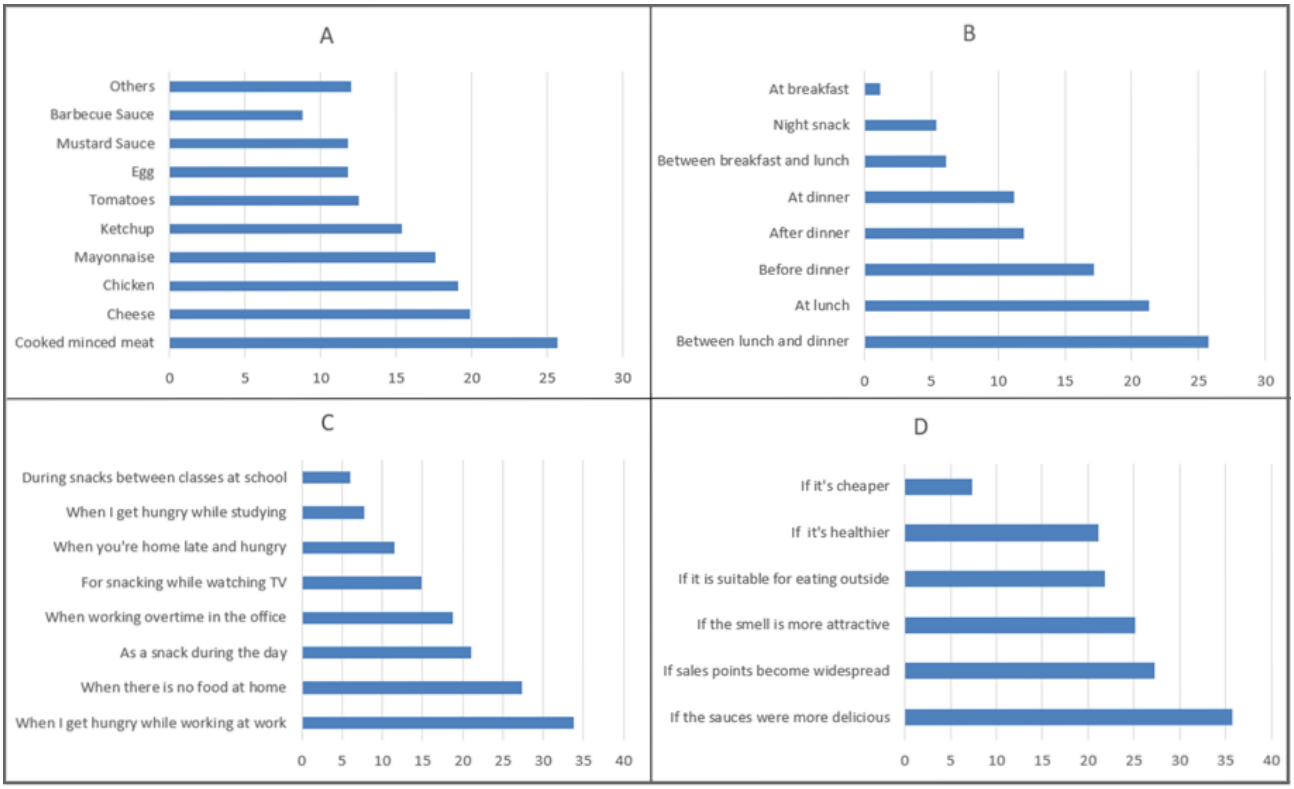

Figure 3. Noodle Consumption Preferences

When asked about conditions that would encourage increased consumption, most consumers indicated that improving the taste of sauces would make them more likely to buy instant noodles. Additional factors included increasing the availability of noodles at retail outlets, enhancing their aroma, and making them more suitable for eating outside the home. Detailed responses are shown in Figure 3D.

Consumers were also asked whether they would purchase healthier functional noodles enriched with protein, vitamins, and reduced calorie content (225 kcal per serving) while retaining the familiar noodle taste. Four out of ten consumers indicated that they would buy such products. Gender-based responses showed that 49.4% of men expressed willingness to purchase healthier noodles, compared to 44% of women. Age-based analysis revealed that 46.1% of consumers aged 18–29, 46.2% of those aged 30–39, and 52.4% of those aged 40–44 would consider purchasing these healthier options. Detailed responses by demographic categories are presented in Table 6.

Table 6. Willingness to Purchase Healthier Functional Noodles by Demographics

	Would Purchase (%)	*Would Not Purchase (%)*
Gender		
Male	49.4	50.6
Female	44.4	56.0
Age		
18-29	46.1	53.9
30-39	46.2	53.8
40-44	52.4	47,6

4. Discussion

This study contributes to the literature by examining the key motivations and packaging preferences behind instant noodle consumption in Türkiye. The findings highlight the growing importance of fast-moving consumer goods in the Turkish market. The observation that the majority of participants choose instant noodles for their convenience and affordability aligns with Wang and Chen's (2020) findings, which indicate that individuals with fast-paced lifestyles often prefer ready-to-eat foods. This demonstrates that the global trend toward practical food solutions driven by busy lifestyles is also prevalent in Türkiye.

Our study found that cup noodle packaging was the most preferred type due to its ease of use. This finding is consistent with the work of Park and Yoo (2021), which emphasizes the decisive role of food packaging

in consumer preferences. A similar trend was identified in a study conducted in the United States, where practical packaging increased consumption frequency (Kim & Lee, 2020). Thus, this study provides evidence that practical packaging is a significant factor for Turkish consumers, adding to the existing body of knowledge on the topic.

The research also shows a notable increase in demand for healthy noodle options, particularly among young adults and women. This finding aligns with Cheng's (2021) study, which highlights the rising demand for functional foods in response to increasing health-consciousness. Solomon (2018) similarly noted the prevalence of health-conscious lifestyles, particularly among young people and women. By emphasizing the interest in low-sodium and nutrient-rich noodles, our research demonstrates that Turkish consumer behavior is in harmony with global health trends (Öztürk, 2021).

Our findings on flavor preferences indicate that Turkish consumers favor traditional taste profiles. Flavors such as vegetable, barbecue, and seafood are among the most popular, while spicy and vegetable-based noodle varieties are particularly favored. These preferences are consistent with Kara and Gürbüz's (2019) findings on noodle consumption in the Turkish market. Additionally, Yılmaz and Demir (2021) highlighted young consumers' willingness to try new flavors, and our study corroborates this trend, showing that young consumers are inclined to diversify their taste experiences.

One of the unique findings of this study is the variation in packaging preferences based on socio-economic status. Consumers in the A and B socio-economic groups prefer cup noodles, suggesting that higher-income groups gravitate toward convenient solutions, a pattern supported by Bryman's (2016) research. Conversely, more affordable single-pack noodles are favored by C1 and C2 groups, highlighting the role of economic factors in packaging preferences. These findings enrich the literature by shedding light on the relationship between packaging preferences and economic status.

The study also provides insights into noodle consumption frequency. Most participants reported consuming noodles at least once a week, with consumption primarily concentrated during weekday lunch or dinner hours. This aligns with Kim and Park's (2019) findings, which emphasize young adults' preference for fast and convenient foods. In Türkiye, young adults' inclination toward quick-to-prepare meals reflects the appeal of instant noodle products as an attractive option for the younger generation.

The rising demand for healthy noodle options, particularly among young adults, underscores the need for the food industry to respond to this trend. The growing popularity of healthy and low-calorie products among Turkish consumers provides valuable data for future product development efforts. This trend, as highlighted by Yılmaz and Demir (2021), points to increasing health awareness among consumers. Manufacturers must adjust their product development strategies to cater to these demands and adapt to market shifts.

Overall, this study provides valuable insights into instant noodle consumption behaviors and preferences in Türkiye, aligning strongly with similar research in the literature. Future studies are recommended to conduct more detailed analyses of preferences across different geographic regions and socio-economic groups. Furthermore, in-depth investigations into the growing demand for healthy noodle options in Türkiye will be crucial for the food industry to meet changing consumer needs effectively.

5. Conclusion

The results of this study indicate that instant noodle consumption is widespread among the A, B, C1, and C2 socio-economic groups aged 18–44. Young and middle-aged individuals are drawn to these convenient foods due to their fast-paced lifestyles. Cup noodles are preferred for their practicality, while single-pack noodles are favored for their affordability. Most consumers eat noodles once a week, typically choosing them for weekday meals, particularly between lunch and dinner. Vegetable-flavored noodles stand out as the most popular variety, followed by barbecue, seafood, and mushroom-flavored options, which also attract significant attention. The growing trend toward healthy eating has increased demand for low-sodium and nutrient-rich noodles. Young adults and women, in particular, are showing a marked interest in healthier products, emphasizing the need for manufacturers to diversify their product portfolios to align with these preferences.

Producers should develop marketing strategies tailored to young adults and middle-aged consumers. The practicality of cup noodles should be highlighted, and portable packaging options should be expanded. To appeal to budget-conscious consumers, single-pack noodles could be offered in a variety of packaging formats. Meeting the demands of health-conscious

individuals requires the introduction of low-sodium and organic noodle options. Vegetable-flavored noodles could serve as an entry point for addressing this demand. Additionally, introducing new flavors to cater to diverse preferences, particularly those of A and B socio-economic groups, could broaden the product appeal.

To support weekday consumption patterns, practical and flavorful products should be emphasized, and campaigns encouraging regular weekly consumption should be organized. Informational campaigns highlighting the benefits of healthier noodle options can play a significant role in increasing consumer awareness and interest. Furthermore, gathering consumer feedback and integrating it into product development processes is crucial for aligning products with market demands and enhancing customer satisfaction.

This study contributes to the understanding of consumer behaviors and preferences in the instant noodle market, providing valuable insights for producers to refine marketing strategies and guide product development. Data on the consumption habits of young and middle-aged groups can serve as a foundation for defining target markets and shaping product portfolios. The rising demand for healthier options indicates that new product development should focus on addressing consumer needs for nutritional foods. This research not only enriches the academic literature but also offers practical perspectives for the food industry. By emphasizing the importance of consumer feedback in product development, the findings shed light on strategies to enhance customer satisfaction and build a loyal customer base. Ultimately, this study provides significant benefits in both academic and industrial contexts.

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Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

C. Güner (0000-0002-7935-4674): *Preparation and Writing, Editing, Ensuring Academic coherence.*
H. Başdoğan (0000-0001-9332-4618): *Data Collection, Investigation, Research Design, Research Coordination, Methodology.*
A. Eriş (0000-0003-1228-5202): *Conceptualization, Research Design, Methodology, Investigation.*

References

Anderson, J., & Anderson, S. (2020). The Global Noodle Market: Trends and Innovations. *Food Industry Journal, 45*(2), 123-135.
Bryman, A. (2016). *Social Research Methods*. (5th ed.). Oxford University Press.
Chan, C. S., & Tan, L. K. (2019). Survey methodologies in food consumption research. *International Journal of Food Research, 28*(1), 58-70.
Cheng, W. (2021). Functional Foods and Their Impact on Public Health: The Case of Noodles. *Nutrition and Health Journal, 39*(3), 98-110.
DeVellis, R. F. (2016). *Scale Development: Theory and Applications*. (4th ed.). Sage.
Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2018). *Multivariate Data Analysis*. (8th ed.). Cengage Learning.
Kara, E., & Gürbüz, O. (2019). Noodle Consumption in Turkey: An Emerging Trend. *Journal of Food and Beverage Studies 12*(1), 45-58.
Kim, S. H., & Lee, J. H. (2020). Consumer behavior towards instant noodles: An empirical study. *Journal of Consumer Studies, 34*(3), 245-257.
Kim, S., & Park, J. (2019). The Evolution of Noodle Consumption: Global Trends and Future Directions. *Food Studies Journal, 32*(1), 45-60.
Öztürk, M. (2021). The Impact of the COVID-19 Pandemic on Food Consumption Patterns in Turkey. *Journal of Consumer Behavior, 19*(2), 112-123.
Pallant, J. (2020). *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using IBM SPSS*. (7th ed.). London: McGraw-Hill, Open University Press.
Park, N., & Yoo, S. (2021). Packaging preferences in food products: A comparative study. *Packaging Technology and Science, 34*(5), 112-124.
Solomon, M. R. (2018). *Consumer Behavior- Buying, Having, and Being: Global Edition*. (12th ed.). Pearson Education Limited.
Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2*(1), 53-55.
Wang, H., &Chen, Y. (2020). Fast Food Consumption and Its Impact on Modern Society. *Journal of Nutritional Studies, 14*(3), 98-110.
Yılmaz, A., & Demir, H. (2021). Noodle Consumption Trends among Young Adults in Turkey. *Turkish Journal of Consumer Research, 33*(4), 67-82.

Effect of Molecular Cooking Techniques on Functional Compounds

Muhammet Ali Çakır[1,*], Deniz Kara[1], Mervenur Çala[1], Şebnem Trak[1], Zeynep İpek[1]

[1] *Kırklareli University, Faculty of Health Sciences, Department of Nutrition and Dietetics, 39100, Kırklareli, Turkiye*

Abstract

The development of technology and current conditions has enabled the diversification of studies on the foods, cooking techniques, and their effects on food composition. One of the emerging cooking methods in this context is molecular cooking, which is applied across various food categories, and offers numerous advantages beyond enhancing the appearance and taste of foods. Techniques such as sous vide, foaming, spherification, use of liquid nitrogen, powdering, flavor-aroma transfer, smoking, gelling, and ultrasonic application techniques are widely used in molecular gastronomy. The application of these cooking techniques can support consumer health by positively affecting the phenolic components and total antioxidant capacity of different foods, as well as promoting innovation in the food industry and presenting foods to consumers with attractive presentations. Moreover, molecular cooking techniques have the potential to innovate and transform the functional compounds of foods, diverging from traditional methods. These changes can significantly impact human health, necessitating a comprehensive evaluation and strategic approaches. This review investigates the effect of molecular cooking techniques on the functional compounds. Recent studies indexed in major databases were analyzed, and the data were systematically organized into tables, offering insights into the role of these techniques in shaping food composition.

Keywords: Bioavailability, Molecular cooking, Functional compounds, Thermal processing, Food processing.

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1. Introduction

In recent times, as a result of technological advancements, lifestyles around the world have changed. Consumers are increasingly focusing on maintaining healthy lifestyles. There is a growing demand for high-quality products that are easy to prepare, fresh, non-sterilized but with extended shelf life, and contain fewer synthetic additives and preservatives (Wereńska, 2024).

Cooking is the process of making food suitable for consumption, enhancing its flavor, and improving its digestibility (Demirel Ozbek et al., 2024). While fruits are typically consumed fresh, vegetables can be consumed both raw and cooked. Thermal processing of food induces various biological, physical, and chemical changes, leading to sensory, nutritional, and textural modifications (Palermo et al., 2014). Moreover, cooking can influence the bioavailability and bioaccessibility of nutrients such as minerals, vitamins, phytochemicals, and fiber (Rinaldi et al., 2021).

Molecular gastronomy, rooted in the contributions of Lavoisier, Brillat-Savarin, and Thomas Graham, was formalized by Nicholas Kurti and Hervé This. It encompasses three key areas: the scientific analysis of culinary techniques, the refinement of recipes for precision, and the exploration of the artistic and social dimensions of cooking (Burke et al., 2016).

Often referred to as a 'scientific approach to cooking,' molecular gastronomy integrates scientific principles into culinary practices. This innovative food movement applies science to cooking, studies flavor through scientific methods, and utilizes laboratory tools to develop advanced cooking techniques (Spence & Youssef, 2018). Unlike traditional food science, molecular gastronomy focuses on the science behind food preparation techniques that can be executed using ingredients readily available in a restaurant or home kitchen. In contrast, food science focuses on large-scale food production, nutrition, and safety. Additionally, molecular gastronomy can include studies on food history and culture (Barham et al., 2010).

* Corresponding Author: Muhammet Ali Çakır
Email: m.ali.cakir@klu.edu.tr
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This culinary science is a new discipline within the field of food science, distinguished primarily by its focus on the kitchen, restaurant, and home cooking levels, setting it apart from traditional studies in food science and technology. Collaboration between food scientists, such as food engineers, food chemists, and sensory scientists, and innovative chefs has led to the application of a new cooking approach known as "molecular cooking" or "science-based cooking" (Caporaso, 2021). The global dissemination of flavors and shifting consumer preferences are driving the development of new foods using molecular cooking methods, building on traditional foods (de Jesús Ramírez-Rivera et al., 2023).

Functional foods can be described as industrially processed or natural foods that, when consumed regularly at effective levels as part of a varied diet, have potentially positive effects on health beyond basic nutrition (Granato et al., 2017). For a food to be considered functional, it must contain bioactive compounds, probiotic microorganisms, or prebiotic substances that exert their effects on specific parts of the body (Erbaş, 2006). Functional foods can be naturally occurring, such as iodized salt, which contains functional components. They can also be created by removing certain compounds, such as reducing sodium content in salt (Dayısoylu et al., 2014). Dietary antioxidants, prebiotic substances, probiotic microorganisms, bioactive compounds, and phytochemicals found in foods can be defined as functional components (Erbaş, 2006).

Food processing has been a method used since ancient times to preserve and enhance the nutritional and sensory qualities of food. However, it can lead to nutrient loss and undesirable outcomes, such as changes in color, flavor, or texture, and, in some cases, the formation of toxic compounds. Nevertheless, the benefits of food processing should not be overlooked, as it improves food safety, enhances nutritional value, and promotes the formation or release of functional and bioactive compounds, such as natural phytochemicals (Zhao et al., 2019; Cakir and Helvaci, 2023). Cooking processes can also affect the bioaccessibility and bioavailability of nutrients (Rinaldi et al., 2021).

This study investigates the question, "What is effect of molecular gastronomy techniques on functional compounds?" To address this, a structured approach was employed, focusing on articles indexed in Google Scholar, Scopus, and Web of Science. The search prioritized studies published until 2024, primarily recent English-language articles. The research methodology consisted of identifying molecular gastronomy techniques and analyzing their effects on functional compounds. The relevant techniques included sous-vide, foaming, flavor and aroma transfer, smoking, gelation, spherification, liquid nitrogen, powdering, and ultrasound, and then their impacts on functional compounds such as polyphenols, antioxidants, and vitamins were reviewed using data from the specified databases. General information about the techniques was also compiled to provide context. The collected data on the effects of these techniques on functional compounds were systematically organized into tables for better clarity. This approach aims to offer insights into the role of molecular gastronomy techniques in shaping the functional composition of foods.

2. Sous Vide

Sous Vide technique, which has gained popularity in recent years, is a cooking method frequently used in the production of ready-to-eat foods (Bıyıklı et al., 2020). This technique involves minimal processing technology and has been in use since the 1960s (Hasani et al., 2022; Ayub & Ahmad, 2019). Meaning "under vacuum," this method involves cooking food in heat-resistant, airtight vacuum-sealed bags under controlled temperature (65–95 °C) and time (1–7 hours) conditions (Singh et al., 2023; Kathuria et al., 2022). The desired temperature-time combination for food preparation can be regulated by altering the water bath temperature (53–81 °C) and time (2–48 hours) with water circulation or by circulating heat and steam in convection or combi-steam oven. Heating at low temperatures reduces cooking loss compared to higher temperatures, resulting in a product that retains more moisture (Wereńska, 2024).

The sous vide technique has specific advantages compared to traditional cooking methods (Table 1). This method improves properties such as texture, tenderness, juiciness, color, and flavor of food by allowing more efficient heat transfer from water to food, while also preserving high nutritional value (Bhuyan et al., 2022). Additionally, it prevents oxidative changes (Kathuria et al., 2022). Prolonged low-temperature cooking in Sous Vide improves mineral bioaccessibility compared to other methods, as used in the sous vide technique, provides superior mineral bioaccessibility compared to other cooking methods (Ayub & Ahmad, 2019). Furthermore, this technique helps extend the shelf life of products during storage by preventing the recontamination of frozen foods (Kathuria et al., 2022).

Table 1. Studies on the effects of the sous vide technique on functional compounds

Reference	*Material*	*Method*	*Results*
Florkiewicz et al., 2019	Cauliflower (*Brassica oleracea* var. *botrytis*): white cauliflower and Romanesco cauliflower (green cauliflower), Brussels sprouts (*Brassica oleracea* var. *gemmifera*), and broccoli (*Brassica oleracea* var. *italica*).	The study evaluated whether the sous vide technique could serve as an alternative to traditional cooking methods for Brassica vegetables. The total phenolic content (TPC) was assessed using the Folin-Ciocialteau reagent. The total phenolic content was also determined chromatographically following the hydrolytic procedure of Nardini and Ghiselli.	The study assessed the suitability of sous vide as an alternative to traditional cooking methods for Brassica vegetables, including white cauliflower, Romanesco, Brussels sprouts, and broccoli. Using Folin-Ciocalteu reagent and chromatography, it was found that sous vide preserved vitamin C and stable phytochemicals (e.g., p-coumaric acid) more effectively. The method showed a strong correlation between antioxidant activity, vitamin C, and total phenolic content, suggesting sous vide as an optimal cooking technique for Brassica vegetables.
Rinaldi et al., 2021	Pumpkin (*Cucurbita maxima Duch.*)	The aim of this study was to compare the cooking performance of pumpkin cubes produced using a home vacuum cooking device in terms of texture, color, microstructural properties, antioxidant and carotenoid content, and organoleptic properties with steaming and sous vide techniques. Pumpkin cubes were processed using three cooking methods: sous vide (SV), steaming (ST), and vacuum cooking (VC). Cooking durations were 9 minutes for steaming, 18 minutes for sous vide, and 29 minutes for vacuum cooking. Antioxidant capacity was determined using a DPPH (2,2-diphenyl-1-picrylhydrazyl free radical) test. Carotenoids were analyzed using HPLC.	Significant polyphenol extraction, particularly of gallic acid and naringenin, was observed in pumpkins cooked sous vide and steamed. The total antioxidant activity, attributable to the effects of carotenoids and polyphenols, increased after cooking for vacuum-cooked, steamed, and sous vide samples, respectively, compared to raw pumpkin. Vacuum cooking and sous vide generally outperformed traditional steaming for pumpkin cubes.
Chiavaro et al., 2012	Carrot (*Daucus carota L.*) and Brussels sprouts (*Brassica oleracea var. gemmifera L.*)	Phytochemicals (carotenoids, phenolic compounds, and ascorbic acid) and antioxidant capacity, measured using TEAC (Trolox Equivalent Antioxidant Capacity), FRAP (Ferric Reducing Antioxidant Power), and TRAP (Total Radical Trapping Antioxidant Parameter) analyses, were evaluated in sous vide-processed carrots and Brussels sprouts. The samples were then refrigerated for 1, 5, and 10 days and compared to their raw and oven-steamed counterparts.	Sous vide preparation improved carotenoid, phenolic compound, and ascorbic acid retention in carrots compared to steaming, with minor losses during storage. For Brussels sprouts, sous vide enhanced carotenoid levels but resulted in reduced phenolic and ascorbic acid contents, making it suitable for short-term preservation.
Lafarga et al., 2018	Brassica vegetables, including broccoli (*Brassica oleracea var. italica*) cv. Marathon, Parthenon, broccoli (*Brassica oleracea var. botrytis*) cv. Graffiti, Pastoret, Espigall del Garraf (*Brassica oleracea var. acephala*), and kale cv. Crispa (*Brassica oleracea var. acephala*).	Sous vide processing conditions: 80°C for 15 minutes for florets or leaves and 80°C for 90 minutes for stems. Samples were rapidly cooled to approximately 3–4°C, frozen using liquid nitrogen, and stored at -80°C. Vitamin C content (ascorbic and dehydroascorbic acid) was determined using HPLC equipped with a UV detector. Total phenolic content (TPC) was measured using the Folin-Ciocalteu method. Antioxidant activity was assessed using FRAP (ferric reducing antioxidant power) and DPPH (2,2-diphenyl-1-picrylhydrazyl radical scavenging activity).	The effect of thermal processing on the antioxidant potential, vitamin C, and total phenolic content of various parts of Brassica vegetables, including edible by-products, was evaluated. Both steaming and sous vide significantly reduced vitamin C and total phenolic content in the studied cruciferous vegetables. For most varieties, no differences were observed between samples processed by steaming or sous vide. However, the phenolic content of stems from broccoli cv. Parthenon and Pastoret processed via sous vide was significantly higher than those obtained after steaming. Conversely, a different trend was observed for broccoli cv. Parthenon florets, where sous vide resulted in greater phenolic content loss compared to steaming.

Table 1. *(Continued)* Studies on the effects of the sous vide technique on functional compounds

Reference	*Material*	*Method*	*Results*
Czarnowska-Kujawska et al., 2022	Fresh spinach (*Spinacia oleracea L.*) and broccoli (*Brassica oleracea L. var. italica Plenck*).	The aim of this study was to compare the effects of traditional cooking methods (boiling, steaming, microwaving) with combi oven and sous vide cooking on the organoleptic and health-related properties of spinach and broccoli. To analyze changes in bioactive compounds in raw and thermally processed spinach and broccoli, the total phenolic content (TPC) was determined using the Folin phenol reagent and a spectrophotometric method. The functional properties of the products were characterized by antioxidant activity measured with the DPPH test.	Cooking under sous vide conditions was identified as the most delicate thermal process for preserving phenolic compounds and maintaining high antioxidant capacity in both broccoli and spinach samples. In spinach, DPPH values decreased in the order of raw > sous vide > traditional methods, whereas in broccoli, the DPPH value significantly increased after sous vide processing compared to raw broccoli. Conversely, the DPPH value of broccoli decreased when prepared using traditional methods compared to its raw state.
Kosewski et al., 2018	Green bell pepper, broccoli, beetroot, white onion, and other vegetables sourced from various countries (e.g., Spain, Poland, Egypt, USA) were included in this study	This study compared the antioxidant properties of raw and thermally processed vegetables using traditional and sous vide methods. Antioxidant activity was assessed using the DPPH assay and the FRAP method, measuring the reduction of Fe3+ to Fe2+.	A reduction in antioxidative potential was observed for most vegetables after processing compared to their raw state. However, vegetables such as kale, beetroot, red bell pepper, sweet potato, carrot, cauliflower, and kohlrabi showed increased antioxidative potential when processed using the sous vide method. When comparing processing methods, the sous vide method provided greater benefits. Additionally, vegetables like red onion, shallot, broccoli, tomato, parsley root, and cauliflower exhibited higher antioxidative potential after sous vide cooking compared to traditional methods.
Törős et al., 2024	Oyster mushroom (*Pleurotus ostreatus L.*)	This study investigated the effects of sous vide cooking on the antioxidant properties (phenols, flavonoids), activity, and β-glucan content of freeze-dried mushroom samples. Mushrooms prepared for sous vide cooking were vacuum-packed and cooked in three different preheated drying cabinets at 70, 80, and 90 °C for 4 hours. Sous vide-cooked and uncooked samples were freeze-dried and ground into fine powder. Total Phenolic Content (TPC), Total Flavonoid Content, DPPH, FRAP, and β-glucan content were analyzed using HPLC. Total dietary fiber was analyzed using an enzymatic-gravimetric method.	Uncooked mushroom powder exhibited superior antioxidant capacities compared to cooked samples. However, mushrooms cooked sous vide at 80 °C demonstrated the highest total phenolic and flavonoid contents. Additionally, mushroom powder pre-cooked at 70 °C significantly surpassed the uncooked control in β-glucan content. Notably, samples pre-cooked at 80 °C and 90 °C displayed significantly higher total dietary fiber levels compared to uncooked samples.
Guclu et al., 2023	White, orange, and purple sweet potatoes (*Ipomoea batatas L.*)	This study applied three different cooking methods (baking, boiling, sous vide (SV)) to Turkish sweet potatoes of three colors (white, orange, purple) and investigated the effects of cooking methods and tuber color on total phenolic compounds, sugars, antioxidant activity, anthocyanins, and phenolic acids. Total phenolic content (TPC) was analyzed using the Folin-Ciocalteu (FC) reagent. Antioxidant potentials of the samples were evaluated using two methods: DPPH and ABTS. Phenolic compounds were determined using LC-DAD-ESI-MS/MS in negative ionization mode.	Purple sweet potatoes exhibited nearly twice the antioxidant capacity compared to white and orange varieties. Among cooking methods, SV yielded the highest antioxidant capacity for purple-fleshed samples, while baking was most effective for white and orange samples. In terms of total phenolic acid concentrations, orange samples had the highest amounts (up to 263.5 mg/100 g), followed by purple (up to 195.2 mg/100 g) and white samples (up to 133.6 mg/100 g). The highest chlorogenic acid levels were found in baked (80.88 mg/100 g) and SV-cooked (65.14 mg/100 g) orange samples. SV cooking preserved anthocyanins (855.9 mg/100 g) better than the other methods and was identified as the most suitable method for preserving these compounds, as seen in other anthocyanin-rich foods.

Table 1. *(Continued)* Studies on the effects of the sous vide technique on functional compounds

Reference	*Material*	*Method*	*Results*
Karafyllaki et al., 2023	Horseradish (*Armoracia rusticana*)	This study aimed to demonstrate the effects of different cooking techniques, including boiling, baking, and sous vide, on individual phenolic compounds, Total phenolic content (TPC), Total Flavonoid Content (TFC), color parameters, inhibition of Advanced Glycation End-products (AGE) formation, and antioxidant activity in horseradish. Phenolic acids and flavonoids were analyzed using the HPLC-DAD-MS method. TPC was determined using Folin's phenol reagent. Qualitative and quantitative analyses of polyphenols were performed with a UHPLC system coupled with a diode-array detector (DAD) and mass spectrometry. Antioxidant capacity was determined using the DPPH and ABTS methods, expressed as Trolox Equivalent Antioxidant Capacity.	Fresh and sous-vide samples were characterized by the highest TPC values, while boiled samples exhibited the highest TFC values. The highest antioxidant capacity was observed in fresh horseradish roots. Flavonoids were found at lower concentrations than phenolic acids, with syringic acid identified as the most abundant phenolic compound. After sous-vide processing, horseradish showed greater inhibition of AGE formation. Thermal processing of horseradish roots increased the saturation of yellow and red hues while reducing color brightness.
Colasanto et al., 2023	Italian black rice (*Oryza sativa L.*)	This study investigated the effects of cooking methods on Artemide black rice, comparing innovative sous vide cooking (at 89 and 99 °C) with traditional home cooking methods such as risotto and pilaf. Spectrophotometric analyses were performed on hydroalcoholic extracts to determine free phenolic fractions. Antioxidant activity (AA) was assessed using the DPPH radical scavenging method. Phenolic content (PC) was determined using Folin's phenol reagent. The pH differentiation method was used to measure anthocyanin (AC) and monomeric anthocyanin (MAC) content.	Sous vide at 89 °C was identified as the best method for preserving total polyphenols and antioxidant capacity, while risotto excelled in preserving anthocyanins. No significant differences were observed in protein fractions across cooking methods. In terms of individual compounds, a general decrease in anthocyanin content was observed. Cyanidin-3-O-glucoside, the most abundant anthocyanin in black rice, decreased by 37% and 45% in sous vide 89 °C and risotto samples, respectively, and by 55% and 56% in pilaf and sous vide 99 °C samples, respectively. Free phenolic acids generally increased after cooking, while the fiber-bound fraction remained unchanged across all cooking methods.
Haraf et al., 2024	Beef (*M. semitendinosus*) and kiwifruit (*A. arguta* cv. 'Ananasnaya')	This study aimed to determine the antioxidant activity (AA) and fatty acid (FA) profile of sous-vide beef marinated with 10%, 20%, and 30% kiwifruit pomace in brine and compare it with control samples marinated in brine alone. Changes in the examined parameters were analyzed after 0, 1, 2, and 3 weeks of refrigerated storage. Total polyphenols (TP) in the kiwifruit pomace were determined using the Folin-Ciocalteu method. AA was analyzed for kiwiberry pomace and beef using FRAP and ABTS methods. Total fat content in kiwiberry pomace and beef was tested using the AOAC method.	Adding kiwifruit pomace to marinated beef significantly increased the antioxidant activity (AA) of sous-vide beef compared to control samples marinated only in 3% brine. However, this activity decreased with longer storage times. After one week of storage, samples marinated with 20% and 30% pomace showed the highest FRAP and ABTS values. Sous-vide beef marinated with kiwifruit pomace was characterized by higher PUFA levels, including LA and ALA, in lipids. The beef showed significantly more favorable PUFA/SFA and P/S ratios compared to controls. However, other lipid indices, such as n-6/n-3, AI, TI, and h/H, did not show improvement. One key finding was the high level of palmitic acid (C16:0) in beef lipids when marinated with 30% kiwifruit pomace.

In a study conducted in 2021, the sous vide method was found to positively influence the sensory quality of poultry meat, making it redder, less yellow, and more tender compared to traditional cooking methods. Sensory evaluations indicated that chicken meat cooked sous vide excelled in terms of color, tenderness, juiciness, and overall quality, although its aroma and flavor were less pronounced (Przybylski et al., 2021). These sensory attributes, along with the sous vide method's ability to preserve functional compounds like antioxidants and phenolics, highlight its dual benefits of enhancing both sensory and nutritional qualities of food.

In conclusion, the sous vide cooking method uses much lower temperatures compared to traditional cooking, allowing the production of more nutritious food products with well-preserved bioactive compounds, which are beneficial for health. In future applications, the sous vide cooking technique holds great potential for producing safe foods with enhanced sensory and nutritional properties (Zavadlav et al., 2020).

Sous vide cooking, which is based on the principles of low-temperature and long-duration cooking, may be effective in preserving phenolic compounds and antioxidant capacity.

Czarnowska-Kujawska et al. (2022) demonstrated that the sous vide method effectively preserves phenolic compounds and antioxidant capacity, confirming its role as a gentle thermal processing technique. This aligns with other studies summarized in Table 1. Additionally, Demirel Ozbek et al. (2024) found that sous vide methods lead to the formation of new phenolic compounds, such as protocatechuic acid and p-coumaric acid. These findings indicate that the sous vide method has significant potential not only for preservation but also for the formation of new compounds.

Research suggests that sous vide cooking may enhance antioxidant activity. In the study by Rinaldi et al. (2021), the antioxidant activity of foods cooked using the sous vide method increased after cooking compared to raw products. Similarly, Kosewski et al. (2018) reported that foods cooked sous vide exhibited higher antioxidative potential than those prepared using traditional cooking methods. These findings highlight the advantages of sous vide cooking in preserving nutritional value and enhancing the functional food properties of products. However, a prudent approach is necessary when interpreting results related to increases in bioactive compounds. During bioactive compound analyses, ensuring equal extraction conditions is crucial, as variations in processing methods might enhance extraction quality, potentially leading to misinterpretation of data.

According to Florkiewicz et al. (2019), the sous vide technique is considered the most advantageous method for preserving vitamin C, both immediately after processing and during the storage of processed vegetables. Similarly, the study by Chiavaro et al. (2012) demonstrated that carrots cooked using the sous vide method contained higher amounts of carotenoids, phenolic compounds, and ascorbic acid compared to steamed products, with only a slight reduction in phenolic compounds during sous vide storage. However, the findings of Lafarga et al. (2018) indicated that both steaming and sous vide processing significantly reduced the vitamin C and total phenolic content (TPC) in the studied cruciferous vegetables. These findings suggest that the degree of nutrient retention varies depending on the type of product and the processing conditions applied.

The study by Törős et al. (2024) revealed that mushroom powder cooked sous vide at 70°C exhibited significantly higher β-glucan content compared to the uncooked control sample. This finding suggests that the sous vide technique may enhance the β-glucan content in mushrooms, contributing to their various health benefits.

3. Foaming

Foam is a two-phase gas system dispersed within a liquid phase, formed by whipping or other agitation methods, where gas bubbles are retained within films of differing compositions. The foaming capacity of a solution is influenced by several factors, including surface activity, surface tension at the water-air interface, the film-forming properties of the foaming agent, and the ability to rapidly adsorb at the air-liquid interface. Proteins, due to their amphiphilic properties, play a crucial role in foam formation (Stantiall et al., 2018). Studies on the effects of foaming techniques on functional compounds are presented in Table 2.

Foams are widely used in the food industry for products such as whipped cream, meringues, and mousses. The foam structure provides the desired texture to foods and aims to reduce mass per volume, thereby lowering calorie intake as fewer products are needed per serving. Since air has low viscosity and

Table 2. A Study on the effect of foaming technique on functional compounds

Reference	*Material*	*Method*	*Results*
Zhu et al., 2024	Egg white, potassium bitartrate, garlic juice, and allicin	This study aimed to investigate the effects of garlic juice and allicin (thio-2-propen-1-sulfinic acid S-allyl ester) on the stabilization mechanism of meringues produced from egg whites. Egg whites were whipped with potassium bitartrate, garlic juice, and allicin in separate containers, and their foam conditions were analyzed using microscopy and Gaussian function calculations.	Adding garlic juice to egg white foams increased foam overflow and stability due to the interaction of allicin with free sulfhydryls in egg white proteins during whipping. Allicin also produced firmer foams without altering the pH of egg whites.

surface tension, stabilizers are often used in foam production. Agar plays a vital role in stabilizing the microstructure of foam-based foods and serves as a healthier alternative to high-calorie fat-based foams (Kaur et al., 2022). Additionally, egg white is a commonly used foaming agent due to its high albumin content. It is widely applied in baking and confectionery products to achieve stable foams (Stantiall et al., 2018).

Foams have a structure that traps air within bubbles, similar to an emulsion where one phase encloses another within its structure. Foam structures can be formed by combining different components, such as proteins, water, or oil. The texture of a foam is determined by the size of the bubbles and the amount of liquid within the foam. Some foams are classified as "stiff" foams, which indicates that the structure has solidified (e.g., in bread dough or souffle preparation) (Logsdon, 2018).

In foam production, introducing air or other gases into a product alters its texture and structure, creating a distinct mouthfeel. The foaming technique allows the combination of various flavors without altering the physical properties of the food (Doğan, 2022). This technique is commonly used in foamy desserts, sauces, sweet and sour foams, appetizers, and creamy soups (Batu, 2019). In this method, water contained in solid or liquid foods is transformed into a foam form using natural lecithin and a foaming machine, making it particularly suitable for garnishing dishes, salads, and desserts (Aksoy and Üner, 2016).

Egg white proteins, particularly ovalbumin, ovotransferrin, ovomucin, and lysozyme, contain more air, which is attributed to their higher sulfhydryl group content and lower number of disulfide bonds. This allows for the formation of more intermolecular disulfide bonds during whipping. Studies have shown that the addition of garlic juice or allicin results in firmer egg white foams. The interaction of these components enhances the quality of foaming, leading to more stable and robust foams (Zhu et al., 2024).

Foaming techniques are known for their ability to modify the physical structure of foods, but their impact on functional components has been less explored. Recent studies suggest that incorporating functional ingredients like antioxidants or phenolics into foams can enhance their stability and bioavailability (Zhu et al., 2024). For example, garlic-based foams have shown increased antioxidant retention due to the encapsulating effects of foam structures. Similarly, proteins used as foaming agents can protect sensitive bioactive compounds during storage and processing. Future research should focus on optimizing health benefits by exploring the interaction between foaming agents and functional components.

4. Flavor-Aroma Transfer

The principle behind the flavor-aroma transfer technique is the transfer of the taste, scent, and aroma of natural aromatic foods to other ingredients (Bozbayır, 2021). This technique, which has gained prominence with the molecular gastronomy movement, plays a key role in innovative culinary applications by utilizing the positive effects of highly aromatic foods on other dishes (Bozbayır, 2021; Seçuk & Pekerşen, 2020). Additionally, it contributes to the development of products with new flavor and aroma combinations (Seçuk & Pekerşen, 2020).

Flavor-aroma transfer can be achieved in two ways. The first method involves injecting the aromatic food into the desired dish using a syringe, or cooking the food covered with the aromatic ingredient using the sous vide technique, ensuring the transfer of flavor and aroma (Bozbayır, 2021). For example, injecting pineapple juice into meat before cooking not only imparts an aromatic flavor to the meat but also provides a marinating effect due to its acidic content (Seçuk & Pekerşen, 2020). In the second method, the aroma of the aromatic food is trapped in a siphon and then transferred to the dish (Bozbayır, 2021). Studies on the effects of the flavor-aroma transfer technique on functional compounds are presented in Table 3.

Table 3. A study on the effect of taste-odor transfer technique on functional compounds

Reference	*Material*	*Method*	*Results*
Özdemir et al., 2014	Meatballs and pomegranate peel extract	This study aimed to investigate the effects of pomegranate peel extract (PPE) on the microbial and oxidative stability of cold-stored meatballs. Aqueous extract from pomegranate peel was freeze-dried into a powder and added to meatball formulations at concentrations of 0.1%, 0.2%, and 0.3%.	Adding higher concentrations of PPE to cold-stored meatballs significantly reduced the formation of unpleasant odors. PPE also exhibited antimicrobial effects, extending the spoilage time. The addition of PPE at different concentrations decreased lipid oxidation (TBARs) levels during cold storage. These findings indicate that PPE, rich in phenolic acids, flavonoids, proanthocyanidins, and hydrolyzable tannins, can serve as an antioxidant source in minced meat.

The current body of research directly investigating the effects of flavor-aroma transfer techniques on functional compounds remains limited. Existing studies predominantly focus on the stability, release, and sensory perception of aroma compounds within food matrices rather than their interaction with functional components like phenolics or antioxidants.

5. Smoking

Smoking is defined as the process in which volatile compounds penetrate food products such as fish and meat, either directly or indirectly, as a result of the incomplete combustion of specific woods (Assogba et al., 2019; Pöhlmann et al., 2012). Aromatic wood chips, such as bay, thyme, apple, and cherry, are commonly used in the smoking process. For instance, fish or meat can be subjected to the smoking technique after being cooked using the sous-vide method. Foods intended for serving can be exposed to aromatic wood smoke using a smoke machine and glass cloches just before serving (Özel, 2018). This technique imparts a highly appealing characteristic aroma, color, and flavor to meat products for consumers (Mastanjević et al., 2020).

The smoking process releases phenolic compounds, which are expected to exhibit antimicrobial and antioxidant properties, contributing to the organoleptic characteristics of food (Hitzel et al., 2013). Smoking enhances the sensory qualities of food by providing a distinct color, flavor, and aroma, while also reducing water content and improving preservation due to its bactericidal and antioxidant effects (Škaljac et al., 2018).

Smoking has been a traditional method used since ancient times (Škaljac et al., 2014). Among the functional components of smoke, phenols and acids exhibit the highest antimicrobial activity. While the color imparted by wood smoke is associated with acids and phenols, the reaction-induced color changes in meat during heating are primarily attributed to acids and carbonyl compounds (Toledo, 2007). The color changes in smoked foods result from chemical and physical phenomena occurring during the process. Key phenomena include the polymerization of smoke components (e.g., phenols and aldehydes), the adhesion of smoke coloring compounds, and oxidation reactions between carbonyl groups in the smoke and amino groups in the proteins on the food surface (Marušić Radovčić et al., 2016).

The pyrolysis of cellulose and hemicellulose in wood generates significant amounts of carbonyl compounds that contribute to the brown color on the surface of smoked meats. Meanwhile, the pyrolysis of lignin produces phenolic compounds that act as antimicrobial and antioxidative agents, adding desirable flavors to smoked sausages (Malarut & Vangnai, 2018). These phenolic components not only enhance the aroma of the food but also make the product more flavorful. Smoke also forms a protective film on the surface of smoked products, serving as a barrier against spoilage (Marušić Radovčić et al., 2016).

In traditional Portuguese dry-fermented sausage production, smoking is used to enhance sensory properties such as aroma, flavor, and color. During smoking, components such as phenolic derivatives, carbonyls, and organic acids are transferred to the product, contributing to its characteristic taste and aroma (Roseiro et al., 2011). In northern China, sugar smoking is a more popular method than wood smoking. This technique produces a distinct aroma often associated with caramel notes (Wang et al., 2022).

In industrial smoking processes, smoke production is controlled in industrial oven chambers, and the removal of undesirable compounds is facilitated by positioning smoke generators away from the smoking chambers. In contrast, traditional smoking methods often reach very high combustion temperatures in ovens, where the food is in direct contact with all components of the produced smoke (Škaljac et al., 2014).

Uncontrolled smoking methods can result in the formation of various chemical contaminants, such as polycyclic aromatic hydrocarbons (PAHs), formaldehyde, dioxins, sulfur oxides, nitrogen compounds, and heavy metals (Ledesma et al., 2015). Smoke generated from wood combustion in low-oxygen environments can contain significant amounts of PAHs (Roseiro et al., 2011). These compounds, consisting of two or more fused aromatic rings, are considered potentially genotoxic and carcinogenic to humans (Škaljac et al., 2018).

The composition and concentration of PAHs in smoked meat products depend on several factors, including the type of wood, moisture content, and the temperature associated with smoke production. These factors directly influence the amount of PAHs transferred to the product. Producers must optimize smoking processes to ensure that PAH concentrations remain within the regulatory limits. According to EU regulations, the maximum allowable total PAH concentration in smoked meat products is set at 5.0 μg/kg (Roseiro et al., 2011). Studies on the effects of smoking techniques on functional compounds are presented in Table 4.

Table 4. Studies on the effects of smoking technique on functional compounds

Reference	*Material*	*Analysis*	*Method*	*Results*
Hitzel et al., 2013	Smoked Frankfurter and mini sausages	- PAH analysis: Pressurized liquid extraction (PLE), Gel permeation chromatography (GPC), Solid-phase extraction (SPE), preparation for Gas Chromatography/Mass Spectrometry (GC/MS), and High-resolution Mass Spectrometry (GC/HRMS) analysis. - Phenolic compound analysis: GC/MS using a mass spectrometric detector.	Smoked Frankfurters and mini sausages were analyzed for PAH and phenolic compounds (e.g., guaiacol, 4-methylguaiacol, syringol, eugenol, and trans-isoeugenol) using beechwood chips combined with various spice mixes, including cherry, juniper berries, and bay leaves	Sausages smoked with poplar wood showed slightly higher or lower total contents of the five phenolic compounds compared to beechwood-smoked sausages. However, the use of walnut and poplar wood resulted in a 35-55% reduction in PAH levels compared to the commonly used beechwood.
Marušić Radovčić et al., 2016	Smoked dry-cured ham	Volatile compound analysis: HS-SPME and GC-MS	Biceps femoris samples of dry-cured ham aged for 12–18 months, sourced from nine different producers, were vacuum-sealed and stored at -20°C until analysis. The study aimed to determine the physicochemical, sensory properties, and volatile flavor compounds of the ham.	A total of 87 volatile aroma compounds were identified in smoked dry-cured ham. Samples with higher NaCl content showed lower aldehyde levels, while samples with a longer smoking phase exhibited higher phenol content. Identified chemical groups included aldehydes (35.6%), phenols (34.3%), alcohols (13.8%), terpenes (6.4%), aromatic hydrocarbons (2.6%), alkanes (2.2%), ketones (2.2%), esters (1.7%), and acids (0.7%). Aside from volatile compounds derived from lipolysis and proteolysis, phenols from the smoking process were the second most abundant group, including 4-methylphenol, 3-methylphenol, 2-methoxy-4-methylphenol, 2-methylphenol, 2,6-dimethoxyphenol, and 4-ethyl-2-methoxyphenol.
Petričević et al., 2018	Smoked dry-cured ham	Volatile compounds: Isolated using HS-SPME and analyzed with GC-MS.	The study utilized 24 dry-cured hams produced from the processing of 24 pork legs. The hams were subjected to cold smoking for 20 days and matured for 15–17 months. The aim was to characterize the hams produced using four different processing methods and to analyze volatile compounds.	A total of 149 volatile compounds were identified in dry-cured hams (25 aldehydes, 18 phenols, 12 alcohols, 16 terpenes, 27 aromatic hydrocarbons, 18 aliphatic hydrocarbons, 17 ketones, 9 esters, and 7 acids), with the quantities of 15 compounds determined. Smoked dry-cured hams exhibited higher levels of phenols, aromatic hydrocarbons, and acids, as well as increased levels of terpenes, ketones, alcohols, esters, and aliphatic hydrocarbons, and were characterized by a spiced aroma. Aldehydes were the most abundant volatile compounds in ham samples, representing 34.46–49.78% of the total volatile composition.
Wang et al., 2022	Sugar-Smoked Chicken Drumsticks	Volatile compounds were extracted using solid-phase microextraction (SPME) and identified by GC/MS with reference to the NIST 11 mass spectral database for characteristic ion fragments.	Volatile compounds were extracted using solid-phase microextraction (SPME) and identified by GC/MS. Nine chicken drumsticks from laying hens were smoked at 350 °C and 400 °C with separate additions of sucrose, maltose, fructose, glucose, and xylose as carbohydrate sources. The drumsticks were boiled for 30 minutes in a 1:2 brine solution before smoking. When the cooking pan reached 350 °C or 400 °C, smoking materials were added to the pan. The control group was subjected to the same process without the addition of carbohydrates.	A total of 33 volatile compounds were identified in the sugar-smoked samples. Compared to the control group, the type and content of furans in the sugar-smoked group increased significantly. The pyrolysis of glucose, sucrose, and fructose was found to produce furans in high yields, such as 5-hydroxymethylfurfural (5-HMF) and furfural. The caramel aroma detected in sugar-smoked chicken drumsticks was reported to be associated with 5-HMF. During the smoking process, 5-HMF was pyrolyzed into 5-methylfurfural, and sucrose was identified as an effective carbohydrate source for generating smoke-flavored furans.

Table 4. *(Continued)* Studies on the effects of smoking technique on functional compounds

Reference	*Material*	*Analysis*	*Method*	*Results*
Pino, 2014	Liquid Smoke Flavor Derived from Rice Husk	Volatile compounds were identified using GC/FID and GC/MS.	This study aimed to characterize the volatile compounds in liquid smoke flavor derived from rice husks. A smoke flavor was developed through the pyrolysis of rice husks, selected for their sensory properties. The liquid smoke flavor was prepared by dry distillation of rice husks obtained from a Cuban rice variety.	In the aqueous liquid smoke flavor derived from rice husks, a total of 94 volatile compounds were identified, and their individual quantities were determined. These compounds mainly included carbonyl compounds, phenols, furans, acids, alcohols, esters, and three nitrogen-containing compounds. The liquid smoke flavor obtained from rice husks was found to contain higher amounts of 2-methoxyphenol and its derivatives, making it more similar to smoke derived from softwood species.

The smoking process involves the polymerization of smoke components, generating phenolic compounds that act as antimicrobial and antioxidative agents, contributing to food preservation and flavor enhancement (Marušić Radovčić et al., 2016; Malarut & Vangnai, 2018). Studies have also observed that extended smoking durations result in higher phenol content in foods (Petričević et al., 2018; Wang et al., 2022). However, smoking can also lead to the formation of polycyclic aromatic hydrocarbons (PAHs), contaminants with genotoxic and carcinogenic potential (Ledesma et al., 2015). The concentration of PAHs depends on factors such as the type of wood used, moisture levels, and smoke temperature (Roseiro et al., 2011). Effective measures like controlled smoking durations, appropriate wood selection, and the use of smoke filters can mitigate PAH formation while preserving the desirable qualities imparted by phenolic compounds (Mastanjević et al., 2020).

In a study by Hitzel et al. (2013), the use of walnut and poplar wood for smoke production reduced PAH formation by 35–55% compared to beechwood. To mitigate PAH formation in foods processed with traditional smoking methods, it has been suggested that controlled smoking durations, attention to wood combustion temperatures, proper use of smoke filters, and reduced smoking times are effective measures (Mastanjević et al., 2020).

While the section provides detailed insights into the smoking process and its sensory and preservative effects, the discussion on functional ingredients remains limited. Although phenolic compounds are mentioned for their antimicrobial and antioxidant properties, there is a lack of specific examples or in-depth analysis of how these functional components interact with other compounds during smoking. Moreover, the potential health benefits or stability of these phenolic compounds after the smoking process are not extensively explored.

6. Gelation

Gel is an advanced material characterized by three-dimensional (3D) networks capable of retaining high amounts of water (hydrogel), oil (oleogel), or air (aerogel) due to properties such as high surface area and porosity (Abdullah et al., 2022). In the gelation method, a wide range of textures can be achieved, from soft and elastic to firm and brittle, depending on the nature and concentration of the gelling molecules. These texture variations illustrate that the process of gelation can be simply defined as transforming any fluid into a static solid state. The gelation method requires the rearrangement and ordered binding of molecules to form networks that trap liquids. These networks act as structural frameworks, immobilizing and suspending particles, thus preventing the collapse of the formed structures (Özel & Özkaya, 2016). A century ago, gelatin derived from animal collagen was the primary gelling agent in Western-style cuisines. Today, a variety of gelling agents derived from diverse organisms are routinely used, allowing for precise control of textures and properties in modern culinary regimes. These gelling agents include xanthan gum, methylcellulose, agar, and gellan, each possessing unique biophysical properties. For example, gelatin gels between 4°C and 35°C, while methylcellulose gels between 50°C and 90°C (Brenner & Sörensen, 2015). Emulsion gels, depending on the biopolymer composition of their gel matrix, are categorized into three types: Protein-based emulsion gels (e.g., casein, gelatin, soy, and whey proteins), Polysaccharide-based emulsion gels (e.g., alginate, starch, pectin, and xanthan gum), Mixed emulsion gels (e.g., xanthan gum-guar gum, zein-sodium caseinate-propylene glycol alginate, and soy protein isolate-beet pectin) (Abdullah et al., 2022).

Hydrocolloids are defined as a group of long-chain polymers that disperse easily in water and exhibit complete or partial solubility and swelling tendencies. They can modify the physical properties of solutions through gel formation (via contact with water and microscopic dispersion), thickening, emulsifying, and stabilizing actions. Hydrocolloids can be used to protect bioactive compounds in food and beverages from chemical degradation during storage and to enhance their bioavailability after consumption. As such, food hydrocolloids are versatile natural ingredients essential for formulating next-generation functional food products designed to improve and enhance human health (McClements, 2021). Hydrocolloids can originate from various sources, including plants, animals, algae, and microorganisms. They can also be semi-synthetic, such as cellulose derivatives. Due to their hydrophilic nature, they are also referred to as hydrophilic colloids. While most hydrocolloids possess viscosity-enhancing properties, only a few have the ability to form gels. Gel-forming hydrocolloids include alginate, carrageenan, furcellaran, pectin, agar, gelatin, modified starch, gellan gum, and methylcellulose. The gel-forming property of hydrocolloids is frequently utilized in products like jellies, puddings, and jams (Pirsa & Hafezi, 2023).

Oleogels are innovative structured fat systems that can serve as substitutes for unhealthy lipids and saturated fats (Wang et al., 2024). As an alternative approach, the oleogelation of liquid oils (commonly vegetable oils) has garnered increasing attention. In the food industry, edible oleogels exhibit various solid-like properties and provide beneficial health characteristics, such as reduced levels of saturated and trans fatty acids (Li et al., 2023). Beyond offering solid-like properties without the use of high levels of saturated fats, oleogels can also act as carriers for bioactive compounds (Martins et al., 2018). Oleogels and oleogel-based emulsions derived from different types of vegetable oils are being developed and incorporated into foods such as margarine, yogurt, cakes, and chocolates (Yang et al., 2022).

To process liquid oils, both direct (self-assembly/crystallization of oleogelators and polymeric networks) and indirect (oil absorption and emulsion templates) methods are available. Edible oleogelator molecules can form a three-dimensional network structure, trapping liquid oil to behave like solid fats. To date, various oleogels have been reported, including those made from fatty alcohols, sorbitan monostearate, glycolipids, sodium stearoyl lactylate, and natural waxes (Li et al., 2023). Over the past decade, emulsion gels have emerged as a promising biomaterial for the protection, transport, and improved sensory textures, digestion, bioaccessibility, and bioavailability of health-promoting functional components, enabling the design of healthier formulations (Abdullah et al., 2022).

Studies related to the effects of gelation techniques on functional compounds are summarized in Table 5.

When examining studies utilizing the gelation technique, it has been observed that using carrageenan as a gel matrix (Alejandre et al., 2017; Salcedo-Sandoval et al., 2015) reduces fat content and lipid oxidation in foods. When hydroxypropyl methylcellulose (HPMC) is used as a gel matrix, it significantly lowers saturated fat content (Espert et al., 2021), whereas the use of gellan is effective in preserving probiotics (Picone et al., 2017). Therefore, the gelation technique offers potential health-supporting benefits.

7. Liquid Nitrogen Application

Nitrogen gas, a significant component of the Earth's atmosphere, constitutes approximately 78% of it. Also known as nitrogen gas, it is colorless and odorless. When nitrogen gas is liquefied, it is referred to as liquid nitrogen (Cömert and Çavuş, 2016). The use of liquid nitrogen in food preparation has gained significant popularity in recent years (Božić and Đurović, 2019). Liquid nitrogen is a low-cost, user-friendly, and effective refrigerant. Its extremely low boiling point (-195.8 °C) and high cooling capacity at atmospheric pressure make it a valuable cooling agent.

By rapidly lowering the temperature of food products, liquid nitrogen prevents the formation of large ice crystals that can damage frozen foods (Onurlar, 2023). It is commonly used for grinding plants, which prevents oxidation and thereby preserves the colors and aromas of the plants (Božić and Đurović, 2019).

Liquid nitrogen is also used in ice cream making, offering a distinct advantage in this area. The rapid freezing capability of liquid nitrogen ensures that the crystals formed are extremely small, resulting in an exceptionally creamy and smooth texture for ice cream made with liquid nitrogen. Additionally, when liquid nitrogen is exposed to air, it creates mist, vapor, and an impressive cloud effect, making it a popular element in molecular gastronomy for visual presentations (Batu, 2019).

Table 5. Studies on the effects of gelation techniques on functional compounds

Reference	*Material*	*Phase Types*	*Gel Matrices*	*Aim and Method*	*Results*
Alejandre et al., 2017	Beef patties	Low-energy emulsion gel (3% carrageenan and 1% algal oil)	Carrageenan	The study aimed to achieve an optimized product with maximum hardness and minimum syneresis by combining ingredients. Formulations included a control formulation with pork back fat set at 9% fat content and a modified formulation where pork back fat was entirely replaced with prepared gel emulsions.	Modified patties showed a 70% reduction in fat content compared to the control formulation. The modified patties also demonstrated a 76% reduction in n-6 fatty acids and a 55% increase in long-chain n-3 fatty acids (EPA + DHA). The inclusion of gel emulsions containing reduced n-6 fatty acids and increased long-chain n-3 fatty acids decreased oxidation levels in the modified patties.
Espert et al., 2021	Chocolate	Sunflower oleogel	Hydroxypropyl methylcellulose (HPMC)	The study aimed to investigate the application of sunflower-HPMC-based oleogels as a cocoa butter replacer in chocolate formulations with reduced saturated fat content. Melting, textural, and sensory properties of the chocolates were analyzed. Oleogels were prepared using an emulsion template approach.	Replacing cocoa butter with sunflower-HPMC-based oleogel significantly reduced the hardness of the chocolate. Saturated fat content decreased by 39%. It was suggested that chocolate produced by replacing 50% of cocoa butter with sunflower-HPMC-based oleogel could be a healthier option
Shao et al., 2023	Harbin red sausages	Vegetable oleogels (sunflower, peanut, corn, and flaxseed oils	Ethyl cellulose (EC)	The study investigated the effects of ethyl cellulose concentration and vegetable oil-based oleogels on color, hardness, oil loss, lipid oxidation, and rheological properties. EC concentrations of 6%, 8%, 10%, and 12% were prepared by adding 3g, 4g, 5g, and 6g EC to 50g vegetable oil, respectively. Oil loss in oleogel samples was determined using a centrifuge method. Harbin red sausages were formulated with varying ratios of lean meat and peanut oil-based oleogels (PO10, PO20, PO30, PO40, PO50)	Higher levels of ethyl cellulose resulted in lower oil loss, higher hardness, and increased lipid oxidation in oleogels. Oleogels formulated with peanut oil showed lower oil loss, while flaxseed oil-based oleogels exhibited higher hardness. Corn and peanut oil oleogels led to lower lipid oxidation.
Salcedo-Sandoval et al., 2015	Pork patties	Enhanced fat combination based on konjac gel (olive oil, flaxseed oil, and fish oil)	Carrageenan	The study aimed to evaluate the technological, microbiological, and sensory properties of pork patties by reducing fat content through replacing animal fat with konjac gel and improving the fatty acid profile using a healthier lipid combination stabilized in a konjac gel matrix. Konjac gel was formulated with 64.8% water, konjac flour (5.0%), and i-carrageenan (1.0%), homogenized with 16.2% water and gelatinized corn starch powder (3.0%), cooled to 10°C, and mixed with 10% $Ca(OH)_2$ solution (1.0%).	Replacing pork back fat with varying levels of konjac gel resulted in significant reductions in lipid oxidation. Fat and energy contents were significantly reduced compared to pork-fat-based products (up to 86% and 55%, respectively).

Table 5. *(Continued)* Studies on the effects of gelation techniques on functional compounds

Reference	*Material*	*Phase Types*	*Gel Matrices*	*Aim and Method*	*Results*
Picone et al., 2017	Various emulsion formulations	Emulsion with 40 g/100 g aqueous phase and 60 g/100 g oil phase	Gellan	The study aimed to evaluate the resistance of gelled systems to degradation using in vitro digestion tests and the survival of microorganisms during digestion. Emulsion gel was prepared by homogenizing a gellan solution (0.5 g/100 mL) with an oil phase and storing it. Viability of live L. rhamnosus cells was analyzed in an MRS broth medium containing 1.5 g/100 mL agar.	The gellan gel network served as a barrier against adverse conditions during digestion in the stomach. Gelled solutions containing 0.5 g/100 mL gellan gum were found to be more effective in protecting probiotics compared to non-gelled solutions, with survival rates exceeding 77% in the gel emulsion. Emulsified probiotic cells were protected from bile effects, with viability increasing to 66.35%.
Da Costa et al., 2020	Guava (*Psidium guajava* L.)	Hydrocolloid gel	Agar, low-acyl gellan, high-acyl gellan gum	The study aimed to evaluate the effects of agar and gellan gum on the morphology, texture, and aroma of structured guava. Volatile organic compounds were analyzed using SPME, GC-MS, and SEM.	The volatile profiles of structured guava included aldehydes, alcohols, esters, and terpenes. Processed guava showed a high release of hexanal, (E)-2-hexanal, 1-hexanol, and β-caryophyllene. Guava bars processed with gellan or agar were found to have gastronomic potential.

Another intriguing culinary application of liquid nitrogen arises from the extreme brittleness of frozen materials. Juice sacs from citrus fruits can be prepared by freezing the peeled fruit segments below -130 °C and then breaking them apart using a rigid object. These tiny sacs can be used to enrich ice cream or garnish desserts. Cryogenic grinding of frozen brittle materials produces finer particles and retains more volatile aroma compounds compared to traditional grinding methods, offering an advantage for processing various spices (Aguilera, 2018).

Although liquid nitrogen has no direct adverse effects on consumer health, precautions should be taken, particularly by operators (chefs), to protect their eyes during use. Consumers must also exercise caution. While ingestion of liquid nitrogen is rare, it can cause severe complications, such as gastrointestinal barotrauma (Sivakumaran & Prabodhani, 2018). Another limitation is the need for specialized storage containers (Dewars), which restricts the widespread use of liquid nitrogen in household or restaurant settings. These logistical challenges make liquid nitrogen applications less common outside specialized culinary environments (Caporaso & Formisano, 2016) (Table 6).

Studies examining the effects of the liquid nitrogen technique on foods have shown that this method preserves a significant proportion of nutrients such as polyphenols, pectin, and vitamin C (Cheng et al., 2020) and reduces the activity of polyphenol oxidase, an enzyme responsible for enzymatic browning (Zhu et al., 2020). As a result, this technique not only reduces enzymatic activity in frozen foods but also preserves their functional compounds, offering positive contributions to both sustainability and health.

8. Spherification Technique

Spherification is a widely used technique in the food industry, particularly in molecular gastronomy applications (Onurlar, 2023). This method was introduced to the culinary world in 2003 by Chef Ferran Adrià at the El-Bulli restaurant (Batu, 2019). In modernist cuisine, this technique plays a central role in the creation of faux caviar, eggs, gnocchi, and dumplings (Lee & Rogers, 2012). Broadly, spherification can also be considered an encapsulation method (Caporaso & Formisano, 2016). It involves forming spheres with a thin, hydrocolloid gel-like membrane encapsulating a liquid center. These spheres can be made in various sizes and from a wide range of foods (Hasic, 2021). One of the most notable features of these spheres is their ability to create a flavor burst when gently pressed in the mouth. The sphere should rupture easily, quickly releasing its flavors or contents (Bubin et al., 2019).

Table 6. Studies on the Effects of Liquid Nitrogen Technique on Functional Compounds

Reference	*Material*	*Aim and Method*	*Results*
Cheng et al., 2020	Fresh blueberries (*Chinensis Sonn. Lanfeng*)	The study aimed to investigate the effects of spray liquid nitrogen rapid freezing (NF −20~−100 °C) and gradient thawing on the physical and functional properties of blueberries. Methods such as immersion freezing, refrigeration freezing, microwave thawing, ultrasonic thawing, room temperature thawing, and low-temperature static water thawing were compared.	NF−80 °C freezing combined with −20~−5~4 °C gradient thawing preserved over 95% of polyphenols and other nutritional compounds (including pectin, soluble sugar, and vitamin C) in thawed blueberries. Ultra-low temperature freezing (−100 °C) did not provide significant advantages. Rapid thawing methods like ultrasound and microwave were found unsuitable for blueberries.
Zhu et al., 2020	Wolfberry (*Lycium barbarum* L.)	The study aimed to evaluate the effects of liquid nitrogen spray freezing on water state distribution, color, epidermal microstructure, and the activities of polyphenol oxidase (PPO) and peroxidase (POD). PPO and POD activities were determined using UV spectrophotometry.	NF-100°C freezing offered advantages such as short freezing times and reduced PPO activity. However, NF-80°C was found to provide better sensory quality, similar water distribution to fresh samples, less internal epidermal cell damage, and lower POD activity, making it the optimal freezing method for wolfberry processing.
Castoldi et al., 2017	Rice husks and eucalyptus sawdust	This study utilized liquid nitrogen for the first time as a pre-treatment of plant biomass for enzymatic saccharification. Soluble materials from treated and untreated biomass were analyzed for total soluble phenolics, hydroxymethylfurfural, and furfural using conventional techniques. Endoxylanase and endocellulase activities were measured using 1% carboxymethylcellulose and xylan substrates in a sodium acetate buffer (50 mmol.L^{-1}, pH 5.0) at 50 °C.	Cryogenic milling significantly increased the initial enzymatic hydrolysis rates of eucalyptus wood sawdust and rice husks by more than tenfold without altering the cellulose, hemicellulose, or lignin contents of the biomass. This treatment enhanced the saccharification efficiency of holocellulose without releasing soluble phenolics, furfural, or hydroxymethylfurfural or generating waste

Alginates, natural polysaccharides derived from brown seaweed, are commonly used in the spherification process. These biopolymers dissolve in water, enhancing viscosity and forming gels (Lee & Rogers, 2012). Spherification techniques are classified into two main types based on their preparation method: basic spherification and reverse spherification (TFS). Basic spherification involves injecting a sodium alginate (SA) solution into a calcium bath. This results in calcium ions entering the SA droplet, forming calcium alginate from the surface inward. Conversely, in reverse spherification (TFS), the calcium solution is injected into SA. This causes calcium ions to diffuse from the calcium bath into the surrounding SA, creating an outer layer of calcium alginate (Tsai et al., 2017).

Limitations associated with spherification include selecting the appropriate acidity and calcium concentration, determining the optimal solution density, and adjusting the concentration of flavor compounds (Caporaso & Formisano, 2016). Additionally, even after the spheres are removed from the calcium bath and rinsed, the gelation process of the liquid continues. Thus, it is crucial to serve the spheres promptly to customers (Batu, 2019).

Studies on the effects of the spherification technique on functional compounds are summarized in Table 7.

Encapsulating polyphenols derived from plant extracts within a matrix or membrane in particle form is an effective strategy for preserving their health-promoting properties (Arriola et al., 2016). Encapsulation techniques are typically employed to maintain the stability of bioactive compounds during processing and storage while preventing unwanted interactions with food matrices. This approach not only enhances stability but also facilitates the controlled release of encapsulated compounds (Arriola et al., 2016). Microencapsulation appears to be a promising alternative for improving the absorption of phenolic compounds by epithelial cells (Silva et al., 2021).

The addition of phenolic extracts has been observed to influence the internal structure of edible bubbles, as evidenced by changes in roughness and elemental composition (Bortolini et al., 2024). Research has demonstrated that phenolic compounds can be absorbed onto the inner wall of edible bubbles, altering its roughness. Moreover, these edible bubbles can protect the adsorbed phenolic compounds during simulated gastrointestinal digestion (Bortolini et al., 2024).

Table 7. Studies on the effects of the spherification technique on functional compounds

Reference	*Material*	*Aim and Method*	*Results*
Bortolini et al., 2024	Red berries and edible flowers	The aim of this study was to evaluate the bioaccessibility of phenolic extracts obtained from edible flowers and red berries encapsulated in edible calcium alginate bubbles. DPPH reagent (2,2-Diphenyl-1-picrylhydrazyl) was used for measuring antioxidant activity, and chromatographic analysis was applied to determine the presence of phenolic compounds before and after digestion.	Edible bubbles exhibited up to 182 µg of total phenolic compound concentration (in GAE/g) and antioxidant activity up to 9748.54 µg TE/g as determined by the DPPH test. Simulated gastrointestinal digestion demonstrated preserved antioxidant activity and higher bioaccessibility in edible bubbles compared to isolated extracts. Chromatographic analysis revealed the release of adsorbed compounds during in vitro gastrointestinal digestion.
Arriola et al., 2016	Bertoni (*Stevia rebaudiana*)	This study aimed to encapsulate the aqueous leaf extract of Stevia rebaudiana Bertoni using sodium alginate and evaluate its effects on total phenolic content (TPC) and antioxidant stability. Encapsulation of the optimized extract was performed using extrusion technology. Wet and lyophilized calcium alginate beads were analyzed and compared for TPC and retention efficiency under storage conditions. The TPC of the aqueous leaf extracts of Stevia was determined following a modified Folin-Ciocalteu procedure.	A high correlation was observed between the TPC of the extract and its antioxidant activity, as determined by free radical scavenging and ferric reducing capacity. Lyophilization significantly influenced bead size and morphology, proving to be a suitable technique for preserving encapsulated polyphenols. Both wet and lyophilized beads demonstrated stability in TPC and maintained antioxidant potential during 30 days of storage at 4°C
Silva et al., 2021	Green tea (*Camellia sinensis var. assamica*)	This study aimed to investigate the in vitro simulated gastrointestinal digestion (SGD) and the gastroprotective effect of green tea extract (GTE) microencapsulated with cashew gum and maltodextrin in an ethanol-induced gastric lesion experimental model in mice. The total extractable polyphenol content of the samples was determined using the Folin-Ciocalteu method. The antioxidant capacity of GTE and GTM (green tea microcapsules) was assessed via the scavenging activity of ABTS●+ cation radicals.	The microencapsulation process (GTM) enhanced the bioavailability of polyphenols (28.2%) and antioxidant activity (24.2%) of green tea after in vitro SGD. A dose-dependent gastroprotective effect was confirmed for GTE and GTM, with a concentration of 10 mg/kg effectively preserving gastric mucosa by maintaining glutathione levels in tissues and reducing malondialdehyde levels after alcohol-induced lesions. Overall, GTM demonstrated significant potential for the development of green tea-enriched products and provided a gastroprotective effect beneficial to consumer health.

9. Powdering

The powdering technique involves transforming substances into powder form in an unconventional way by utilizing their chemical and physical properties, rather than traditional grinding methods (Dağlıoğlu, 2019). Using this method, products such as chocolate, hazelnut cream, mayonnaise, olive oil, and bacon can be converted into powder form (Özbek, 2023; Dağlıoğlu, 2019). This technique is applied in two main ways, the first being the transformation of high-fat liquids into fine powders. The process involves adding an additive to the product until it achieves a powder-like consistency, with the feasibility of the technique largely depending on the low density of the additive (Alpaslan et al., 2020). This method is based on mixing high-fat food items with low-density maltodextrin derived from tapioca sugar (tapioca starch) until a powdered form is obtained (Dağlıoğlu, 2019; Aksoy and Sezgi, 2017). These high-fat foods, powdered by mixing with tapioca starch, revert to their liquid form in water-containing environments. One of the most common applications in molecular gastronomy is the powdering of olive oil using maltodextrin (Dağlıoğlu, 2019).

Maltodextrins are primarily formed by the bonding of beta-D-glucose units and are typically classified based on their dextrose equivalent (DE). The DE value determines the reducing capacity of a maltodextrin and is inversely proportional to its average molecular weight. Maltodextrins with different DE values exhibit varying physicochemical properties, such as viscosity, solubility, and freezing point. However, maltodextrins with the same DE value may possess distinct characteristics depending on factors like starch source, hydrolysis procedure, and amylose/amylopectin ratio. Maltodextrins are widely used in food emulsions as stabilizers, sweeteners, and flavor carriers (Guiné et al., 2012).

The second powdering method involves freezing liquid or solid foods by immersing them in liquid nitrogen, followed by breaking them into pieces of the desired size (Alpaslan et al., 2020). In this approach, fluid or non-fluid foods change form when placed in a container filled with liquid nitrogen. The rapid freezing process enhances the brittleness of the food, making it easier to process and break into desired-sized pieces. These granulated products revert to liquid form upon contact with body heat during tasting (Özbek, 2023).

Table 8. Studies on the effects of the powdering technique on functional compounds

Referance	*Material*	*Purpose and Method*	*Results*
Gawałek & Domian, 2020	Aronia berry juice concentrate, tapioca dextrin, maltodextrin	This study aimed to evaluate the efficacy of tapioca dextrin as an alternative carrier to potato maltodextrin in food drying processes. Aronia berry juice concentrate served as the primary research material, with tapioca dextrin used as a carrier and maltodextrin for comparison. The concentrate was spray-dried using a spray dryer, and the resulting powders were analyzed under an electron microscope.	Tapioca starch as a carrier produced powders with superior functional properties compared to potato maltodextrin. Drying speed, temperature, and carrier type significantly influenced powder yield, polyphenol content, and antioxidant capacity. Increased carrier content, higher speeds, and elevated temperatures were found to decrease polyphenol content during the spray drying process of aronia berries.
Moreno et al., 2016	Grape pomace extract, maltodextrin, pea protein isolate, whey protein isolate	This study aimed to compare the effectiveness of natural carriers—maltodextrin, pea protein isolate, and whey protein isolate—in formulating polyphenol-enriched grape pomace extract using spray drying. The outcomes were evaluated based on total phenolic content, flavonoid content, anthocyanin levels, and oxygen radical absorbance capacity.	The drying process indicated that the outlet temperature had a greater impact on particle characteristics than the inlet temperature. When the extract was spray-dried without any carrier material, a 22% reduction in total phenolic content (TPC) was observed. However, even minimal addition of carrier reduced this loss to below 12%. Pea protein and whey protein outperformed maltodextrin in preserving total phenolic and anthocyanin content. Whey protein isolate showed a superior increase in both chemical and cellular antioxidant activities compared to the other carriers.

Studies examining the effects of the powdering technique on functional compounds are summarized in Table 8.

The increasing global consumption of convenience foods has led to a growing demand for dried products, as consumers seek items that facilitate quick and easy meal preparation and storage (Gawałek and Domian, 2020). Spray drying, commonly used in studies, involves optimizing key factors such as feed temperature, inlet air temperature, and outlet air temperature. The feed temperature is related to the viscosity of the liquid and its capacity for homogeneous spraying. The inlet air temperature is directly proportional to the drying rate and final moisture content, while the outlet air temperature serves as an index for controlling the dryer (Moreno et al., 2016).

Drying characteristics and the carrier materials used have been found to influence the properties of the powders. One study indicated that drying speed and temperature significantly affect the nutritional content, emphasizing the importance of selecting appropriate conditions (Gawałek and Domian, 2020). Another study highlighted that the addition of carrier materials reduced the loss of phenolic compounds during the drying process (Moreno et al., 2016).

10. Ultrasonic Applications

"Ultrasound" is typically defined as a form of mechanical energy with frequencies above 20 kHz, beyond the range of human hearing. Ultrasound technology, widely used in the food industry, is a significant and innovative approach with potential applications in gastronomy, including decontamination, marination, tenderization, cutting, diagnostic analysis, homogenization, emulsification, dehydration, rehydration, and molecular gastronomy (Baslar, 2024). In 2010, Sang-Hoon Degeimbre, chef and owner of the renowned restaurant L'air du temps in Noville sur Mehaigne, Belgium, introduced ultrasonic technology to the culinary world as an innovative technique (Onurlar, 2023).

Among the advantages of ultrasonic processing are its chemical- and additive-free nature, its simplicity and speed, and the fact that it does not cause significant chemical alterations in food (Caporaso & Formisano, 2016). Considering these benefits, this technique holds great potential for producing high-quality, functional, and unique food products in the future. Furthermore, the combination of heat and pressure in industrial applications could lead to the broader adoption of microbial and enzymatic inactivation processes (Türksönmez & Diler, 2021). For instance, high-

Table 9. Studies on the effects of ultrasonic applications in molecular gastronomy

Reference	*Material*	*Purpose and Method*	*Results*
Chang and Chen, 2002.	Wine made from rice and corn	The study aimed to investigate whether aging with 20 kHz ultrasonic waves has the potential to produce a wine comparable in quality to traditionally aged wine.	The pH value of rice wine treated with 20 kHz ultrasonic waves slightly increased as the number of treatments increased, resulting in a less sour taste and making the ultrasonically aged wine more favorable. In contrast, the pH value of corn wine treated with 20 kHz ultrasonic waves remained the same as that of untreated corn wine despite multiple treatments. It was observed that the alcohol loss in ultrasonically aged corn wine was slightly lower than that in rice wine. While rapid aging was achieved in rice wine, proper aging could not be accomplished in corn wine.
Doguer et al., 2021	Purple basil (*Ocimum basilicum* L.)	This study aimed to investigate the potential anticancer activities of sirkencubin syrup enriched with purple basil on human colon carcinoma cells (Caco-2). Additionally, the effects of ultrasonic treatment on purple basil components and bioactive compounds were explored in terms of changes in total phenolic, flavonoid, ascorbic acid, and total antioxidant content using modeling and optimization methods.	Ultrasonic treatment (UT) was found to enhance the antioxidant activity and increase the levels of bioactive flavonoid and phenolic compounds in sirkencubin syrup enriched with purple basil. The ultrasonic treatment of purple basil syrup (PBS) samples reduced the total amount of ketones by 45.5%. Moreover, it was observed that the ester aroma compounds in PBS were 0.19 μg/kg lower than in UT-treated PBS samples. The aroma and sensory properties of UT-PBS were found to be more acceptable compared to other beverages, marking an important observation.
Yıkmış et al., 2022	Purple onion (*Allium cepa*)	This study evaluated antihypertensive, anticancer, antidiabetic, antimicrobial properties, volatile profiles, phenolic compounds, organic acids, minerals, and sugar components for untreated purple onion vinegar (U-POV), thermally pasteurized purple onion vinegar (P-POV), and ultrasound-enriched purple onion vinegar (UT-POV) samples. Total phenolic content (TPC) was analyzed using the Folin-Ciocalteu method, antioxidant activities were assessed through the DPPH radical scavenging assay, and the total antioxidant capacity was determined using the CUPRAC assay. Flavonoid content was measured via aluminum chloride colorimetric analysis	Ultrasonically treated purple onion vinegar (UT-POV) demonstrated enhanced antidiabetic and antihypertensive effects. The ultrasound process increased the amounts of polyphenols, including catechin, gallic acid, hydroxybenzoic acid, and protocatechuic acid. Additionally, UT-POV samples were enriched with potassium (K) and zinc (Zn) minerals. Compared to thermally pasteurized purple onion vinegar (P-POV), UT-POV had a lesser impact on volatile compounds. Ultrasonically processed purple onion vinegar is considered a promising option for sustainable gastronomy
Dahroud et al., 2016	*Lactobacillus casei subsp.casei* ATTC 39392	This study aimed to evaluate the effects of low-intensity ultrasound technology on improving metabolic activity for the production of L-lactic acid by Lactobacillus casei in different media (MRS broth)	Enhanced fermentation was observed, with increases in lactic acid production, cell proliferation, and substrate consumption. No adverse effects on cell morphology were detected.

intensity ultrasound can be a preferred method for preserving milk and dairy products due to its ability to deactivate pathogenic microorganisms and enzymes. Additionally, it can induce physical-chemical changes in food, positively influencing probiotic viability and metabolic activity (Guimarães JT et al., 2019). Table 9 provides an overview of a study examining the effects of ultrasonic applications on molecular gastronomy.

Various studies employing ultrasonic applications have demonstrated positive effects of ultrasonic waves in accelerating wine aging (Chang and Chen, 2002) and enhancing fermentation processes (Dahroud et al., 2016). Ultrasonic treatment applied to purple onion vinegar has been observed to increase the levels of polyphenols such as catechin, gallic acid, hydroxybenzoic acid, and protocatechuic acid (Yıkmış et al., 2022). Evaluating these studies reveals that ultrasonic applications hold significant importance in terms of health and sustainability.

Conclusion and Recommendations

Molecular cooking techniques offer innovative alternatives that significantly influence the functional components of foods, providing benefits in both nutrition and safety. Methods such as low-temperature cooking, vacuum processing, and smoking can enhance antioxidant capacity and bioavailability while preserving essential nutrients like vitamins and polyphenols. These techniques also help prevent the formation of harmful compounds, such as acrylamides and heterocyclic amines, which are commonly

associated with high-temperature cooking processes. Furthermore, molecular cooking contributes to food safety by reducing pathogenic microorganisms without compromising sensory quality.

To advance this field, the effects of molecular cooking techniques on functional components across various food systems must be further investigated. Standardizing cooking parameters is necessary to ensure consistent health benefits. The food industry can leverage these techniques to create healthier, safer, and more sustainable food products that align with the increasing demand for functional and nutrient-rich foods.

Molecular cooking techniques play a vital role in promoting sustainability through energy efficiency. Methods such as low-temperature cooking and vacuum processing can reduce energy consumption, thereby minimizing environmental impact. Controlled processing environments help optimize water usage and reduce food waste, contributing to a more sustainable food production system. From a practical standpoint, molecular gastronomy enables the creation of innovative food products with nutritional richness and diverse flavor profiles, offering consumers healthier and more enjoyable options.

Recommendations for the Implementation of Molecular Cooking Techniques:

1. Raising Awareness and Education: Educating food scientists, chefs, and consumers about molecular cooking techniques can help build a broader knowledge base, highlighting their advantages and proper application methods.
2. Improving Equipment Accessibility: Developing molecular cooking equipment that is more affordable and accessible can facilitate the widespread adoption of these techniques.
3. Establishing Health and Safety Standards: Creating and enforcing clear health and safety standards for molecular cooking techniques is essential to ensure the safe processing and consumption of foods.
4. Developing Innovative Food Products: Leveraging the advantages of molecular cooking techniques can lead to the creation of new food products that offer high nutritional value and unique flavor experiences.
5. Integrating Molecular Techniques into the Agri-Food Chain: Applying molecular cooking techniques throughout the farm-to-table process can reduce food waste and ensure the delivery of fresh, nutritious foods to consumers.
6. Conducting Comparative Studies: Further research is needed to evaluate the effects of molecular cooking techniques on food components in comparison to traditional methods, as well as their environmental impacts.

In conclusion, molecular cooking techniques contribute to the production of foods that are both nutritionally rich and flavorful, enhancing consumer health and satisfaction. These techniques hold significant potential in advancing health, sustainability, and future applications. Their broader adoption and further development can open pathways to a more sustainable and innovative future for the food industry. However, ongoing in-depth studies are required to thoroughly understand their effects on the chemical stability and nutritional value of functional compounds, ensuring their optimal use in food production systems.

Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

M.A. Çakır (0000-0001-5066-1956): *Conceptualization, writing – original draft, methodology, resources, review and editing*
D. Kara (0009-0008-4875-4529): *Resources, methodology, writing –review and editing.*
M. Çala (0009-0008-2626-6639): *Resources, methodology, writing –review and editing.*
Ş. Trak (0009-0006-9902-9955): *Resources, methodology, writing –review and editing.*
Z. İpek (0009-0005-1247-665X): *Resources, methodology, writing –review and editing.*

References

Abdullah, Liu, L., Javed, H. U., & Xiao, J. (2022). Engineering Emulsion Gels as Functional Colloids Emphasizing Food Applications: A Review. *Frontiers in nutrition*, *9*, 890188. https://doi.org/10.3389/fnut.2022.890188

Adeyeye, S. A. O., & Oyewole, O. B. (2016). An overview of traditional fish smoking in Africa. *Journal of culinary science & technology, 14*(3), 198-215. https://doi.org/10.1080/15428052.2015.1102785

Aguilera J. M. (2018). Relating Food Engineering to Cooking and Gastronomy. *Comprehensive reviews in food science and food safety*, *17*(4), 1021–1039. https://doi.org/10.1111/1541-4337.12361

Aksoy, M., & Sezgi, G. (2017). Moleküler mutfak tekniklerinin duyusal analiz yöntemiyle değerlendirilmesi. *Journal of Tourism & Gastronomy Studies*, *5*(4), 546-565.

Aksoy, M., & Üner, E. H. (2016). Rafine mutfağın doğuşu ve rafine mutfağı şekillendiren yenilikçi mutfak akımlarının

yiyecek içecek işletmelerine etkileri. *Gazi Üniversitesi Sosyal Bilimler Dergisi*, *3*(6), 1-17.

Alejandre, M., Passarini, D., Astiasarán, I., & Ansorena, D. (2017). The effect of low-fat beef patties formulated with a low-energy fat analogue enriched in long-chain polyunsaturated fatty acids on lipid oxidation and sensory attributes. *Meat science*, *134*, 7–13. https://doi.org/10.1016/j.meatsci.2017.07.009

Alpaslan, K., Pamukçu, H., & Tanrısever, C. (2020). Moleküler gastronomi yöresel yemeklerde kullanılabilir mi? (Can molecular gastronomy be usefull for local food?). *Journal of Tourism & Gastronomy Studies*, *8*(1), 231-256.

Arriola, N. D. A., de Medeiros, P. M., Prudencio, E. S., Müller, C. M. O., & Amboni, R. D. D. M. C. (2016). Encapsulation of aqueous leaf extract of Stevia rebaudiana Bertoni with sodium alginate and its impact on phenolic content. *Food Bioscience*, *13*, 32-40. https://doi.org/10.1016/j.fbio.2015.12.001

Assogba, M. F., Anihouvi, D. G. H., Iko Afé, O. H., Kpoclou, Y. E., Mahillon, J., Scippo, M. L., Hounhouigan, D. J., & Anihouvi, V. B. (2019). Processing methods, preservation practices and quality attributes of smoked and smoked-dried fishes consumed in Benin. Cogent Food & Agriculture, 5(1), 1641255. https://doi.org/10.1080/23311932.2019.1641255

Ayub, H., & Ahmad, A. (2019). Physiochemical changes in sous-vide and conventionally cooked meat. *International journal of gastronomy and food science*, *17*, 100145. https://doi.org/10.1016/j.ijgfs.2019.100145

Barham, P., Skibsted, L. H., Bredie, W. L., Frøst, M. B., Møller, P., Risbo, J., Snitkjaer, P., & Mortensen, L. M. (2010). Molecular gastronomy: a new emerging scientific discipline. *Chemical reviews*, *110*(4), 2313–2365. https://doi.org/10.1021/cr900105w

Baslar, M. (2024). An Innovative Approach in Gastronomy: Ultrasound Technology. *International Journal of Gastronomy Research*, *3*(1), 24–29. https://doi.org/10.56479/ijgr-38

Batu, A. (2019). Moleküler gastronomi: Gıda üretiminde yeni bir devrim. *Aydın Gastronomy*, *3*(1), 43-54.

Bhuyan, A., Hussain, I. A., & Sarma, P. (2022). Sous-Vide Technique. *Agriculture & Food: E-newsletter*, *4*(5).

Bıyıklı, M., Akoğlu, A., Kurhan, Ş., & Akoğlu, İ. T. (2020). Effect of different Sous Vide cooking temperature-time combinations on the physicochemical, microbiological, and sensory properties of turkey cutlet. *International Journal of Gastronomy and Food Science*, *20*, 100204. https://doi.org/10.1016/j.ijgfs.2020.100204

Bortolini, D. G., Maciel, G. M., & Haminiuk, C. W. I. (2024). Edible bubbles: A delivery system for enhanced bioaccessibility of phenolic compounds in red fruits and edible flowers. *Innovative Food Science & Emerging Technologies, 91*, 103523. https://doi.org/10.1016/j.ifset.2023.103523

Bozbayır, U. (2021). Aşçıların İnovasyon Davranışı Düzeyleri ile Füzyon Mutfak ve Moleküler Gastronomi Uygulamalarına Bakış Açıları. Gaziantep Üniversitesi. Gaziantep.

Božić, A., & Đurović, M. (2019). Moleclar Gastronomy–New Trend In Restaurant Business. *Knowledge-International Journal, 30*(6), 1785-1790.

Brenner, M. P., & Sörensen, P. M. (2015). Biophysics of molecular gastronomy. *Cell*, *161*(1), 5–8. https://doi.org/10.1016/j.cell.2015.03.002

Bubin, S. F. A., Mat Ali, S., Shukri, R., Wan Ibadullah, W. Z., Ramli, N. S., Mustapha, N. A., & Mohammad Rashedi, I. F. (2019). Characterization and stability of pitaya pearls from hydrocolloids by reverse spherification. *International Journal of Food Properties*, *22*(1), 1353–1364. https://doi.org/10.1080/10942912.2019.1647234

Burke, R., This, H., & Kelly, A. (2016). Molecular gastronomy. https://doi.org/10.1016/B978-0-08-100596-5.03384-9

Cakir, M. A., & Helvacioglu, I. (2023). Bioavailability and health effects of some carotenoids by different cooking methods. International Journal of Gastronomy Research, 2(2), 70–77. https://doi.org/10.56479/ipeak.2023.12181

Caporaso, N., & Formisano, D. (2016). Developments, applications, and trends of molecular gastronomy among food scientists and innovative chefs. *Food Reviews International*, *32*(4), 417–435. https://doi.org/10.1080/87559129.2015.1094818

Castoldi, R., Correa, V. G., de Morais, G. R., de Souza, C. G. M., Bracht, A., Peralta, R. A., Peralta-Muniz Moreira, R. F., & Peralta, R. M. (2017). Liquid nitrogen pretreatment of eucalyptus sawdust and rice hull for enhanced enzymatic saccharification. *Bioresource technology*, *224*, 648–655. https://doi.org/10.1016/j.biortech.2016.11.099

Chang, A. C., & Chen, F. C. (2002). The application of 20 kHz ultrasonic waves to accelerate the aging of different wines. Food Chemistry, 79(4), 501-506.https://doi.org/10.1016/j.lwt.2019.108923

Cheng, L., Wu, W., An, K., Xu, Y., Yu, Y., Wen, J., Wu, J., Zou, Y., Liu, H., Zhu, J., & Xiao, G. (2020). Advantages of liquid nitrogen quick freezing combine gradient slow thawing for quality preserving of blueberry. *Crystals*, *10*(5), 368. https://doi.org/10.3390/cryst10050368

Chiavaro, E., Mazzeo, T., Visconti, A., Manzi, C., Fogliano, V., & Pellegrini, N. (2012). Nutritional quality of sous vide cooked carrots and brussels sprouts. *Journal of agricultural and food chemistry*, *60*(23), 6019–6025. https://doi.org/10.1021/jf300692a

Colasanto, A., Travaglia, F., Bordiga, M., Coisson, J. D., Arlorio, M., & Locatelli, M. (2023). Impact of Traditional and Innovative Cooking Techniques on the Composition of Italian Black Rice (Oryza Sativa L., Artemide Cv). *Available at SSRN 4538456*.

Cömert, M., & Çavuş, O. (2016). Moleküler gastronomi kavramı. *Journal of Tourism and Gastronomy Studies, 4*(4), 118-131.

Czarnowska-Kujawska, M., Draszanowska, A., & Starowicz, M. (2022). Effect of different cooking methods on the folate content, organoleptic and functional properties of broccoli and spinach. *LWT*, *167*, 113825. https://doi.org/10.1016/j.lwt.2022.113825

da Costa, J. N., Leal, A. R., Nascimento, L. G., Rodrigues, D. C., Muniz, C. R., Figueiredo, R. W., Mata, P., Noronha, J. P., & de Sousa, P. H. M. (2020). Texture, microstructure and volatile profile of structured guava using agar and gellan gum. *International Journal of Gastronomy and Food Science*, *20*, 100207. https://doi.org/10.1016/j.ijgfs.2020.100207

Dağlıoğlu, P. (2019). Tüketicilerin moleküler gastronomi ürünlerine olan tutumlarının değerlendirilmesi: Didim örneği. Aydın Adnan Menderes Üniversitesi. Aydın.

Dahroud, B. D., Mokarram, R. R., Khiabani, M. S., Hamishehkar, H., Bialvaei, A. Z., Yousefi, M., & Kafil, H. S. (2016). Low intensity ultrasound increases the fermentation efficiency of Lactobacillus casei subsp.casei ATTC 39392. *International journal of biological*

macromolecules, *86*, 462–467. https://doi.org/10.1016/j.ijbiomac.2016.01.103

Dayısoylu, K. S., Gezginç, Y., & Cingöz, A. (2014). Fonksiyonel gıda mı, fonksiyonel bileşen mi? Gıdalarda fonksiyonellik. *Gıda*, *39*(1), 57-62.

de Jesús Ramírez-Rivera, E., Galván-Herrera, M. E., González-López, C., Tello-Torres, M., Sánchez-González, C. N., Guerrero-Ortiz, C. A., Hernández-Salinas, G., Cabal-Prieto, A., & Herrera-Corredor, J. A. (2023). Novel Oaxaca cheese-based food products prepared by molecular cooking techniques: An insight into attributes, emotions, memories, and liking. *International Journal of Gastronomy and Food Science, 32*, 100694. https://doi.org/10.1016/j.ijgfs.2023.100694

Demirel Ozbek, Y., Saral, O., & Turker, P. F. (2024). Modern and traditional cooking methods affect the antioxidant activity and phenolic compounds content of Trachystemon Orientalis (L.) G. Don. *Plos one*, *19*(2), e0299037. https://doi.org/10.1371/journal.pone.0299037

Doguer, C., Yıkmış, S., Levent, O., & Turkol, M. (2021). Anticancer effects of enrichment in the bioactive components of the functional beverage of Turkish gastronomy by supplementation with purple basil (Ocimum basilicum L.) and the ultrasound treatment. *Journal of Food Processing and Preservation*, *45*(5), e15436. https://doi.org/10.1111/jfpp.15436

Doğan, M., (2022). Gıdalar, Özellikleri, Fonksiyonları ve Mutfak Uygulamaları, *Nobel Akademik Yayınları, Ankara*., Ed: Doğan M. ISBN: 978-625-427-785-6

Erbaş, M. (2006). Yeni bir gıda grubu olarak fonksiyonel gıdalar. Türkiye, 9, 24-26.

Espert, M., Hernández, M. J., Sanz, T., & Salvador, A. (2021). Reduction of saturated fat in chocolate by using sunflower oil-hydroxypropyl methylcellulose based oleogels. *Food Hydrocolloids*, *120*, 106917. https://doi.org/10.1016/j.foodhyd.2021.106917

Florkiewicz, A., Socha, R., Filipiak-Florkiewicz, A., & Topolska, K. (2019). Sous-vide technique as an alternative to traditional cooking methods in the context of antioxidant properties of Brassica vegetables. *Journal of the science of food and agriculture*, *99*(1), 173–182. https://doi.org/10.1002/jsfa.9158

Gawałek J, Domian E. (2020). Tapioca Dextrin as an Alternative Carrier in the Spray Drying of Fruit Juices—A Case Study of Chokeberry Powder. Foods. 2020; 9(8):1125. https://doi.org/10.3390/foods9081125

Granato, D., Nunes, D. S., & Barba, F. J. (2017). An integrated strategy between food chemistry, biology, nutrition, pharmacology, and statistics in the development of functional foods: A proposal. *Trends in Food Science & Technology*, *62*, 13-22. https://doi.org/10.1016/j.tifs.2016.12.010

Guclu, G., Dagli, M. M., Ozge Aksay, Keskin, M., Kelebek, H., & Selli, S. (2023). Comparative elucidation on the phenolic fingerprint, sugars and antioxidant activity of white, orange and purple-fleshed sweet potatoes (*Ipomoea batatas* L.) as affected by different cooking methods. *Heliyon*, *9*(8), e18684. https://doi.org/10.1016/j.heliyon.2023.e18684

Guimarães, J. T., Balthazar, C. F., Scudino, H., Pimentel, T. C., Esmerino, E. A., Ashokkumar, M., Freitas, M. Q., & Cruz, A. G. (2019). High-intensity ultrasound: A novel technology for the development of probiotic and prebiotic dairy products. *Ultrasonics sonochemistry*, *57*, 12–21. https://doi.org/10.1016/j.ultsonch.2019.05.004

Guiné, R. P., Dias, A., Peixoto, A., Matos, M., Gonzaga, M., & Silva, M. (2012). Application of molecular gastronomy principles to the development of a powdered olive oil and market study aiming at its commercialization. *International Journal of Gastronomy and Food Science*, *1*(2), 101-106. https://doi.org/10.1016/j.ijgfs.2013.05.001

Hagos, L. (2021). Smoking methods and microbiological characteristics of smoked fishes: A review. *Journal of Food and Nutrition Sciences, 9*(5), 113-116.

Haraf, G., Goluch, Z., Teleszko, M., & Latocha, P. (2024). Antioxidant Activity and Fatty Acid Profile of Sous-Vide Beef Marinated with Kiwiberry Fruit Pulp: Effects of Level Addition and Refrigerated Storage. *Foods (Basel, Switzerland)*, *13*(10), 1446. https://doi.org/10.3390/foods13101446

Hasani, E., Csehi, B., Darnay, L., Ladányi, M., Dalmadi, I., & Kenesei, G. (2022). Effect of Combination of Time and Temperature on Quality Characteristics of Sous Vide Chicken Breast. *Foods (Basel, Switzerland)*, *11*(4), 521. https://doi.org/10.3390/foods11040521

Hasic, S. (2021). Spherification. In *Handbook of Molecular Gastronomy* (pp. 819-824). CRC Press.

Hitzel, A., Pöhlmann, M., Schwägele, F., Speer, K., & Jira, W. (2013). Polycyclic aromatic hydrocarbons (PAH) and phenolic substances in meat products smoked with different types of wood and smoking spices. *Food chemistry*, *139*(1-4), 955–962. https://doi.org/10.1016/j.foodchem.2013.02.011

Karafyllaki, D., Narwojsz, A., Kurp, L., & Sawicki, T. (2023). Effects of different processing methods on the polyphenolic compounds profile and the antioxidant and anti-glycaemic properties of horseradish roots (*Armoracia rusticana*). *European Food Research and Technology*, *249*(7), 1739-1747. https://doi.org/10.1007/s00217-023-04248-3

Kathuria, D., Dhiman, A. K., & Attri, S. (2022). Sous vide, a culinary technique for improving quality of food products: A review. *Trends in Food Science & Technology*, *119*, 57-68. https://doi.org/10.1016/j.tifs.2021.11.031

Kaur, R., Simnani, F. Z., & Singh, S. (2022). Enhancement of Probiotics for Functional Food. *In Recent Advances in Food Biotechnology* (pp. 97-137). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-16-8125-7_6

Kosewski, G., Górna, I., Bolesławska, I., Kowalówka, M., Więckowska, B., Główka, A. K., Morawska, A., Jakubowski, K., Dobrzyńska, M., Miszczuk, P., & Przysławski, J. (2018). Comparison of antioxidative properties of raw vegetables and thermally processed ones using the conventional and sous-vide methods. *Food chemistry*, *240*, 1092–1096. https://doi.org/10.1016/j.foodchem.2017.08.048

Lafarga, T., Viñas, I., Bobo, G., Simó, J., & Aguiló-Aguayo, I. (2018). Effect of steaming and sous vide processing on the total phenolic content, vitamin C and antioxidant potential of the genus Brassica. *Innovative Food Science & Emerging Technologies*, *47*, 412-420. https://doi.org/10.1016/j.ifset.2018.04.008

Ledesma, E., Rendueles, M., & Díaz, M. (2015). Characterization of natural and synthetic casings and mechanism of BaP penetration in smoked meat products. *Food Control*, *51*, 195-205. https://doi.org/10.1016/j.foodcont.2014.11.025

Lee, P., & Rogers, M. A. (2012). Effect of calcium source and exposure-time on basic caviar spherification using

sodium alginate. *International Journal of Gastronomy and Food Science, 1*(2), 96-100. https://doi.org/10.1016/j.ijgfs.2013.06.003

Li, Y., Zhang, C., Hu, B., Gao, Z., Wu, Y., Deng, Q., Nishinari, K., & Fang, Y. (2023). Formation and application of edible oleogels prepared by dispersing soy fiber particles in oil phase. *Food research international (Ottawa, Ont.)*, *164*, 112369. https://doi.org/10.1016/j.foodres.2022.112369

Logsdon, J. (2018). Modernist Köpükler Nasıl Yapılır?. http://www.amazingfoodmadeeasy.com/info/modernist techniques/more/culinaryfoams-technique

Malarut, J. A., & Vangnai, K. (2018). Influence of wood types on quality and carcinogenic polycyclic aromatic hydrocarbons (PAHs) of smoked sausages. *Food Control, 85*, 98-106. https://doi.org/10.1016/j.foodcont.2017.09.020

Martins, A. J., Vicente, A. A., Cunha, R. L., & Cerqueira, M. A., (2018). Edible oleogels: an opportunity for fat replacement in foods. *Food & function*, *9*(2), 758–773. https://doi.org/10.1039/c7fo01641g

Marušić Radovčić, N., Vidaček, S., Janči, T., & Medić, H. (2016). Characterization of volatile compounds, physico-chemical and sensory characteristics of smoked dry-cured ham. *Journal of food science and technology*, *53*(11), 4093–4105. https://doi.org/10.1007/s13197-016-2418-2

Mastanjević, K., Kartalović, B., Puljić, L., Kovačević, D., & Habschied, K. (2020). Influence of different smoking procedures on polycyclic aromatic hydrocarbons formation in traditional dry sausage Hercegovačka kobasica. *Processes*, *8*(8), 918 https://doi.org/10.3390/pr8080918.

McClements, D. J. (2021). Food hydrocolloids: Application as functional ingredients to control lipid digestion and bioavailability. *Food Hydrocolloids*, *111*, 106404. https://doi.org/10.1016/j.foodhyd.2020.106404

Moreno, T., de Paz, E., Navarro, I. et al. Spray Drying Formulation of Polyphenols-Rich Grape Marc Extract: Evaluation of Operating Conditions and Different Natural Carriers. Food Bioprocess Technol 9, 2046–2058 (2016). https://doi.org/10.1007/s11947-016-1792-0

Onurlar, B. (2023). Molecular gastronomy. *Global Concepts in Gastronomy*, 265.

Özbek, A. (2023). Moleküler Gastronomi Teknikleri ve Tabak Sunumuna Uygulanması. Yüksek Lisans Tezi. İstanbul Topkapı Üniversitesi. İstanbul.

Özdemir, H., Soyer, A., Tağı, Ş., & Turan, M. (2014). Nar kabuğu ekstraktının antimikrobiyel ve antioksidan aktivitesinin köfte kalitesine etkisi. *Gıda*, *39*(6), 355-362.

Özel, K. (2018). Moleküler mutfak tekniklerinden; Kapsülleştirme, tütsüleme, sous-vide, soğuk pişirme, sıvı-azot tekniklerinin duyusal analiz yöntemiyle incelenerek örnek standart reçetelerin hazırlanması. *Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.*

Özel, K., & Özkaya, F. D. (2016). Moleküler gastronomide zeytinyağı. *Zeytin Bilimi, 6*(2), 49-59.

Palermo, M., Pellegrini, N., & Fogliano, V. (2014). The effect of cooking on the phytochemical content of vegetables. *Journal of the Science of Food and Agriculture*, *94*(6), 1057–1070. https://doi.org/10.1002/jsfa.6478

Petričević, S., Marušić Radovčić, N., Lukić, K., Listeš, E., & Medić, H. (2018). Differentiation of dry-cured hams from different processing methods by means of volatile compounds, physico-chemical and sensory analysis. *Meat science, 137*, 217–227. https://doi.org/10.1016/j.meatsci.2017.12.001

Picone, C. S. F., Bueno, A. C., Michelon, M., & Cunha, R. L. (2017). Development of a probiotic delivery system based on gelation of water-in-oil emulsions. Lwt, 86, 62-68. https://doi.org/10.1016/j.lwt.2017.07.045

Pino J. A. (2014). Characterisation of volatile compounds in a smoke flavouring from rice husk. *Food chemistry*, *153*, 81–86. https://doi.org/10.1016/j.foodchem.2013.12.041

Pirsa, S., & Hafezi, K. (2023). Hydrocolloids: Structure, preparation method, and application in food industry. *Food chemistry*, *399*, 133967. https://doi.org/10.1016/j.foodchem.2022.133967

Pöhlmann, M., Hitzel, A., Schwägele, F., Speer, K., & Jira, W. (2012). Contents of polycyclic aromatic hydrocarbons (PAH) and phenolic substances in Frankfurter-type sausages depending on smoking conditions using glow smoke. *Meat science, 90*(1), 176–184. https://doi.org/10.1016/j.meatsci.2011.06.024

Przybylski, W., Jaworska, D., Kajak-Siemaszko, K., Sałek, P., & Pakuła, K. (2021). Effect of Heat Treatment by the Sous-Vide Method on the Quality of Poultry Meat. *Foods (Basel, Switzerland)*, *10*(7), 1610. https://doi.org/10.3390/foods10071610

Rinaldi, M., Santi, S., Paciulli, M., Ganino, T., Pellegrini, N., Visconti, A., Vitaglione, P., Barbanti, D., & Chiavaro, E. (2021). Comparison of physical, microstructural and antioxidative properties of pumpkin cubes cooked by conventional, vacuum cooking and sous vide methods. *Journal of the science of food and agriculture*, *101*(6), 2534–2541. https://doi.org/10.1002/jsfa.10880

Roseiro, L. C., Gomes, A., & Santos, C. (2011). Influence of processing in the prevalence of polycyclic aromatic hydrocarbons in a Portuguese traditional meat product. *Food and chemical toxicology : an international journal published for the British Industrial Biological Research Association*, *49*(6), 1340–1345. https://doi.org/10.1016/j.fct.2011.03.017

Salcedo-Sandoval, L., Cofrades, S., Ruiz-Capillas, C., Carballo, J., & Jiménez-Colmenero, F. (2015). Konjac-based oil bulking system for development of improved-lipid pork patties: technological, microbiological and sensory assessment. *Meat science*, *101*, 95–102. https://doi.org/10.1016/j.meatsci.2014.11.010

Seçuk, B., & Pekerşen, Y. (2020). Bursa İli 5 Yıldızlı Şehir Otellerinde Çalışan Aşçıların Moleküler Gastronomi Konusundaki Görüşlerinin Belirlenmesi. *Türk Turizm Araştırmaları Dergisi*, *4*(1), 181-201.

Shao, L., Bi, J., Li, X., & Dai, R. (2023). Effects of vegetable oil and ethylcellulose on the oleogel properties and its application in Harbin red sausage. *International journal of biological macromolecules*, *239*, 124299. https://doi.org/10.1016/j.ijbiomac.2023.124299

Silva, F. M. R., da Silva, L. M. R., Duarte, A. S. G., da Silva Monteiro, C. E., Campos, A. R., Holanda, D. K. R., de Lima, A. C. S., de Sousa Sabino, L. B., & de Figueiredo, R. W. (2021). Microencapsulation of green tea extract (Camellia sinensis var assamica) to increase the bioaccessibility of bioactive compounds and gastroprotective effects. *Food Bioscience*, *42*, 101190. https://doi.org/10.1016/j.fbio.2021.101190

Singh, P., Sultan, Z., Pandey, V. K., & Singh, R. (2023). Sous vide processing for food quality enhancement: A review. *Food and Humanity*, *1*, 543-552. https://doi.org/10.1016/j.foohum.2023.06.028

Sivakumaran, K., & Prabodhani, W. D. M. H. (2018). An overview of the applications molecular gastronomy in

food industry. *International Journal of Food Science and Nutrition, 3*(3), 35-40.

Škaljac, S., Jokanović, M., Tomović, V., Ivić, M., Tasić, T., Ikonić, P., Sojić, B., Džinić, N., & Petrović, L. (2018). Influence of smoking in traditional and industrial conditions on colour and content of polycyclic aromatic hydrocarbons in dry fermented sausage "Petrovská klobása". *Lwt, 87,* 158-162. https://doi.org/10.1016/j.lwt.2017.08.038

Škaljac, S., Petrović, L., Tasić, T., Ikonić, P., Jokanović, M., Tomović, V., Džinić, N., Šojić, B., Tjapkin, A., & Škrbić, B. (2014). Influence of smoking in traditional and industrial conditions on polycyclic aromatic hydrocarbons content in dry fermented sausages (Petrovská klobása) from Serbia. *Food Control, 40*, 12-18. https://doi.org/10.1016/j.foodcont.2013.11.024

Spence, C., & Youssef, J. (2018). Assessing the long-term impact of the molecular gastronomy movement on haute cuisine. *International Journal of Gastronomy and Food Science*, *14*, 35-44. https://doi.org/10.1016/j.ijgfs.2018.10.001

Stantiall, S. E., Dale, K. J., Calizo, F. S., & Serventi, L. (2018). Application of pulses cooking water as functional ingredients: The foaming and gelling abilities. *European Food Research and Technology*, *244*, 97-104. https://doi.org/10.1007/s00217-017-2943-x

Toledo, R. T. (2007). Wood Smoke Components and Functional Properties Proc. In *Int. Conf. on Smoked Seafood (Alaska: Sea Grant College Program)*.

Törős, G., Prokisch, J., Peles, F., Nagy, R., Nagy, J., & Béni, Á. (2024). The effect of sous-vide cooking on the antioxidant properties of oyster mushroom (Pleurotus ostreatus L.). *Acta Agraria Debreceniensis*, (1), 177-184. https://doi.org/10.34101/actaagrar/1/13483

Tsai, F. H., Chiang, P. Y., Kitamura, Y., Kokawa, M., & Islam, M. Z. (2017). Producing liquid-core hydrogel beads by reverse spherification: Effect of secondary gelation on physical properties and release characteristics. *Food Hydrocolloids, 62*, 140-148. https://doi.org/10.1016/j.foodhyd.2016.07.002

Türksönmez, Ç., & Diler, A. (2021). Gıda endüstrisinde ultrason uygulamaları. *Aydın Gastronomy*, 5(2), 177-191.

Wang, X., Liu, D., Du, C., & Ma, S. (2022). Characteristics and formation mechanism of key volatile compounds in sugar-smoked chicken. *Journal of food science and technology, 59*(2), 768–783. https://doi.org/10.1007/s13197-021-05071-y

Wang, Y., Liu, S., Zhang, L., Nagib, A., Li, Q., Geng, R., Yu, X., Xu, T., Zhang, S., Duan, R., Ma, C., & Abd El-Aty, A. M. (2024). Formation, characterization, and application of natural bioactive phytosterol-based oleogels: A review. *Food chemistry*, *454*, 139821. https://doi.org/10.1016/j.foodchem.2024.139821

Wereńska M. (2024). Effect of different sous-vide cooking temperature-time combinations on the functional and sensory properties of goose meat. *Poultry science*, *103*(6), 103701. https://doi.org/10.1016/j.psj.2024.103701

Yang, S., Saleh, A. S., Yang, Q., Cui, X., Duan, Y., & Xiao, Z. (2022). Effect of the water and oleogelator content on characteristics and stability of BC-loaded oleogel-based emulsion. *LWT*, *167*, 113824. https://doi.org/10.1016/j.lwt.2022.113824

Yıkmış, S., Erdal, B., Bozgeyik, E., Levent, O., & Yinanç, A. (2022). Evaluation of purple onion waste from the perspective of sustainability in gastronomy: Ultrasound-treated vinegar. *International Journal of Gastronomy and Food Science*, *29*, 100574. https://doi.org/10.1016/j.ijgfs.2022.100574

Zavadlav, S., Blažić, M., Van de Velde, F., Vignatti, C., Fenoglio, C., Piagentini, A. M., Pirovani, M. E., Perotti, C. M., Bursać Kovačević, D., & Putnik, P. (2020). *Sous-Vide* as a Technique for Preparing Healthy and High-Quality Vegetable and Seafood Products. *Foods (Basel, Switzerland)*, *9*(11), 1537. https://doi.org/10.3390/foods9111537

Zhao, C., Liu, Y., Lai, S., Cao, H., Guan, Y., San Cheang, W., Liu, B., Zhao, K., Miao, S., Riviere, C., Capanoglu, E., & Xiao, J. (2019). Effects of domestic cooking process on the chemical and biological properties of dietary phytochemicals. *Trends in food science & technology, 85,* 55-66. https://doi.org/10.1016/j.tifs.2019.01.004

Zhu, D., Sadat, A., Joye, I. J., Vega, C., & Rogers, M. A. (2024). Scientific gastronomy: On the mechanism by which garlic juice and allicin (thio-2-propene-1-sulfinic acid S-allyl ester) stabilize meringues. *Food chemistry*, *431*, 137121. https://doi.org/10.1016/j.foodchem.2023.137121

Zhu, Z., Luo, W., & Sun, D. W. (2020). Effects of liquid nitrogen quick freezing on polyphenol oxidase and peroxide activities, cell water states and epidermal microstructure of wolfberry. *Lwt*, *120*, 108923.

Effects of Different Chloride Salts and Fat Levels on the Quality Characteristics of Beef Patties

Barış Yalınkılıç[1,*]

[1] *İstanbul Gedik University, Faculty of Architecture and Design, Department of Gastronomy and Culinary Arts, 34876, Kartal, Istanbul, Turkiye*

Abstract

The aim of this study was to investigate the effects of different chloride salts (four formulation with NaCl, KCl, $CaCl_2$, and $MgCl_2$) at 2% w/w level on the pH, color, sensory, and cooking properties of beef patties formulated with two levels of tail fat (10% and 20%). The results indicated that the use of $CaCl_2$ and/or $MgCl_2$ resulted in a significant ($P < 0.01$) decrease in the pH values of both uncooked and cooked beef patties. The salt factor significantly influenced the a^* value of uncooked beef patties ($P < 0.05$). It also affected the a^* ($P < 0.01$) and b^* ($P < 0.01$) values of cooked beef patties.. The highest L^* value ($P < 0.05$) in uncooked beef patties was observed with 20% fat usage. Use of $CaCl_2$ and/or $MgCl_2$ in the salt formulation significantly affected the cooking yield, moisture retention ($P < 0.01$), patty diameter, and shrinkage parameters ($P < 0.05$). On the other hand, the fat factor significantly influenced all cooking properties at the $P < 0.01$ level, except for the decrease in thickness. Except for salinity and bitterness, the salt factor significantly influenced the sensory scores of the samples. The use of $CaCl_2$ and/or $MgCl_2$ in the salt mixture for beef patties resulted in lower sensory scores for the product's sensory parameters. In conclusions, KCl was found to produce satisfactory results as a substitute for NaCl. In contrast, it was concluded that $CaCl_2$ and/or $MgCl_2$ salts were not suitable substitutes for NaCl.

Keywords: Beef patty; Cooking properties; Sensory properties; Color; Chloride salts.

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1. Introduction

Beef patties are fresh meat products composed of ground muscle meat with varying levels of fat and salt. To enhance flavor and textural properties, non-meat ingredients such as spices and textured soy protein can be incorporated into the formulation, and a heat treatment like cooking or frying is typically applied prior to consumption (Heinz and Hautzinger, 2007).

Animal fat and sodium chloride (NaCl) play a significant role in patty production by improving sensory and textural properties. However, fat and salt are increasingly associated with various health issues, including cardiovascular diseases. To mitigate the adverse effects of animal fat on human health, numerous studies have focused on fresh meat products, achieving promising results (Yılmaz, 2004; Serdaroğlu, 2006; Tobin et al., 2012; Poyato et al., 2015; Gibis et al., 2015; Salcedo-Sandoval et al., 2015).

Regarding salt consumption, health authorities recommend a daily intake of 6 g of NaCl for optimal health (Desmond, 2006). Various strategies have been explored to produce low-sodium meat products, including reducing the NaCl content in formulations, partially or entirely replacing NaCl with other chloride salts, substituting a portion of NaCl with non-chloride salts, using binders, and employing alternative processing techniques (Verma and Banerjee, 2012). Among these approaches, the partial or complete substitution of NaCl with other chloride salts has been applied successfully to several meat products (Soglia et al., 2014; Monteiro et al., 2015; Marchetti et al., 2015; Kaban et al., 2022; Şimşek et al., 2023; Yalınkılıç, 2023).

The production processes of beef patties differ from other meat products made using techniques such as fermentation, curing, and smoking, making it challenging to predict the effects of different chloride salts. Studies aimed at determining the effects of different chloride salts in patty and burger production

* Corresponding Author: Barış Yalınkılıç
Email: yalinkilicbaris@gmail.com
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have investigated the impact of using KCl and/or $CaCl_2$ as part of salt formulations containing NaCl (Ketenoğlu and Candoğan, 2011; Lilic et al., 2015; Ramos et al., 2020; Nayak and Pathak, 2022; Ünal et al., 2024). However, $MgCl_2$ is another salt that can be used in combination with KCl and $CaCl_2$ as a substitute for NaCl and has been demonstrated to affect the quality characteristics of various meat products to which it is added. In this context, the investigation of the effects of salt formulations containing $MgCl_2$ on the quality characteristics of low-sodium patties is crucial for providing a more comprehensive understanding of findings from previous studies. Furthermore, the use of different levels of animal fat in patty formulations is a significant factor affecting the sensory properties of the product (Tobin et al., 2012). However, the investigation of the effects of salt mixtures containing $MgCl_2$ and other chloride salts on the quality characteristics of patties with varying fat levels has emerged as a notable gap in the literature. This study focused on the potential use of different chloride salts as part of NaCl reduction strategies in meat products. It specifically aimed to explore the feasibility of using chloride-containing salts (NaCl, KCl, $CaCl_2$, and $MgCl_2$) and different fat levels (10% and %20) in beef patty formulations and to investigate their effects on the color, sensory, and cooking properties of patties.

2. Material and Methods

2.1. Production of beef patty

The beef round and sheep tail fat were purchased from a local slaughterhouse in Erzurum, Türkiye. The beef was trimmed with a sharp knife to remove excess fat and connective tissue. Both the beef and tail fat were ground separately using a meat grinder with a 3 mm plate. To prepare the patty doughs, the ground beef and fat were combined to achieve two fat levels: A (90% ground beef + 10% ground tail fat) and B (80% ground beef + 20% ground tail fat). Eight different patty doughs (four from Dough A and four from Dough B) were prepared for each replicate, and these were salted with the chloride salt or salt mixtures as described in Table 1. The salt formulations were adopted from Yalınkılıç et al. (2023).

The salt or salt mixtures were added at a concentration of 2% (w/w) based on the total dough weight. To ensure homogeneous salt diffusion, the salted doughs were rested in a cooler at 4°C for 6 hours. The patties were then shaped using a patty mold. The patties were cooked on a hot plate for 5 minutes on each side at 150°C.

To specifically evaluate the effects of different chloride salts and fat levels on the patties, spices or any additional ingredients were excluded from the patty formulations. The experiments were conducted in two replicates. Analyses of pH, color, and cooking properties were performed on both uncooked and cooked patties, while sensory evaluations were conducted only on the cooked samples.

2.2. Determination of moisture content

The moisture content of the beef patty samples was analyzed according to the AOAC (2005) standard method.

2.3. pH Analysis

The pH meter was calibrated using appropriate buffer solutions prior to measurement. Subsequently, 10 g of homogenized sample was weighed in duplicate, and 100 ml of distilled water was added to each. The mixtures were homogenized using an ultra-turrax device (IKA Werk), and the pH values were determined with a pH meter.

2.4. Color analysis

Following the cooking process, patties were allowed to cool to room temperature to ensure uniform measurement conditions. Measurements were taken directly from the surface of the patties (Başlar et al., 2024). The color intensity of the samples (L^*, a^*, and b^*) was measured using a calibrated Minolta colorimeter (CR-400, Minolta Co., Osaka, Japan). The measurements were performed based on the criteria specified by the International Commission on Illumination (CIE) in the CIELAB three-dimensional color measurement system.

Table 1. The fat and salt mixture used in formulation of beef patties

Group	*Tail Fat (%)*	*Salt Composition*			
		NaCl (%)	*KCl (%)*	*CaCl2 (%)*	*MgCl2 (%)*
C/10	10	100	-	-	-
C/20	20	100	-	-	-
S1/10	10	50	50	-	-
S1/20	20	50	50	-	-
S2/10	10	40	40	20	-
S2/20	20	40	40	20	-
S3/10	10	30	40	20	10
S3/20	20	30	40	20	10

2.5. Cooking properties

The cooking properties were determined using the methods outlined by Serdaroğlu and Değirmencioğlu (2004).

2.5.1. Cooking yield

Cooking yield was calculated for each group using five beef patty samples. The weights of the samples were recorded before and after cooking, and the percentage yield was determined using the following equation (Eq. 1):

$$CY = \frac{W_c}{W_u} \times 100 \quad \text{Eq.1}$$

where CY is cooking yield (%), W_c is the weight of the cooked sample (g), and W_u is the weight of the uncooked sample (g).

2.5.2. Moisture retention

Moisture retention (%) was calculated using the cooking yield data combined with the moisture content of the cooked beef patties. The following equation (Eq.2) was used:

$$MR = \frac{CY \times MC_c}{100} \quad \text{Eq.2}$$

where MR is moisture retention (%), CY is cooking yield (%), and MC_c is the moisture content in the cooked sample (%).

2.5.3. Change in patty diameter

The percentage reduction in patty diameter was calculated by measuring the diameters of both uncooked and cooked patties. The change in patty diameter (%) was determined using the following equation (Eq.4):

$$CD = \frac{D_u - D_c}{D_u} \times 100 \quad \text{Eq.3}$$

where CD is the change in patty diameter (%), D_u is the diameter of the uncooked patty (mm), and D_c is the diameter of the cooked patty (mm).

2.5.4. Change in patty thickness

The percentage reduction in patty thickness was calculated by comparing the thickness of uncooked and cooked patties. The change in patty thickness (%) was determined using the following equation (Eq.4):

$$CT = \frac{T_u - T_c}{T_u} \times 100 \quad \text{Eq.4}$$

where CT is the change in patty thickness (%), T_u is the uncooked patty thickness (mm), and T_c is the cooked patty thickness (mm).

2.5.5. Shrinkage

The shrinkage percentage was determined using the diameter and thickness measurements of the uncooked and cooked patties. The shrinkage (%) was calculated using the equation (Eq.4):

$$CY = \left(\frac{(T_u - T_c) + (D_u - D_c)}{(T_u + T_c)}\right) \times 100 \quad \text{Eq.4}$$

where S is the shrinkage (%), T_u is the uncooked patty thickness (mm), T_c is the cooked patty thickness (mm), D_u is the uncooked patty diameter (mm), and D_c is the cooked patty diameter (mm).

2.6. Sensory analysis

Cooked beef patty samples from each experimental group were subjected to sensory evaluation by a panel of 20 trained panelists for each replicate. The panelists were selected based on their prior experience with sensory analysis and were trained to recognize and score the specific attributes being assessed. Following the cooking, samples were served on white plates coded with random three-digit numbers to prevent bias. Panelists were instructed to cleanse their palate with water and white bread between samples to avoid flavor carryover. Appearance, texture, smell, bitterness, salinity, juiciness, and overall acceptability parameters were assessed using a 9-point scale.

2.7. Statistical analysis

The data obtained in the study were subjected to variance analysis (ANOVA) using the SPSS 13 software package. Means of the treatment groups were further compared using Duncan's multiple comparison test.

3. Results and Discussion

3.1. Effects on pH value

The effects of different chloride salt mixtures and fat levels on the pH values of uncooked and cooked patties are presented in Table 2. The salt factor significantly affected the pH values of both uncooked and cooked patties at the $P < 0.01$ level. The pH of uncooked patties ranged between 5.55 and 5.81. Cooking increased the pH across all groups (5.72–6.15). The increase in pH observed in cooked patties is likely attributed to nitrogenous compounds released as a result of heat-induced changes in the proteins within the product composition (Sohn and Ho, 1995; Alugwu et al., 2022).

Table 2. pH values of uncooked and cooked beef patties.

Group	*Uncooked patties*	*Cooked beef patties*
C/10	5.78±0.08^{b}	6.10±0.11^{b}
C/20	5.77±0.07^{b}	6.10±0.11^{b}
S1/10	5.80±0.06^{b}	6.13±0.09^{b}
S1/20	5.81±0.07^{b}	6.15±0.10^{b}
S2/10	5.58±0.06^{a}	5.73±0.06^{a}
S2/20	5.56±0.05^{a}	5.72±0.09^{a}
S3/10	5.58±0.03^{a}	5.80±0.11^{a}
S3/20	5.55±0.06^{a}	5.77±0.11^{a}

Values within the same column with different lowercase letters (a, b, c) differ significantly based on Duncan's test ($P < 0.05$). Control: 100% NaCl; Salt 1: 50% NaCl+50% KCl; Salt 2: 40% NaCl+40% KCl+20% $CaCl_2$; Salt 3: 30% NaCl+40% KCl+20% $CaCl_2$+10% $MgCl_2$.

In contrast, the lower pH observed particularly in cooked products containing $CaCl_2$ and/or $MgCl_2$ is likely attributable to the relative binding properties of divalent salts to the negative charges of proteins (Nayak et al., 1998). The highest pH values were recorded in both uncooked and cooked patties in the control groups (C/10 and C/20), which contained 100% NaCl, as well as in the treatment groups (S/10 and S/20), which used a 50% NaCl and 50% KCl mixture. No statistically significant differences in pH values were observed between these groups ($P > 0.05$). Conversely, patties containing $CaCl_2$ and $MgCl_2$ (S2/10, S2/20, S3/10, S3/20) exhibited significantly lower pH values compared to the control groups, both in uncooked and cooked samples ($P < 0.05$). This study is consistent with the findings of Ünal et al. (2024), who reported that the use of KCl in the salt formulation for turkey burgers did not alter the pH values of the product compared to the control group, while the inclusion of $CaCl_2$ led to a decrease in pH values. In contrast to our results, studies in the literature have also indicated that the use of KCl in patty and burger formulations can increase the product's pH (Nayak and Pathak, 2022; Ramos et al., 2020). Additionally, the fat factor did not have a statistically significant effect ($P > 0.05$) on the pH values of either uncooked or cooked patties.

3.2. Effects on color parameters

Table 3 presents the color parameters (L^*, a^*, b^*), illustrating the effects of different salt mixtures and fat levels on the color properties of uncooked and cooked patties. Color plays a critical role in the sensory perception and consumer acceptability of meat products (Yalınkılıç and Çiğdem, 2004). The salt factor significantly influenced the a^* value of uncooked patties ($P < 0.05$) and both the a^* ($P < 0.01$) and b^* ($P < 0.01$) values of cooked patties. The fat factor significantly affected only the L^* value of uncooked patties at the $P < 0.05$ level, while it did not exhibit a statistically significant effect ($P > 0.05$) on other color parameters of either uncooked or cooked patties. Similar to our findings, Serdaroğlu (2006) reported that varying fat levels (5%, 10%, and 20%) in beef patties increased the L^* value of uncooked patties but had no effect on their a^* and b^* values. The researchers associated this color change with the yellow-white characteristics of the fat used in the formulation. A study conducted by Nayak and Pathak (2022) on chevon meat patties produced with NaCl, KCl, and $CaCl_2$ revealed that the substitution of KCl did not cause any alterations in the product's color parameters. Similarly, Ramos et al. (2020) observed that the substitution of KCl in beef burgers containing varying ratios of NaCl and KCl, stored for 120 days, had no significant impact on the burgers' color parameters. In uncooked patties, the L^* value ranged from 39.68 to 43.18, with the highest brightness observed in the S3/20 group, which contained 20% fat and included $CaCl_2$ and $MgCl_2$. Following cooking, a decreasing

Table 3. Color of uncooked and cooked beef patties

	Uncooked patties			*Cooked beef patties*		
Group	L^*	a^*	b^*	L^*	a^*	b^*
C/10	40.18±3.86^{a}	16.00±1.43^{a}	4.27±1.68^{a}	39.90±0.83^{cd}	8.84±0.59^{c}	3.58±0.47^{ab}
C/20	41.54±1.48^{abc}	16.18±1.91^{ab}	4.83±1.15^{a}	37.58±1.70^{a}	8.52±0.69^{c}	3.39±0.79^{a}
S1/10	39.68±2.53^{a}	17.13±1.77^{abc}	3.92±0.74^{a}	40.21±2.05^{d}	8.30±0.67^{bc}	4.97±0.97^{c}
S1/20	41.17±0.86^{abc}	17.98±1.18^{bc}	5.05±0.82^{a}	38.02±1.43^{ab}	8.41±0.69^{c}	4.04±0.59^{b}
S2/10	40.03±1.50^{ab}	18.32±1.58^{c}	4.81±0.82^{a}	40.74±1.84^{d}	7.50±0.48^{a}	5.56±0.39^{c}
S2/20	42.07±2.74^{bc}	17.06±1.53^{abc}	4.83±1.35^{a}	38.57±1.04^{abc}	7.75±0.32^{ab}	5.59±0.52^{c}
S3/10	40.14±1.76^{ab}	16.19±2.32a^{b}	4.05±0.54^{a}	39.34±0.64^{bcd}	7.66±0.36^{a}	5.37±0.65^{c}
S3/20	43.18±1.13^{c}	15.66±1.91^{a}	5.05±1.03^{a}	38.63±0.91^{abc}	7.81±0.47^{ab}	5.35±0.40^{c}

Values within the same column with different lowercase letters (a, b, c) differ significantly based on Duncan's test ($P < 0.05$). Control: 100% NaCl; Salt 1: 50% NaCl+50% KCl; Salt 2: 40% NaCl+40% KCl+20% $CaCl_2$; Salt 3: 30% NaCl+40% KCl+20% $CaCl_2$+10% $MgCl_2$.

trend in L^* values was observed, with the most pronounced reduction occurring in the C/20 group containing 20% fat. The redness values (a^*) in uncooked patties ranged from 15.66 to 18.32, with slightly higher values observed in patties containing $CaCl_2$ and $MgCl_2$. However, a decrease in a^* values was noted after cooking, with the highest redness value measured in the C/10 group, which contained 10% fat and used only NaCl. On the other hand, the b^* values in uncooked patties ranged from 3.92 to 5.05. After cooking, an overall increase in b^* values was observed, with the highest value recorded in the S2/10 group. Generally, groups containing NaCl (C/10 and C/20) exhibited higher a^* and L^* values after cooking. In the study conducted by Ünal et al. (2024) on turkey burger production, it was concluded that the use of KCl or $CaCl_2$ as a substitute for NaCl significantly influenced the L^* and b^* values of the cooked product. They also observed that the L^* value of the cooked product was lower than that of the uncooked burger, while the a^* value was higher. In the present study, apart from the effects of salt and fat factors, the differences observed between uncooked and cooked beef patties are likely attributable to pH changes during cooking, reactions occurring on the surface of the product in contact with the heat source, and the fat and moisture loss associated with the cooking process (Ramos et al., 2020).

3.3. Effects on cooking properties

The effects of different salt mixtures on the cooking properties of patties are presented in Table 4. As presented in the table, the salt factor significantly influenced the cooking yield and moisture retention properties of cooked patties at the $P < 0.01$ level, while its effect on the decrease in patty diameter and shrinkage parameters was significant at the $P<0.05$ level. The fat factor, on the other hand, significantly affected all cooking properties at the $P < 0.01$ level, except for the decrease in thickness ($P > 0.05$). Across the groups, the C/10 group containing only NaCl demonstrated superior performance, achieving the highest cooking yield (75.14%), moisture retention capacity (46.22%), and the lowest decrease in diameter (17.86%) compared to the other groups.

In the C/10 group, the decrease in diameter was determined to be the lowest at 17.86%, enhancing the product's ability to maintain physical stability during cooking. In contrast, cooking performance was negatively affected in groups containing $CaCl_2$ and $MgCl_2$. In the S2/20 group, the cooking yield was found to be 60.44%, moisture retention 32.39%, and the decrease in diameter 27.20%. Similarly, in the S3/20 group, the cooking yield was found to be 61.87%, moisture retention 33.21%, and the decrease in diameter 27.16%. These findings can likely be attributed to the reduction in product pH caused by the inclusion of $CaCl_2$ and $MgCl_2$ in the salt mixtures. The pH values of cooked patties containing these divalent salts were observed to be closer to the isoelectric point of red meats, which likely contributed to a decrease in water-holding capacity and subsequently impacted the cooking properties of the product (Cassens, 1994). Consistently, Rahman and Perera (2007) emphasized the critical role of pH and water content in determining the quality of meat and meat products. Salts that contribute to higher pH levels, such as NaCl and KCl, resulted in better water-holding capacity, lower diameter and thickness loss, and reduced shrinkage in patties. In contrast, the pH-lowering effects of $CaCl_2$ and $MgCl_2$ led to adverse outcomes in these parameters. A study on chevon meat patties found that the use of KCl and $CaCl_2$ alongside NaCl in the formulation had no significant effect on the cooking properties of the product (Nayak and Pathak, 2022). Similarly, in frozen beef burgers, the use of NaCl and

Table 4. Cooking values of cooked beef patties

Group	*Cooking Yield (%)*	*Moisture Retention (%)*	*Diameter reduction (%)*	*Decrease in beef patty thickness (%)*	*Shrinkage (%)*
C/10	75.14±3.68^{d}	46.22±1.84^{f}	17.86±4.10^{a}	23.15±13.06^{ab}	12.88±3.91^{a}
C/20	65.35±4.79^{bc}	36.29±2.78^{cd}	22.03±2.38^{bc}	27.47±9.81^{ab}	16.90±2.16^{ab}
S1/10	72.06±2.50^{d}	42.89±1.90^{e}	19.39±4.33^{ab}	20.41±13.41^{b}	15.40±4.82^{ab}
S1/20	65.12±3.19^{bc}	35.54±1.81^{bc}	25.35±3.14^{c}	32.61±11.80^{ab}	19.28±4.01^{bc}
S2/10	66.41±3.84^{c}	37.41±3.07^{cd}	20.03±2.78^{ab}	36.64±20.78^{a}	14.15±3.89^{a}
S2/20	60.44±4.87^{a}	32.39±2.58^{a}	27.20±3.75^{d}	28.41±9.36^{ab}	20.81±4.05^{c}
S3/10	67.12±4.74^{c}	38.83±3.59^{d}	20.39±3.22^{ab}	24.49±13.74^{ab}	15.44±2.62^{ab}
S3/20	61.87±4.61^{ab}	33.21±2.01^{ab}	27.16±2.52^{d}	27.95±7.02^{ab}	21.26±2.75^{c}

Values within the same column with different lowercase letters (a, b, c) differ significantly based on Duncan's test ($P < 0.05$). Control: 100% NaCl; Salt 1: 50% NaCl+50% KCl; Salt 2: 40% NaCl+40% KCl+20% CaCl2; Salt 3: 30% NaCl+40% KCl+20% CaCl2+10% MgCl2.

KCl was found to result in no statistically significant change in cooking loss values (Ramos et al., 2020). Consistently, Ünal et al. (2024) concluded in their study on turkey meat patties that the inclusion of KCl and $CaCl_2$ in the product formulation did not significantly affect the moisture retention or cooking yield parameters. The differences between the findings of this study and those of other studies are likely attributable to variations in the cooking techniques and durations employed. Specifically, in the aforementioned three studies, the cooking methods included preheated convection oven cooking at 180°C for 14 minutes, preheated grilling at 170°C until an internal temperature of 72°C was reached, and hot plate cooking at 180°C for 8 minutes, respectively. According to the data presented in Table 4, a slight decline in cooking properties was observed in patty groups containing 20% fat (including the control group). Notably, groups containing 20% fat with $CaCl_2$ (S2/20) and $MgCl_2$ (S3/20) exhibited greater reductions in cooking yield, moisture retention capacity, diameter, and shrinkage values. Similar to our findings, Serdaroğlu (2006) reported that an increase in fat content in beef patties adversely affected cooking properties. Specifically, when 20% fat was used, lower cooking yield, fat retention, and moisture retention values were obtained compared to 5% and 10% fat levels, which in turn resulted in greater reductions in product diameter.

3.4. Efects on sensory properties

The results in Table 5 present the effects of different salt mixtures and fat levels on the sensory properties of patties. The salt factor significantly influenced appearance, aroma, juiciness, and overall acceptability parameters at the $P < 0.01$ level, while its effect on texture parameter was significant at the $P < 0.05$ level. However, the salt mixture did not have a statistically significant effect ($P > 0.05$) on the saltiness and bitterness parameter. Similarly, the fat factor did not exhibit a significant effect ($P > 0.05$) on any of the parameters examined. In terms of overall acceptability, the control groups containing only NaCl (C/10 and C/20) achieved the highest scores, with 7.0±1.2 and 7.0±1.0, respectively. The control groups (C/10 and C/20) also demonstrated superior performance in appearance (7.7–7.9), texture (7.2–7.4), and juiciness (7.3–7.2) compared to other groups. Moreover, the use of KCl in combination with NaCl (S1/10 and S1/20) showed no statistically significant difference in sensory properties compared to the control samples. This finding is particularly significant as it highlights the potential of KCl as an acceptable substitute for NaCl.

Salt mixtures containing $CaCl_2$ and $MgCl_2$ were found to significantly deteriorate the sensory properties of the patties at a statistically significant level. The groups containing these salts had the lowest overall acceptability scores, recorded as 5.7±1.3 and 5.4±1.4, respectively. The patties showed the most unfavorable average results in terms of appearance, texture, aroma, and bitterness parameters when these salts were used. The unfavorable outcomes in sensory parameters are likely related to the negative results observed in the cooking properties of the groups containing salt mixtures with $CaCl_2$ and $MgCl_2$. On the other hand, studies extensively investigating the effects of salt mixtures containing NaCl, KCl, $CaCl_2$, and $MgCl_2$ on various meat products have also found that salt mixtures containing $CaCl_2$ and $MgCl_2$, in particular, have adverse effects on the sensory quality characteristics of the products (Armenteros et al., 2009; Yalınkılıç et al., 2023). Similar to our findings, a study on beef burgers utilizing varying ratios of NaCl and KCl reported that the replacement of NaCl with different proportions of KCl did not result in significant differences in the product's color, aroma, flavor,

Table 5. Sensory properties of cooked beef patties

Group	*Appearance*	*Texture*	*Smell*	*Bitterness*	*Salinity*	*Juiciness*	*Overall Acceptability*
C/10	7.7 ± 0.6^{bc}	7.2 ± 0.9^{ab}	6.3 ± 1.3^{b}	2.1 ± 1.8^{a}	5.1 ± 1.7^{a}	7.3 ± 1.5^{c}	7.0 ± 1.2^{c}
C/20	7.9 ± 0.7^{c}	7.4 ± 0.8^{b}	6.8 ± 1.5^{b}	1.9 ± 1.7^{a}	5.6 ± 1.8^{a}	7.2 ± 1.3^{c}	7.0 ± 1.0^{c}
S1/10	7.2 ± 0.8^{abc}	7.0 ± 1.3^{ab}	6.5 ± 1.1^{b}	3.0 ± 2.5^{a}	4.9 ± 2.0^{a}	6.6 ± 1.4^{bc}	6.4 ± 1.3^{bc}
S1/20	7.2 ± 1.0^{abc}	6.7 ± 1.0^{ab}	6.5 ± 1.2^{b}	3.0 ± 2.3^{a}	5.0 ± 1.8^{a}	6.0 ± 1.3^{ab}	6.5 ± 0.8^{bc}
S2/10	6.4 ± 1.3^{a}	6.6 ± 1.4^{ab}	5.7 ± 1.5^{ab}	2.7 ± 2.0^{a}	4.5 ± 1.7^{a}	5.9 ± 1.6^{ab}	6.0 ± 1.2^{ab}
S2/20	6.6 ± 1.3^{a}	6.6 ± 1.0^{a}	5.7 ± 1.7^{ab}	2.8 ± 2.1^{a}	4.5 ± 1.5^{a}	5.4 ± 1.5^{a}	5.7 ± 1.1^{ab}
S3/10	6.6 ± 1.9^{a}	6.7 ± 1.3^{ab}	5.2 ± 1.9^{a}	3.4 ± 2.3^{a}	4.5 ± 1.6^{a}	5.7 ± 1.4^{ab}	5.7 ± 1.3^{ab}
S3/20	6.9 ± 1.4^{ab}	6.4 ± 1.5^{a}	5.7 ± 1.7^{ab}	3.2 ± 2.2^{a}	5.1 ± 2.0^{a}	5.5 ± 1.3^{a}	5.4 ± 1.4^{a}

Values within the same column with different lowercase letters (a, b, c) differ significantly based on Duncan's test ($P < 0.05$). Control: 100% NaCl; Salt 1: 50% NaCl+50% KCl; Salt 2: 40% NaCl+40% KCl+20% CaCl2; Salt 3: 30% NaCl+40% KCl+20% CaCl2+10% MgCl2.

texture, or overall acceptability scores (Ramos et al., 2020). In another study examining the effects of NaCl, KCl, and $CaCl_2$ on the sensory characteristics of chevon meat patties, it was found that the type of salt used did not influence the overall appearance of the product. However, the lowest scores for flavor, saltiness, juiciness, mouth-coating, and overall acceptability, except for texture, were recorded in groups containing only NaCl + KCl (Nayak and Pathak, 2022). Conversely, Ünal et al. (2024) concluded in their study on turkey patties that the use of NaCl, KCl, and $CaCl_2$ did not cause any significant differences in the sensory characteristics of the product, including color, flavor, aroma, texture, and overall acceptability.

4. Conclusions

In the production of beef patties, formulations predominantly containing NaCl were found to have a positive impact on the quality characteristics examined in this study. The findings demonstrated that NaCl yielded significantly better results compared to other tested salts in terms of both cooking properties and sensory quality, highlighting KCl as the most effective substitute for NaCl. Conversely, salt mixtures containing $CaCl_2$ and $MgCl_2$ had adverse effects on both the cooking and sensory properties of the product. This suggests that the use of these salts as substitutes for NaCl would likely lead to negative outcomes in terms of consumer acceptability for beef patties. Furthermore, an increase in fat content was observed to have particularly detrimental effects on the cooking properties of the product. To mitigate the adverse changes in cooking properties associated with higher fat levels, the incorporation of various fiber sources into patty production could be explored in future studies

Declaration of Competing Interest

The author declares that they have no financial or non-financial competing interests.

Author's Contributions

B. Yalınkılıç (0000-0002-6195-7821): *Methodology, Research, Data Analysis, Writing, Editing*.

References

Alugwu, S. U., Okonkwo, T.M. & Ngadi, M.O. (2022). Effect of Cooking on Physicochemical and Microstructural Properties of Chicken Breast Meat. *European Journal of Nutrition & Food Safety, 14*(11), 43-62.

AOAC. (2005). *Official Methods of Analysis* (18th ed.). AOAC-International Suite, Gaitherburg, USA

Armenteros, M., Aristoy, MC., Barat, JM. Toldra, F. (2009). Biochemical and sensory properties of dry-cured loins as affected by partial replacement of sodium by potassium, calcium, and magnesium. *Journal of Agricultural and Food Chemistry, 57*, 9699–9705.

Başlar, M., Yalınkılıç, B., Erol, K. F., & İrkilmez, M. Ü. (2024). Evaluation of the Use of Vacuum-Dehydrated Minced Meat in Beef Patty Production. *AgriEngineering, 6*(2), 1712-1724.

Cassens, R. G. (1994). Meat preservation: Preventing losses and assuring safety. Food & Nutrition Press, Inc.

Desmond, E., 2006. Reducing salt: A challenge for the meat industry. *Meat Science, 74*(1), 188-196.

Gibis, M., Schuh, V., & Weiss, J. (2015). Effects of carboxymethyl cellulose (CMC) and microcrystalline cellulose (MCC) as fat replacers on the microstructure and sensory characteristics of fried beef patties. *Food Hydrocolloids, 45*, 236-246.

Heinz, G and Hautzinger, P., (2007). *Meat processing technology, for small to medium scale producers*. Food And Agriculture Organizatıon of the United Nations Regional Office for Asia and the Pacific (FAO, RAP Publication 2007/20).

Kaban, G., Bayraktar, F., Jaberi, R., Fettahoğlu, K., & Kaya, M. (2022). Effects of NaCl substitution with KCl on quality properties of heat-treated sucuk during the production stages. *Journal of Food & Nutrition Research, 61*(1), p43.

Ketenoğlu, O., & Candoğan, K. (2011). Effect of low-sodium salt utilization on some characteristics of ground beef patties. *Gıda, 36*(2): 63-69.

Lilic, S., Brankovic, I., Koricanac, V., Vranic, D., Spalevic, L., Pavlovic, M., & Lakicevic, B. (2015). Reducing sodium chloride content in meat burgers by adding potassium chloride and onion. *Procedia Food Science, 5*, 164-167.

Marchetti, L., Argel, N., Andrés, S. C., & Califano, A. N. (2015). Sodium-reduced lean sausages with fish oil optimized by a mixture design approach.Meat science, 104, 67-77.

Monteiro, M. L. G., Márs ico, E. T., Canto, A. C. V., Costa-Lima, B. R., Lázaro, C. A., Cruz, A. G., & Conte-Júnior, C. A. (2015). Partial sodium replacement in tilapia steak without loss of acceptability. *Food Science and Technology International, 21*(4), 295-305.

Nayak, N. K., & Pathak, V. (2022). Development and quality assessment of low-sodium functional chevon patties. *British Food Journal, 124*(9), 2805-2816.

Nayak, R. Kenney, P.B. Slider, S. et al. (1998). Myofibrillar protein solubility of model beef batters as affected by low levels of calcium, magnesium and zinc chloride. *Journal of food science, 63*(6), 951-954.

Poyato, C., Astiasarán, I., Barriuso, B., & Ansorena, D. (2015). A new polyunsaturated gelled emulsion as replacer of pork back-fat in burger patties: Effect on lipid composition, oxidative stability and sensory acceptability. *LWT-Food Science and Technology, 62*(2), 1069-1075.

Rahman, M. S., & Perera, C. O. (2007). Drying and food preservation. In M. S. Rahman (Ed.), *Handbook of food preservation* (pp. 403–432). Boca Raton, FL: CRC Press.

Ramos, T. R., Torrecilhas, J. A., do Prado, I. N., Mottin, C., Valero, M. V., Vital, A. C. P., ... & Guerrero, A. (2020). *Sodium reduction by hyposodic salt on quality and chemical composition of hamburgers* (No. ART-2020-118020).

Salcedo-Sandoval, L., Cofrades, S., Ruiz-Capillas, C., Carballo, J., & Jiménez-Colmenero, F. (2015). Konjac-based oil bulking system for development of improved-lipid pork patties: Technological, microbiological and sensory assessment. *Meat science, 101*, 95-102.

Serdaroglu, M. (2006). The characteristics of beef patties containing different levels of fat and oat flour. *International journal of food science & technology, 41*(2), 147-153.

Serdaroğlu, M., & Değirmencioğlu, Ö. (2004). Effects of fat level (5%, 10%, 20%) and corn flour (0%, 2%, 4%) on some properties of Turkish type meatballs (koefte). *Meat Science, 68*(2), 291-296.

Soglia, F., Petracci, M., Mudalal, S., Vannini, L., Gozzi, G., Camprini, L., & Cavani, C. (2014). Partial replacement of sodium chloride with potassium chloride in marinated rabbit meat. *International Journal of Food Science & Technology, 49*(10), 2184-2191.

Sohn, M., & Ho, C. T. (1995). Ammonia generation during thermal degradation of amino acids. *Journal of agricultural and food chemistry, 43*(12), 3001-3003.

Şimşek, D., Yılmaz Oral, Z. F., Jaberi, R., Kaya, M., & Kaban, G. (2023). Partial Replacement of NaCl by KCl, MgCl2 and CaCl2 Chloride Salts in the Production of Sucuk: Effects on Volatile Compounds, Lipid Oxidation, Microbiological and Sensory Properties. *Foods, 12*(19), 3525.

Tobin, B. D., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2012). Effect of varying salt and fat levels on the sensory quality of beef patties. *Meat Science, 91*(4), 460-465.

Ünal, K., Kırkyol, M., & Akköse, A. (2024). Farklı Klorür Tuzları Kullanılarak Üretilen Hindi Burgerlerin Kalite Özelliklerinin Belirlenmesi. *Gıda Bilimi ve Mühendisliği Araştırmaları, 3*(2), 104-113.

Verma, A. K., & Banerjee, R. (2012). Low-sodium meat products: retaining salty taste for sweet health. *Critical reviews in food science and nutrition, 52*(1), 72-84.

Yalınkılıç, B., Kaban, G., & Kaya, M. (2023). Effect of sodium replacement on the quality characteristics of pastırma (a dry-cured meat product). *Food Science and Human Wellness, 12*(1), 266-274.

Yalinkilic, B., & Cigdem, A. (2024). Effects of Various Citrus Fiber Coatings on the Color, Texture, and Sensory Properties of Chicken Nuggets. *International Journal of Gastronomy Research, 3*(1), 17-23.

Yılmaz, I. 2004. Effects of rye bran addition on fatty acid composition and quality characteristics of low-fat meatballs. *Meat Science, 67*(2), 245-249.