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ABSTRACTING & INDEXING

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Kefir Consumption Patterns of Students from Ataturk University, Turkiye: A Survey Study

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Abstract

Kefir is a fermented beverage produced by the lactic fermentation of milk using kefir grains or a starter culture. It has many health benefits due to its anti-inflammatory, antimicrobial, and anti-diabetic properties, while it could also regulate the gut microbiota. Thus, interest in kefir is growing in the scientific community. In this study, a survey was conducted on 401 students from Atatürk University during the 2019-2020 academic year to examine their consumption habits and knowledge level of kefir. The data were collected through a face-to-face questionnaire. The findings showed that 42.14% of the participants were aware of kefir, but only 16.96% of them consumed it. The majority of the students expressed their interest in consuming kefir due to its health benefits. They also stated that they have very little information about kefir except that it boosts immunity and is good for health. Interestingly, participants who were not familiar with kefir showed interest in consuming it after a brief explanation and kefir tasting. The findings suggest that people are interested in healthy foods, indicating a potential for spreading information and increasing kefir consumption among the younger generations.

Keywords: Kefir, Consumption habits, Kefir, University students.

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1. Introduction

Kefir is an acidic and carbonated fermented milk beverage with a low alcohol content obtained as a result of the fermentation of bacteria and yeasts in kefir grains in milk or water (Farnworth, 2003; Zamberi et al., 2016). According to the definition of the Turkish Food Codex Communiqué on Fermented Dairy Products, kefir is defined as "a fermented dairy drink that contains a minimum of two of the typical microorganisms of kefir grains, comprising *Lactobacillus kefiri, Lactobacillus kefiranofaciens, Lactobacillus kefirgranum,* and *Kluyveromyces marxianus* and Saccharomyces spp. from lactose-fermenting yeasts." In addition, kefir, produced with kefir grains or starter cultures which may contain species belonging to *Lactobacillus, Leuconostoc, Lactococcus, Acetobacter* and similar bacterial genera and different yeast species, is defined as a "fermented milk product" (Anonymous 2009). Originating in the Balkans, Eastern Europe and the Caucasus, kefir has spread to other parts of the world over time due to its positive effects on health. This sour and viscous beverage has become popular among people in countries, such as the United States, Japan, France and Brazil (Fiorda et al., 2017). The kefir grains, also known as kefir yeast, differentiate kefir from other dairy products (Azizi et al., 2021). Kefir grains vary in size from 1 to 4 cm and resemble small cauliflower florets in shape and colour (Garofalo et al., 2020). This gelatinous and slimy structure consists of kefiran, a natural exopolysaccharide (EPS), and a protein matrix in which lactic acid bacteria (LAB), yeasts and acetic acid bacteria symbiotically coexist (Kesenkaş et al., 2017). The physicochemical properties and biological activity of kefir are highly influenced by the diversity of this microbial flora, fermentation time, fermentation temperature and the amount of grain used (Angulo et al., 1993; Lin et al.,1999; Talib et al., 2019; Wang et al., 2020).

Many studies have shown that kefir consumption has crucial health benefits, including antimicrobial, antitumor, anti-carcinogenic, hypocholesterolemic, anti-hypertensive, anti-diabetic, immunomodulatory and contributing to the digestion of lactose (Güven et al., 2003, Güzel-Seydim et al., 2011, Bourrie et al., 2016, Van 2019, Şanlier et al., 2019, Kaur et al., 2020). The microflora is a significant factor in kefir-related

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health benefits due to the metabolites present in the product (Garofalo et al., 2020). In other words, the organoleptic and health-promoting properties of kefir can be attributed to its nutrient content, microbiota, and by-products (including postbiotics) produced from their metabolic activities. A unique combination of volatile metabolites, organic acids, free amino acids, and vitamins provides therapeutic properties and enhances the nutritional value of kefir (Parvez et al., 2006).

Milk and dairy products are significant sources of calcium, magnesium, potassium, phosphorus, vitamin D, riboflavin, vitamin B12, and vitamin A (Mobley et al., 2014). Regular consumption of dairy products, especially those containing probiotics like kefir, could have therapeutic and anti-inflammatory effects, enhance the immune system, lower cholesterol levels, and possess antioxidant qualities that may aid in preventing diabetes, as mentioned previously (Rosa et al., 2017). Despite the beneficial effects of these probiotic products on human health, they have not been adequately recognized, resulting in low consumption due to a lack of consumer knowledge about probiotic products and their benefits. Unfortunately, milk and dairy products in Turkiye are not produced or consumed at the desired levels. According to 2021 data, consumption of fermented dairy products, such as kefir, cheese and yogurt, has declined sharply in Turkiye (Anonymous, 2022). Therefore, it is important to investigate the knowledge and consumption of these products among individuals. In the present study, a group of associate's, undergraduate's and master's degree students from Atatürk University were surveyed about their knowledge and consumption habits of kefir. The present study aimed to investigate the consumption habits and level of knowledge of kefir among students. Additionally, this study sought to raise awareness among students about the benefits of kefir consumption, identify any problems they encounter, and take necessary measures to address them. In light of the findings obtained in this study, solutions have been recommended to increase kefir consumption and establish a foundation for encouraging healthier lifestyles.

2. Material and Methods

This study was conducted with the participation of volunteer students studying in different departments at Atatürk University in November 2019. A total of 401 students participated in the survey conducted by tasting the kefir drink that we produced traditionally. Home-made kefir beverages were produced using kefir grains by inoculating them in UHT milk at 25°C for 20 h. At the end of incubation, kefir grains were filtered. A total of 40 liters of kefir were produced for approximately 15 days or approximately 2.5 liters per day. The project team set up a stand in the Technical Sciences Vocational School and Medico Social Building at Ataturk University and served kefir to approximately 500 students and academic staff. At the kefir service, brochures were distributed to the participants and information about kefir was given. The slogan of the brochure was 'Drink Kefir to Stay Healthy.' The brochure included detailed information about kefir grains and kefir, as well as the benefits and nutritional value of kefir. The survey questions were structured based on the studies by Irmão and Rezende Costa (2018), Yelce and Gül (2020) and Ürkek and Taş (2021). Firstly, questions on social data were used to determine the demographic characteristics of the participants (Table 1). Following the 10-item questionnaire expert, input was administered to participants in face-to-face interviews after notification by the researchers. The survey questions consisted of detailed questions about knowledge about kefir, its consumption and behavioral structures, including consumers' opinions, preferences and perceptions, in accordance with the purpose of this study. After completing the questionnaire, the students were given a serving of kefir. The data for the analysis were prepared in electronic tables using the Microsoft Excel® for Windows program, version 2019. The results of this study were explained in categorical variables in number and percentage.

This research was conducted with written consent obtained from the participants in this study. They voluntarily agreed to participate in this study and were granted permission to use their data to analyze and for publication processes.

3. Results and Discussion

The demographic characteristics of the students are presented in Table 1. A total of 401 university students participated in the survey. Ages 18 to 45, with the majority (93.76%) belonging to the 18-25 age group. Among the participants, 59.85% were male and 40.15% were female. Among those whose education was examined, 42.4%, 53.12%, and 4.48% had associate's, undergraduate's, and master's degrees, respectively. Based on the evaluation results regarding the health status of the participants, the answer deemed "good" attained the highest score of 88.28%, while the answer labeled "bad" was received at a rate of 0.99%.

Table 1. Demographic characteristic of the students

Demographic characteristic		*n*	*%*
Sex	Female	161	40.15
	Male	240	59.85
Age	18-25	376	93.76
	26-32	19	4.74
	33-45	6	1.5
Education degree	Associate	170	42.4
	Undergraduate	213	53.12
	Master's	18	4.48
Health	Good	354	88.28
	Moderate	43	10.73
	Bad	4	0.99

Table 2. The knowledge of students about kefir

Answer	*Sex*	*n*	*%*
Yes	Female	76	18.70
	Male	94	23.44
	Total	169	42.14
No	Female	85	21.20
	Male	146	36.41
	Total	231	57.61
Few	Female	1	0.25
	Male	0	0.00
	Total	1	0.25
Total		401	100.00

Table 3. The sources of information on kefir definition

Sources	*Sex*	*n*	*%*
Newspaper, TV, Internet	Female	34	20.00
	Male	42	24.71
	Total	76	44.71
Social environment, Relatives	Female	26	15.29
	Male	36	21.18
	Total	62	36.47
Food Engineer	Female	14	8.24
	Male	4	2.35
	Total	18	10.59
Not sure	Female	2	1.18
	Male	12	7.06
	Total	14	8.24
Total		170	100.00

Table 4. Milk and dairy products consumption of the students

Answer	*Sex*	*n*	*%*
Yes	Female	148	37.09
	Male	225	56.39
	Total	373	93.48
No	Female	12	3.01
	Male	14	3.51
	Total	26	6.52
Total		399	100.00

Participants were initially surveyed about their awareness of kefir to determine whether they had any knowledge of kefir. Of the respondents, 42.14% answered "yes", while a significant proportion (57.61%) answered "no", and only 0.25% stated that she had little knowledge (Table 2). The data collected suggests that compared to other fermented products kefir, a special fermented dairy product, is less known and consumed by the students than other fermented products. Considering that these answers did not provide a clear result, therefore, the survey was continued with further detailed questions.

In order to detail the information of the participants who have knowledge about the source of this information, 44.71% said they learned about it from the newspaper, 36.47% from their friends and 10.59% from the food engineers. However, some of students (8.24%) participating in the survey stated that they were not sure of the source of the information they had about kefir. Table 3, displays the distribution of these answers.

The students were asked questions about the consumption of milk and dairy products, including kefir. As can be seen in Table 4, 93.48% of students participated in the survey stated that they consumed milk and dairy products, regularly. Regarding this, the consumption rate was higher in male students (56.39%) than for female students (37.09%). In the Turkish Nutrition Guide, it is advised that adults should consume three portions of milk and dairy products, while children, adolescents, pregnant and lactating women and post-menopausal women should consume between two and four portions of these products. One portion includes a medium-sized mug of milk (240 mL), yogurt (200-240 mL), or two matchbox-sized portions of cheese (40-60 g on average) (Pekcan et al., 2016).

The students were asked about their consumption frequency of milk and dairy products. The data collected showed that 53.27% of the students consumed dairy products at least once a day (Table 5). In addition, 32.66% of the student population reported consuming milk and dairy products weekly, 10.30% monthly, and 3.77% annually. Aktaç et al. (2021) conducted a survey analyzing attitudes towards traditional fermented food consumption among 1233 students. The study found that 89.7% of participants had positive traditional fermented food consumption and 45.2% of this consumption rate was associated with health benefits. In the research carried out by Ürkek and Taş (2021), 39.8% of the university students determined that they preferred fermented milk products because they liked them, and 40.9% of them preferred them because they were healthy.

Table 5. The frequency of milk and dairy products consumption among students

Answer	*Sex*	*n*	*%*
Once a year	Female	5	1.26
	Male	10	2.51
	Total	15	3.77
Once a month	Female	16	4.02
	Male	25	6.28
	Total	41	10.30
Once a week	Female	44	11.06
	Male	86	21.61
	Total	130	32.66
Once a day	Female	94	23.62
	Male	118	29.65
	Total	212	53.27
Total		398	100.00

Table 6. The knowledge that kefir is a dairy product

Answer	*Sex*	*n*	*%*
Yes	Female	136	34.09
	Male	188	47.12
	Total	324	81.20
No	Female	24	6.02
	Male	51	12.78
	Total	75	18.80
Total		399	100

Table 7. The consumption rates of kefir per gender of the students

Answer	*Sex*	*n*	*%*
Yes	Female	30	7.48
	Male	38	9.48
	Total	68	16.96
No	Female	131	32.67
	Male	202	50.37
	Total	333	83.04
Total		401	100

Table 8. Reasons for kefir non-consumption by the students

Answer	*Sex*	*n*	*%*
Not benefit	Female	3	1.18
	Male	4	1.57
	Total	7	2.76
Not safe	Female	3	1.18
	Male	10	3.94
	Total	13	5.12
Expensive	Female	17	6.69
	Male	24	9.45
	Total	41	16.14
Not need	Female	77	30.31
	Male	116	45.67
	Total	193	75.98
Total		254	100.00

An evaluation was made to determine whether the students knew that kefir is a dairy product. 81.20% of students conveyed their awareness, whereas 18.80% admitted to a lack of knowledge (Table 6). This information was so important for this study. Because kefir, which is consumed with pleasure in many countries around the world, is unfortunately not known and consumed enough in Turkiye.

Table 7 shows the kefir consumption rates of the students. According to the answers of the students participating in the survey regarding their kefir consumption habits, 83.04% stated that they did not consume kefir, while only the remaining 16.96% stated that they consumed kefir. Among those who consume kefir, 9.48% are men and 7.48% are women. Regarding non-consumers, 50.37% are men and 32.67% are women. Similarly, in the research conducted by Yelce and Gül (2020), 70.83% of the consumers living in Antalya city center stated that they do not consume kefir. It appears that the consumption of kefir is lower among university students.

The surveyed students who did not regularly drink kefir were questioned about their reasons (Table 8). Respondents ranked their reasons for not using kefir in the following order; not needed (75.98%), expensive (16.14%), not safe (5.12%) and not benefiting (2.76%).

The students who participated in the survey were asked whether they knew how kefir is produced (Table 9). Of all participants, 57.14% of the students stated that they did not know, 25.31% stated that they had some knowledge and 17.54% stated that they had knowledge about kefir production. Although the majority of students know that kefir is a dairy product, it is understood that they have no idea how it is produced. Sharing information about the production process of kefir for more conscious consumption will benefit society in terms of general culture. It is believed that providing information about kefir production in the brochures distributed as part of the current study may be useful in this regard.

The surveyed students were asked whether they had any information about the health benefits of kefir (Table 10). Only 31.08% of students answered 'yes' whereas 39.6% of them said 'no'. Tarakci et al. (2015) investigated the consumption habits of fermented dairy products among consumers in Ordu province, and 42.0% answered yes and 58.0% answered no to the question. 'Do you have any information about the effect of kefir on human health?'. Unfortunately, in Turkiye, kefir is not as well-known as other dairy products, and the health benefits of kefir are only known to a very

Table 9. The knowledge about how kefir is produced

Answer	*Sex*	*n*	*%*
Yes	Female	32	8.02
	Male	38	9.52
	Total	70	17.54
Few	Female	44	11.03
	Male	57	14.29
	Total	101	25.31
No	Female	84	21.05
	Male	144	36.09
	Total	228	57.14
Total		399	100.00

Table 10. The awareness of the health benefits of kefir

Answer	*Sex*	*n*	*%*
Yes	Female	62	15.54
	Male	62	15.54
	Total	124	31.08
Few	Female	43	10.78
	Male	74	18.55
	Total	117	29.32
No	Female	55	13.78
	Male	103	25.81
	Total	158	39.60
Total		399	100.00

Table 11. Answers to the query 'Would you consume kefir after today?'

Answer	*Sex*	*n*	*%*
Yes	Female	53	13.28
	Male	67	16.79
	Total	120	30.08
No	Female	39	9.77
	Male	48	12.03
	Total	87	21.80
Sometimes	Female	68	17.04
	Male	124	31.08
	Total	192	48.12
Total		399	100.00

small number of people. For this reason, this study was carried out to explain its advantages and introduce it to university students in particular. The definition of kefir, its production and health benefits were explained in detail in the brochures distributed to the students during the survey.

Students were asked the question, 'Would you consume kefir after today?' The highest response rate was recorded for the 'sometimes' option at 48.12%. The lowest response rate was for 'no' (21.8%), while 30.08% of the participants answered positively (Table 11). Most of the students who had no knowledge about kefir before and had never drunk kefir answered this question positively. However, students who do not currently consume milk and products and students who do not like the taste and smell of kefir responded negatively. Kefir, a probiotic milk product, is a wonderful drink due to its functional properties. However, its consumption is low in our country and society needs to be informed about it. From the answers to this question, it can be concluded that this goal has been partially achieved.

4. Conclusion

According to the results of the present study, students at Ataturk University have limited knowledge about kefir and do not consume enough dairy products. Although kefir is not a popular beverage among students, they have shown a considerable interest in it. The reason for the lower consumption of traditional fermented drinks like kefir could be because these drinks are usually produced at home or by small-scale producers in certain regions of Turkiye. Food preferences of university students are influenced by advertisements, social media, and the internet, which leads them to consume fast food and reduce the consumption of traditional fermented foods, including kefir. However, this study has confirmed that kefir, an affordable and probiotic food with acceptable sensory features, has the potential for increased consumption by the younger generation. Consequently, promoting kefir as a healthy food is a practical and promising.

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Declaration of Competing Interest

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

Author's Contributions

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H. Nadaroğlu (0000-0002-7015-5169): *Data Collection, Conceptualization, Methodology, Editing.*
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Investigation of Knowledge and Awareness about Food Nanotechnology of Nutrition and Dietetics Students

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Abstract

In this study, it was aimed to examine the knowledge and awareness levels of nutrition and dietetics department students about food nanotechnology. This descriptive study was conducted with 242 students aged 18 and over who were studying at the Department of Nutrition and Dietetics.52.1% of the participants are 22 years old and over, and 66.9% have heard of the concept of food nanotechnology (nano food). In the study, it was determined that the level of knowledge and awareness about food nanotechnology was high among those who had heard of the concept of food nanotechnology (nano food) before (p=0.017) and those who had knowledge of food nanotechnology (nano food) (p=0.000). Those who think that smart packaging systems that provide information about the quality of packaged food during storage and transportation will not be useful (p=0.001), those who think that smart packaging methods will be preferred instead of traditional packaging techniques with the development of nanotechnology (p=0.000), have ethical concerns about the use of nanotechnology in the field of food. The level of knowledge and awareness about food nanotechnology was found to be high among those who thought that the use of nanotechnology in the field of food was very low (p=0.000) and those who stated that the perceived risk level was very low (p=0.000). It shows that nutrition and dietetics students have limited knowledge about the wide application of food nanotechnology.

Keywords: Knowledge and awareness, Nano food, Nanotechnology, Nutrition and Dietetics Students.

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1. Introduction

Nanotechnology is an interdisciplinary branch of science with countless applications in many fields, including the food industry. Nanoscale structures can affect the stability, processability, texture, flavor and many other features of foods during storage (Jafari, 2017a). The principle of nanotechnology is based on changing the physicochemical features of the material by reducing the particle size to an average of less than 1 micrometer (µm), that is, to the nano size (Müller & Keck, 2008). The food industry is facing huge difficulties in developing and implementing environmentally acceptable and sustainable systems for the production of efficient, high quality and safe food. Many innovations for processes, products and tools are being developed to meet these difficulties (Anandharamakrishnan, 2014). The applications of food nanotechnology in the food industry are developing rapidly and nanotechnology offers many innovations and opportunities to solve these problems. The use of various nanoscale materials can improve or change the features of foods during their shelf life, leading to changes in macro-scale properties such as texture, taste, other sensory properties, coloring power, processability and stability. In addition, food nanotechnology has the potential to improve the water solubility, thermal stability and bioaccessibility of bioactive compounds (Akhavan et al., 2018; Huang et al., 2010; Jafari, 2017b; Mcclements et al., 2009; Silva et al., 2012). Food nanotechnology has areas of application in all stages and processes that food undergoes from farm to fork (Çakır, 2020).

In food applications, nanosensors, nanocomposites, nanofibers, nanotubes, nanoparticles and nanoemulsions that contain food components have been used for numerous purposes (Duncan, 2011). Thereby enabling the production of foods with better solubility, thermal stability and higher bioavailability

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and bioaccessibility (Hamad et al., 2018; Ni et al., 2017). Progress in the field of nano foods has also enabled the development of healthier foods (Saka and Gülel, 2015). Food nanotechnology will contribute greatly to the production of functional foods by enabling more effective use of bioactive compounds and nutraceuticals that have positive effects on health (Dağ, 2014). Thus, new products for health-improving nutrition can be developed (Pogarska et al., 2017). The preparation of food nanoemulsions that increase the bioavailability of vitamin D in order to eliminate vitamin deficiency in elderly populations (Walia & Chen, 2020) and the development of nanosized droplets that increase the uptake of polyunsaturated fatty acids for use in oral therapies (Dey et al., 2019) are examples of their use for this purpose. The long-term health risks of nanotechnology, which is a new area, are not yet completely understood. Very few in vivo studies have been conducted on the possible effect of the use of nano foods on human health (Sağlam & Var 2015). Due to these areas of application, food nanotechnology is important for nutritional sciences.

Food and nutrition professionals who understand the structural and functional characteristics of foods, nutrients, and metabolites can develop new food distribution systems. Improvements in food safety and sanitation practices can be created with the vision of food and nutrition professionals who comprehend post-harvest critical points in the post-production flow of food. Patient services for the treatment of specific diseases can be refocused or redirected. Food and nutrition experts can develop educational materials for all segments of the population to better understand the science behind nanotechnology and its applications. To better inform public policies related to health and medicine, the environment, and food and water supply, food and nutrition professionals can enhance their knowledge about nanotechnology (Nickols Richardson, 2007). In this respect, the knowledge and awareness of nutrition and dietetics students are crucial.

Although nanotechnology education in universities is progressing, it is still reported to be insufficient. It is observed that the importance of nanotechnology education, particularly in the field of engineering, has increased in the curriculum of universities in Turkey. As food nanotechnology emerges and is utilized in daily food items, individuals need to be aware not only of the benefits of this technology but also of its consequences. The concept of nano food is crucial for both individuals' nutrition and their health. Therefore, the knowledge and awareness of nutrition experts on this matter are of great importance. For the issues related to public health that may arise with the development of food nanotechnology, which has beneficial effects on health in the field of nutritional sciences, stakeholders in the field of nutrition and dietetics have a lot of work to do. For these reasons, it is necessary to determine the knowledge and awareness levels of students studying in these departments. In this regard, this study will provide a better understanding of students' knowledge and awareness of the risks and benefits of food nanotechnology applications.

2. Material and Methods

2.1. Study Design

This descriptive study was conducted between July and August 2021. The population of the study consisted of students aged 18 years and over studying in the Department of Nutrition and Dietetics at Kırklareli University. No sample selection was made in the study, and 242 people who volunteered to participate in the study were reached. Approval for the study was obtained from the Ethics Committee of the Institute of Health Sciences of Kırklareli University (21.06.2021-PR0340R0).

2.2. Data Collection Tools

Google form was prepared for the data and administered online. The first question of the questionnaire asked the participants to confirm their voluntary participation in the study. The participants who voluntarily agreed to participate in the study were not allowed to answer the questionnaire afterwards. The questionnaire form was prepared by the researchers, the first section includes descriptive characteristics, the second section includes questions about the level of knowledge and awareness about food nanotechnology, and the third section includes propositions about the level of knowledge and awareness about food nanotechnology. A 24-question food nanotechnology knowledge and awareness level scale was prepared based on the literature (Chaudhry & Castle 2011; Grobe et al., 2008). The propositions are arranged on a 6-point Likert scale as "Don't know / No opinion (0), Strongly disagree (1), Disagree (2), Neither agree nor disagree (3), Agree (4), Strongly agree (5)". A minimum score of 0 and a maximum score of 120 can be obtained from the scale. High scores indicate a high level of knowledge and awareness about food nanotechnology. In the reliability analysis in this study, the Cronbach's Alpha coefficient of the list of propositions was calculated as 0.953. In factor analysis, Kaiser-Meyer-Olkin Measure value was 0.937 (p=0.000).

2.3. Analysis of the Data

Number (n), percentage (%), mean and standard deviation (SD) were used in the analysis. The normality of the distribution was tested with the Kolmogorov-Smirnov test. Reliability analysis was done for the reliability of the data and the results were analyzed with Cronbach's alpha coefficient. Mann-Whiytney U test was used for the comparison of two independent group means and Kruskal-Wallis analysis of variance was used for the comparison of three or more independent group means. Data were analyzed in SPSS 26.0 statistical package program and significance level was accepted as $p<0.05$.

3. Results

Table 1 shows the descriptive characteristics of the participants. 52.1% of the participants were 22 years of age or older, 91.7% were female, 31.8% were fourth grade students.

Table 1. Distribution of descriptive characteristics of participants

Descriptive characteristics		*n*	*%*
Age	≤ 21	116	47.9
	≥ 22	126	52.1
Gender	Female	222	91.7
	Male	20	8.3
Class level	1st grade	59	24.4
	2nd grade	65	26.9
	3rd grade	41	16.9
	4th grade	77	31.8

Table 2 shows the characteristics of the level of food nanotechnology knowledge and awareness of the participants. 66.9% of the students had heard the concept of food nanotechnology (nano food) before. They mostly obtained this information from the internet, visual or written media (44.6%). 81.8% of the participants said that they had some knowledge about food nanotechnology (nano food). Students stated that nanotechnology in the field of food can be used mostly in food processing (63.6%) and development of packaging systems (57.0%). When asked "Do you think smart packaging systems that provide information about the quality of packaged food during storage and transportation would be useful?" 88.4% of the students answered yes. 78.9% of the students think that with the development of nanotechnology, smart packaging methods will be preferred instead of traditional packaging techniques. 44.2% of the research group stated that they did not know whether there were any ethical problems with the use of nanotechnology in the field of food. 36.8% of the group stated that they did not know the risk level of the use of nanotechnology in food. The highest response to the risk level was that the high area/volume ratio of nanomaterials makes them more reactive and more toxic (38.0%). 86.8% of the students expect safety criteria to be determined for food products containing nanomaterials. 86.0% of the participants expressed that they would like to receive training on food nanotechnology. 73.6% of the students think that developments in food nanotechnology will be beneficial for their profession and 73.6% of the students think that courses on food nanotechnology should be included in the Nutrition and Dietetics curriculum.

Table 3 shows the distribution of the mean scores of the responses to the statements regarding the level of knowledge and awareness of the participants about food nanotechnology. Based on this, the highest mean scores are "It can maintain the desired flavor and color of foods and beverages (3.38±1.45)" and "Nanosensors can be used for the detection of animal and plant pathogens (3.17±1.66)". The lowest scores were for the statements "It can improve the bioavailability of nutraceuticals (2.16±1.90)" and "Better absorption and absorption of nutraceuticals can be achieved (2.22±1.93)".

Table 4 shows the relationship between some features of the participants and the scale of knowledge and awareness level about food nanotechnology. It was found in the study that those who had heard the concept of food nanotechnology (nano food) before (p=0.017) and those who had knowledge of food nanotechnology (nano food) (p=0.000) had a high level of knowledge and awareness about food nanotechnology. Among those who think that smart packaging systems that provide information about the quality of packaged food during storage and transportation will not be useful (p=0.001), those who think that smart packaging methods will be preferred instead of traditional packaging techniques with the development of nanotechnology (p=0.000), The level of knowledge and awareness about food nanotechnology was found to be statistically higher in those who thought that there was no ethical objection to the use of nanotechnology in food (p=0.000) and those who stated that the perceived risk level in the use of nanotechnology in food was very low (p=0.000).

Table 2. Characteristics related to the level of participants' knowledge and awareness of food nanotechnology

	n	*%*
Have you heard of Food Nanotechnology (Nano food) before?		
Yes	162	66.9
No.	80	33.1
Where did you first hear about Food Nanotechnology?		
Internet, visual or written media	108	44.6
Scientific publications such as articles and reviews	17	7.0
Events such as panels, conferences	7	2.9
During my education	42	17.4
Are you familiar with Food Nanotechnology (Nano food)?		
Yes	11	4.5
A little bit	198	81.8
No.	33	13.6
Which applications in food can nanotechnology be used for?		
Food processing	154	63.6
Development of packaging systems	138	57.0
Development of functional products	132	54.5
Increasing the nutritional value of foods	115	47.5
Detection of pathogens and improving food safety	109	45.0
New product development	88	36.4
Transport and controlled release of bioactive substances	87	36.0
Use as an additive	69	28.5
Do you think smart packaging systems that provide information about the quality of packaged food during storage and transportation		
Yes	214	88.4
No.	6	2.5
I don't know	22	9.1
Do you think that with the development of nanotechnology, smart packaging methods will be preferred over traditional packaging tech-		
Yes	191	78.9
No.	14	5.8
I don't know	37	15.3
Do you think there are any ethical problems with the use of nanotechnology in food?		
Yes	31	12.8
No.	104	43.0
I don't know	107	44.2
What do you think is the level of risk of using nanotechnology in food?		
Too much	3	1.2
More	9	3.7
Medium level	80	33.1
Low	51	21.1
Very low	10	4.1
I don't know / no idea	89	36.8
*Which one(s) pose a risk in the use of nanotechnology in food?**		
Maximum limits not known	65	26.9
Use in food processing and packaging	50	20.7
No labeling requirement to identify the nanomaterials in the product	62	25.6
Lack of particle size range information	60	24.8
The high area/volume ratio of nanomaterials makes them more reactive and toxic	92	38.0
Nanoparticles can easily react with other components because they are more reactive	90	37.2
Nanoparticles released into the environment and indirectly contaminated food	81	33.5
Positively charged and hydrophilic nanoparticles increase circulation time in the body	52	21.5
The large surface areas of nanoparticles provide surfaces to which toxic chemical contaminants can bind and be transported	83	34.3
The ability of nanoparticles to enter the body and cells can cause toxic substances to spread inside the body, resulting in cell and tissue damage and defects in defense mechanisms	88	36.4
Inhalation of nanoscale substances can cause lung diseases	18	7.4
*What do you expect from food products containing nano materials?**		
Being labeled	177	73.1
Determination of safety criteria	210	86.8
Laboratory protocols have been established	171	70.7
Approval of organizations such as international food authorities (FDA, FAO, etc.)	195	80.6
Would you like to receive training in food nanotechnology?		
Yes	208	86.0
No.	34	14.0
Do you think that developments in food nanotechnology will benefit your profession?		
Yes	178	73.6
No.	7	2.9
Not sure/don't know	57	23.6
Do you think that courses on food nanotechnology should be included in the Nutrition and Dietetics curriculum?		
Yes	178	73.6
No.	12	5.0
Not sure/don't know	52	21.5

*Multiple options are selected.

Table 3. Distribution of responses to the propositions regarding the level of knowledge and awareness of participants about food nanotechnology

Proposals	Don't know/ No idea	Strongly disagree	Disagree	Undecided	Agree	Fully agree
Pesticides, fertilizers and other agricultural chemicals can be used more efficiently (Item mean score; 2.93±1.61)	20.2	0.4	3.7	23.1	46.3	6.2
It can ensure controlled use of growth hormones (Item mean score; 2.59±1.62)	24.0	1.2	7.9	28.9	34.7	3.3
Nanosensors can be used to monitor soil conditions and crop growth (Item mean score; 3.02±1.72)	21.9	0.4	2.9	12.8	52.1	9.9
Nanosensors can be used for the detection of animal and plant pathogens (Item mean score; 3.17±1.66)	19.0	0.8	2.9	10.7	55.0	11.6
Nanocapsules can be used to distribute vaccines (Item mean score; 2.62±1.87)	30.6	1.2	2.9	16.5	38.8	9.9
May play a role in the delivery of DNA and chemicals to plant tissues/cells (Item mean score; 2.72±1.74)	25.6	1.2	5.0	18.6	43.0	6.6
Can improve bioavailability of nutraceuticals (Item mean score; 2.16±1.90)	41.3	0.4	3.3	16.5	33.1	5.4
Can be used to enhance flavor (Item mean score; 3.01±1.57)	16.5	1.7	9.1	17.8	46.7	8.3
It can maintain the desired flavor and color of foods and beverages (Item mean score; 3.38±1.45)	12.4	0.8	5.0	11.6	59.1	11.2
Can be used as a gelling and viscosity enhancer (Item mean score; 3.00±1.67)	20.2	1.7	5.0	12.4	52.9	7.9
Plant-based steroid nanocapsules can be used instead of meat cholesterol (Item mean score; 2.76±1.66)	21.5	2.9	7.4	21.5	39.7	7.0
It can be used to remove pathogens or chemicals detected in foods (Item mean score; 3.25±1.56)	16.1	0.8	2.5	13.6	56.2	10.7
Food components can provide a more homogeneous and better distribution (Item mean score; 3.07±1.68)	20.2	0.8	2.5	14.5	51.7	10.3
May mask unpleasant tastes (Item mean score; 2.97±1.64)	18.6	2.9	6.6	16.1	46.7	9.1
Can be used to detect chemicals or foodborne pathogens (Item mean score; 3.17±1.64)	18.6	0.4	3.7	10.3	56.2	10.7
Biodegradable nanosensors can be used for temperature, humidity and time monitoring (Item mean score; 3.07±1.73)	21.5	0.8	2.5	11.2	52.1	12.0
Nanoclays and nanofilms can be used as barrier materials to prevent degradation and oxygen absorption (Item mean score; 2.73±1.86)	29.3	0.4	2.1	14.5	43.4	10.3
Nanoparticles containing antimicrobial and antifungal can be used for surface coatings (Item mean score; 2.57±1.86)	30.6	1.7	5.0	16.1	36.4	10.3
Lighter, stronger and heat resistant films made of silicate nanoparticles can be used (Item mean score; 2.42±1.90)	35.5	1.2	2.1	14.5	40.1	6.6
The permeability of the packaging material can be modified (Item mean score; 3.10±1.64)	19.0	0.8	4.1	12.0	55.0	9.1
Nanoscale transforming technologies can be used to increase the absorption of nutrients (Item mean score; 2.79±1.77)	24.8	1.7	6.2	14.0	44.2	9.1
Nanoparticles can be used as drug carriers (Item mean score; 2.69±1.85)	28.5	2.1	3.7	13.6	41.7	10.3
Better absorption and absorption of nutraceuticals can be achieved (Item mean score; 2.22±1.93)	40.5	0.8	3.3	14.0	34.3	7.0
Nanoclays and nanofilms can be used as barrier materials to prevent degradation and oxygen absorption (Item mean score; 2.73±1.86)	29.3	0.4	2.1	14.5	43.4	10.3
Nanoparticles containing antimicrobial and antifungal can be used for surface coatings (Item mean score; 2.57±1.86)	30.6	1.7	5.0	16.1	36.4	10.3
Lighter, stronger and heat resistant films made of silicate nanoparticles can be used (Item mean score; 2.42±1.90)	35.5	1.2	2.1	14.5	40.1	6.6
The permeability of the packaging material can be modified (Item mean score; 3.10±1.64)	19.0	0.8	4.1	12.0	55.0	9.1
Nanoscale transforming technologies can be used to increase the absorption of nutrients (Item mean score; 2.79±1.77)	24.8	1.7	6.2	14.0	44.2	9.1
Nanoparticles can be used as drug carriers (Item mean score; 2.69±1.85)	28.5	2.1	3.7	13.6	41.7	10.3
Better absorption and absorption of nutraceuticals can be achieved (Item mean score; 2.22±1.93)	40.5	0.8	3.3	14.0	34.3	7.0
It can be used for more efficient delivery of nutrients to body cells without affecting the color or taste of food (Item mean score; 2.89±1.73)	22.7	1.2	5.0	16.5	44.6	9.9

Table 4. The relationship between some characteristics of the participants and knowledge and awareness level scale about food nanotechnology

Proposals		*Mean*	*Std. Dev.*	*p-value*
Age	≤ 21	65.84	28.33	0.803
	≥ 22	64.87	27.11	
Gender	Female	65.79	27.76	0.277
	Male	60.30	26.58	
Class level	1st grade	64.07	29.37	0.824
	2nd grade	66.60	27.90	
	3rd grade	63.85	27.68	
	4th grade	66.03	26.51	
Previous knowledge of the concept of food nanotechnology (nano food)	Yes	68.80	25.10	0.017
	No	58.33	31.20	
State of knowledge about food nanotechnology (nano food)	Yes	74.55	31.40	0.000
	A little bit	68.67	24.50	
	No	42.24	33.26	
Do you think smart packaging systems that provide information about the quality of packaged food during storage and transportation would be useful?	Yes	67.67	26.15	0.001
	No	68.33	27.13	
	I don't know	41.77	31.99	
Do you think that with the development of nanotechnology, smart packaging methods will be preferred over traditional packaging techniques?	Yes	69.84	24.57	0.000
	No	61.79	33.53	
	I don't know	43.41	30.29	
Ethical concerns about the use of nanotechnology in food	Yes	71.03	20.91	0.000
	No	75.88	21.77	
	I don't know	53.43	29.87	
Perceived level of risk in the use of nanotechnology in food	Too much	56.67	29.26	0.000
	More	77.33	16.78	
	Medium level	76.96	16.88	
	Low	74.25	23.00	
	Very low	83.40	25.52	
	I don't know / no idea	46.82	29.25	
Willingness to receive training on food nanotechnology	Yes	66.11	27.39	0.334
	No	60.62	29.17	

4. Discussion

In this study, the level of knowledge and awareness of food nanotechnology was found to be high in those who had heard the concept of food nanotechnology (nano food) before and those who had knowledge of food nanotechnology (nano food). On the other hand, in a study conducted with Western University students,nanotechnology awareness and familiarity with nanotechnology were found to be low. Students in the field of nutrition were found to have stronger knowledge about nanotechnology and its applications in food than non-nutrition students. One third of nutrition students stated that "technology should not be associated with food" (Hekmat & Dawson, 2019).

It was found that those who thought that smart packaging systems that provide information about the quality of packaged food during storage and transportation would not be useful, and those who thought that smart packaging methods would be preferred instead of traditional packaging techniques with the development of nanotechnology had a high level of knowledge and awareness about food nanotechnology. Furthermore, as a result of the study, it was seen that the participants evaluated the development of nanotechnology as beneficial, but were aware that the use of nanotechnology carries certain risks. The participants of the study are hesitant towards the use of nanotechnology in the field of food due to lack of knowledge on the subject. A study by Ho et al. (2011) suggested that the more people know about nanotechnology, the more likely they are to have positive attitudes towards it (Ho et al., 2011). Another study reported that university students expressed some positive opinions towards the development of nanotechnology-based foods that provide beneficial effects but were concerned about the risks associated with it (Kim & Kim, 2013).

The knowledge and awareness level about food nanotechnology was found to be high among those who thought that there were no ethical concerns about the use of nanotechnology in food and those who stated that the perceived level of risk in the use of nanotechnology in food was very low. It has been shown that ethical and moral concerns affect public acceptance of new food technologies and nanotechnology is no exception (Frewer et al., 2014). Optimism regarding the application of nanotechnology in Iran in general has been reported (Farshchi et al., 2011). Similar results have been reported for high school students and adults in Turkey (Sahin & Ekli 2013; Senocak, 2014).

In the study, nutrition and dietetics students reported that the biggest risk groups in the use of nanotechnology in food are nanoparticles being more reactive and toxic and entering the body and cells. In a similar study conducted at the University of North Carolina, engineering students stated that there may be toxicological risks of nanoparticles entering the body barriers and that nano food packaging particles can enter the food and then into the body (Gardner et al., 2010).

Nanotechnology is not a term or concept that people often encounter. As nanotechnology is a very new field, most people have limited knowledge about it, except for scientists in the field (van Giesen et al., 2018; Ho et al., 2020). Results show that nutrition and dietetics students have limited knowledge about the broad application of food nanotechnology. The participants seem to have different levels of awareness on this issue, despite receiving information from basically the same source (internet, visual or written media).

The absence of the concept of nanotechnology in the curriculum is a disadvantage. Students obtain partial information during their research for the assignments given in the courses and this information is thought to be insufficient. The reason for this limited knowledge about nanotechnology is estimated to be that it is learned through extra-curricular sources such as the internet, visual or written media (Aydın Sayılan & Mercan, 2016). However, students were found to be eager to learn more about nanotechnology. A number of studies among students have shown that participants are very enthusiastic about nanotechnology (Elmarzugi et al., 2014) and have a critical view of the potential risks and benefits of its applications (Gardner et al., 2010; Nerlich et al., 2007).

The increase in knowledge also increases the curiosity to learn. For this reason, students' scientific knowledge is expected to increase as the grade level increases. In the study, no significant difference was found between the grade levels in terms of awareness towards nanotechnology. In a study conducted by Baybek et al. (2017), it was found that nanotechnology attitudes did not differ between classes.

Three quarters of the students think that developments in food nanotechnology will benefit their profession and that courses on food nanotechnology should be included in the Nutrition and Dietetics curriculum. Nanotechnology is fast becoming a leading interdisciplinary field with broad implications for society. Advances in nanoproducts have the potential to change areas of food management such as purchasing, storage and preparation, as well as management systems such as hazard analysis critical control point (HACCP). Nanotechnology products may also reduce energy and personnel costs by changing food, preparation and cooking methods and equipment requirements. Moreover, this developing technology increases the number of functional food products and has the potential to change nutrient intakes accordingly. From this perspective, nutrient intakes and their possible toxic effects on individuals need to be closely examined. Possible imbalances in micronutrient intake, nutrient-drug interactions, changes in digestion and absorption of nutrients need to be monitored more closely. Likewise, advances in food nanotechnology will change medical diagnostics and nutritional therapy delivery, and metabolic changes need to be well understood by nutritionists. Since nanotechnology has not fully penetrated the nutrition and dietetics profession, nutrition and dietetics professionals need to educate themselves on this emerging science (Nickols Richardson, 2007). Activities for consumer education and the development of legislation on nano food applications should be intensified in the future. In particular, nutritionists need to develop themselves in food safety and consumer education. Nanotechnology education is offered in Bachelor's, Master's and PhD degrees by many universities worldwide (Schummer, 2004). As a result of the stated reasons and the study, food nanotechnology should take its rightful place in undergraduate, graduate and doctoral curricula in the field of nutrition and dietetics, and it is beneficial for the department to be open to new technological developments.

5. Conclusions and Recommendations

Two-thirds of the students had heard of the concept of food nanotechnology (nano food) before; four-fifths expressed that they had some knowledge about food nanotechnology (nano food). Three-quarters of the students think that improvements in food nanotechnology will benefit their profession and that courses on food nanotechnology should be included in the Nutrition and Dietetics curriculum. It was found in the study that those who had heard the concept of food nanotechnology (nano food) before and those who had knowledge of food nanotechnology (nano food) had a high level of knowledge and awareness about food nanotechnology. Statistically high levels of knowledge and awareness about food nanotechnology were found in those who thought that smart packaging systems that provide information about the quality of packaged food during storage and transportation would not be useful, those who thought that smart packaging methods would be preferred instead of traditional packaging techniques with the development of nanotechnology, those who thought that there were no ethical problems with the use of nanotechnology in the field of food, and those who stated that the perceived risk level in the use of nanotechnology in the field of food was very low. In conclusion, it shows that nutrition and dietetics students have limited knowledge about the wide application of food nanotechnology.

It is expected that the knowledge and awareness levels of students will increase with the inclusion of courses on food nanotechnology in the Nutrition and Dietetics curriculum.

Limitations of the study

It is difficult to generalize the results of the study to the students studying in Nutrition and Dietetics Departments due to the risk of not reaching individuals without internet access in this online study. It is considered as a limitation that the participants of the study consisted only of nutrition and dietetics students of the university, except for students in other health fields. As the results are limited to the university where the study was conducted, they cannot be generalized to all universities.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

Author's Contributions

M.A. Çakır (0000-0001-5066-1956): *Idea/Concept, Literature Review, Writing.*
Y. Mercan (0000-0002-7099-4536): *Idea/Concept, Supervision/Consultancy, Analysis and/or Interpretation, Critical Review.*

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International Journal of Gastronomy Research

Determination of Thermotolerant Yeast Population in Dairy Products

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Abstract

Thermotolerant yeasts constitute a critical indicator for the effective management of product quality, food safety, and production processes in the dairy industry. This study aims to investigate the presence of thermotolerant yeasts in diverse dairy products within the context of Turkiye. In this study, pH and thermotolerant yeast properties of Turkish white cheese, butter, cream (Kaymak), and Tulum cheese were investigated. Thermotolerant yeast counts in butter samples ranged between 4.30 and 4.82 log CFU/g, with pH values ranging from 4.91 to 6.68. Thermotolerant yeast counts of Tulum cheese, white cheese and cream samples were <2 log CFU/g. The pH values of cream and Tulum cheese were ranged from pH 5.07-6.79 and pH 4.91-6.68, respectively. The mean pH value for white cheeses was 4.98. As a results, thermotolerant yeast counts of Tulum cheese, white cheese and cream samples were below the detectable value; however, a high number of thermotolerant yeasts were determined in butter samples. In conclusions, these findings offer valuable insights for evaluating the microbiological quality of different dairy products, aiding producers in enhancing safety and quality for consumers.

Keywords: Yeast, Thermotolerant, Cheese, Butter, Cream, Tulum.

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1. Introduction

As an ideal source of nutrition, milk is a foodstuff that supports intelligence and body development with the nutrients it contains. Drinking milk produced from raw milk is the most widely used dairy product. In addition to drinking milk, yogurt, buttermilk, cheese, ice cream and butter are other dairy products. Cheese is a dairy product produced by coagulating milk, separating the whey and processing the clot in various manners. White cheese is the most widely produced and most consumed type of cheese among cheese types (Demirci & Şimşek, 1997; Metin, 2005). White cheese is a risky product in terms of microbiology due to its structure and consumption without any processing. Pathogenic microorganisms can contaminate milk during cheese making and this poses a risk to public health. For the production of safe white cheese, there are some important rules that must be followed. When necessary precautions are taken, it is possible to produce hazard-free white cheese. HACCP (Hazard Analysis Critical Control Points) is the most effective method for this (Boztunç, 2000).

Despite the fact that Tulum cheese takes its name from its packaging material (Tulum), the great majority of Tulum cheeses offered for sale in the market today are in plastic drums. Storage in Tulum was preferred in the past because cans and other packaging materials were not available. Furthermore, studies indicate that the cheeses in plastic cans are superior in appearance, taste, odor and structure to those in Tulum made of goat skin (Dağdemir, 2000).

In the world, the lack of durability of butter is an important problem. Most of the butter produced cannot be kept even for a few weeks. Therefore, either many sensory defects occur or it is converted into clarified butter by salting or melting to increase its durability. This situation restricts the use of butter for breakfast (Öztürk, 2002; Sagdic et al., 2010).

Turkish cream is a dairy product specific to our culture and is not a product of the same quality in western countries (Öncü & Arun, 2013). In Turkiye, cream is used especially with desserts (Yılsay & Bayizit,

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2002). Cream is not a fermentable product and its high water content creates a very good environment for the growth of saprophytic microorganisms. In addition, since its shelf life is short and pasteurization or heat treatment is required. As a dairy product with low durability, the microbial safety of cream depends on the temperature of transportation, sales outlets and home storage. Temperature causes pathogenic microorganisms to multiply and thus threatens human health (Tosun, 2016).

Yeasts are unicellular, heterotrophic, eukaryotic microorganisms that belong to the Ascomycetes and Basidiomycetes. Among their important differences from other microorganisms are cell size, cell structure and metabolic activities (Jacques & Casaregola, 2008; Kurtzman & Fell, 1998). In general, yeasts grow well in warm, humid, sugary, salty, acidic and aerobic environments and are widely distributed in air, water, soil and organic matter. They can utilize lipids, proteins and carbohydrates (Jacques & Casaregola, 2008; Durlu Özkaya & Kuleaşan, 2000). Most of the mesophilic industrial yeasts grow at 20-30°C. At 12-15°C is the optimum temperature range for psychrophilic yeasts. They are well adapted to low temperatures and cause spoilage in frozen foods (Querol & Fleet, 2006). The thermophilic yeasts grow at 20-46°C (Deegenaars & Watson, 1998). This study aimed to determine the presence of thermotolerant yeasts in different dairy products.

2. Material and Methods

2.1. Material

For this study, 10 samples of white cheese, butter, cream and Tulum cheese were obtained from Kayseri, Tunceli, Erzincan and Elazığ provinces. Samples were taken under aseptic conditions and brought to the laboratory under suitable conditions.

2.2. pH Analysis of Samples

Ten grams of cheese, butter and cream samples were taken and 90 ml of distilled water was added. Then the samples were homogenized in Ultraturrax (IKA T18 Basic, Germany). The pH values of homogenized samples were measured with a calibrated pH meter (WTW, Inolab 720, Germany).

2.3. Microbiological Analysis of Samples

Ten g samples were taken from the samples that were brought to the laboratory under sterile conditions and they were placed in sterile stomacher bags. Then 90 ml of sterile maximum recovery diluent (MRD) solution was added and the samples were homogenized in a stomacher (Stomacher, IUL, Barcelona, Spain). Prepared butter and cream samples were kept at 45°C for 5 minutes and after homogenizing the Tulum and white cheeses, serial dilutions were prepared (Sagdic et al., 2010). From these dilutions, Dichloran Rose Bengal Chloramphenicol (DRBC) Agar medium was cultured by spreading method. The plates were incubated at 42°C for 7 days for counting thermotolerant yeasts (Arthur and Watson, 1976). After incubation, colonies were counted and the results were given as log CFU/g.

3. Results

The pH values of the butter samples are given in Table 1. It was determined that the pH values of the butter samples varied between pH 4.22-4.81. In addition, as can be seen in the table, the pH values of the butter samples were mostly pH <5. It was determined that the pH values of butter samples B6 and B8 were higher than the other samples and had pH values of 4.78 and 4.76, respectively. The sample numbered B3 was

Table 1. pH values of dairy products

Butter		*Cream*		*Tulum Cheese*		*White Cheese*	
B1	4.38±0.05	C1	6.79±0.01	T1	5.33±0.03	W1	5.08±0.02
B2	5.29±0.05	C2	5.07±0.01	T2	6.68±0.01	W2	5.24±0.01
B3	4.23±0.01	C3	6.53±0.01	T3	5.50±0.01	W3	4.99±0.01
B4	4.56±0.02	C4	6.32±0.01	T4	4.91±0.01	W4	5.07±0.01
B5	4.69±0.3	C5	6.51±0.03	T5	5.31±0.01	W5	4.80±0.04
B6	4.78±0.03	C6	6.17±0.02	T6	4.91±0.01	W6	5.05±0.01
B7	4.67±0.01	C7	6.47±0.01	T7	5.02±0.01	W7	4.77±0.01
B8	4.76±0.02	C8	6.06±0.04	T8	5.10±0.01	W8	4.70±0.32
B9	4.43±0.01	C9	6.27±0.10	T9	5.94±0.10	W9	5.28±0.01
B10	4.28±0.01	C10	6.63±0.01	T10	5.11±0.02	W10	4.85±0.01

observed to have the smallest pH value with a value of 4.23. Thermotolerant yeast counts in the butter are given in Table 2. The highest number of thermotolerant yeasts in sample B1 was 4.82 log CFU/g, while the lowest number of thermotolerant yeasts was 4.30 log CFU/g in butter sample B8.

The analysis indicated that the number of thermotolerant yeasts in all cream samples was <2 log CFU/g. Consequently, it was determined that the number of thermotolerant yeasts in the cream samples was below the detectable limits.

The pH values of the cream samples are given in the Table 1. It was determined that the pH values of the cream samples varied between pH 5.06-6.80. Particularly in the cream sample numbered C2, the pH values were determined to be pH <6. On the other hand, as can be seen in the table, the pH values of the other cream samples were found to be pH >6. The pH values of the cream samples C1 and C10 were higher than the other samples and were determined to have pH values of 6.79 and 6.63, respectively.

Thermotolerant yeast counts were <2 log CFU/g in all Tulum and white cheese samples as a result of the analysis. In conclusion, it was determined that the number of thermotolerant yeasts in Tulum and white cheese samples was below the detectable limits (Table 2).

The pH values of Tulum and white cheese samples are given in the Table 1. It was determined that the pH values of Tulum cheese samples ranged from pH 4.91-6.68. In particular, it was found that the pH values of T4 and T6 Tulum cheese samples were pH <5. On the other hand, as can be observed in the related table, the pH values of the other Tulum cheese samples were pH >5. It was observed that the pH values of T2 and T9 Tulum cheese samples were higher than the other samples and had pH values of 6.68 and 5.94, respectively. Among the white cheese samples, W1, W2, W4, W6 and W9 were pH >5 and had pH values of pH 5.08, 5.24, 5.07, 5.05, and 5.28, respectively. The other white cheese samples were found to be pH <5. Sample W8 was found to have the smallest pH value with a pH value of 4.70.

4. Discussion

Nowadays, cheese types that are produced in different ways are available to consumers through markets and neighborhood bazaars. The most consumed cheese varieties that can be consumed at any time of the day are Tulum cheeses and have an important place in nutrition. There is no standard production method for these cheeses and they may vary from region to region. Nevertheless, some of the traditional Tulum cheeses have been patented and the geographical marking system has started to be implemented (Dağdemir, 2000).

In Turkiye, butter production is mostly done uncultured, which prevents the desired flavor, standardization and aroma from being achieved in the final product (Sagdic et al., 2002). As butter is usually made from raw cream in small enterprises, it carries a health risk. However, in some enterprises, the cream is pasteurized, but since starter culture is not added, the taste and aroma are insufficient. Therefore, the taste and aroma of butter is formed by the microorganisms that are dominant in the environment (Atamer, 1993; Sagdic et al., 2002; Sagdic et al., 2010).

Different animal milks are used in the production of cream, but generally buffalo milk is preferred. Buffalo milk is preferred because of its high cream binding rate and white color. In recent years, the decrease in wetlands has led to a decrease in the number of buffalos. Therefore, cow's milk with increased dry

Table 2. Thermotolerant counts of dairy products (log CFU/g)

Butter		*Cream*		*Tulum Cheese*		*White Cheese*	
B1	4.82±0.22	C1	<2	T1	<2	W1	<2
B2	4.78±0.17	C2	<2	T2	<2	W2	<2
B3	4.64±0.03	C3	<2	T3	<2	W3	<2
B4	4.64±0.06	C4	<2	T4	<2	W4	<2
B5	4.67±0.06	C5	<2	T5	<2	W5	<2
B6	4.72±0.04	C6	<2	T6	<2	W6	<2
B7	4.63±0.05	C7	<2	T7	<2	W7	<2
B8	4.30±0.03	C8	<2	T8	<2	W8	<2
B9	4.61±0.05	C9	<2	T9	<2	W9	<2
B10	4.32±0.04	C10	<2	T10	<2	W10	<2

matter content is used instead of buffalo milk to meet the demand especially in big cities (Tosun, 2016).

In this study, no thermotolerant yeast was found in cream and Tulum and white cheeses. Thermotolerant yeast was found in butter. A research conducted on thermotolerant yeast population in Turkiye dairy products was not found in the literature. There are some researches on determination of yeast and mold population in mesophilic temperature incubation conditions (at 25°C).

In the studies carried out on this subject, the number of yeast-mold in butter samples was found to be between 2 log CFU/g and 5.86 log CFU/g (Tosun, 2016). In the studies carried out in Erzurum province, the number of yeast and molds in butter was determined between 0-112x105 CFU/g (Kurdal and Koca, 1987). In a study performed with 70 butter samples consumed in Samsun, yeast and mold counts were found to be above the standards in all of the samples (Çon and Oysun, 1990). Another study carried out in Konya showed that the average number of yeasts and molds in breakfast butter was 7.1x104 CFU/g (Yalçın et al., 1993). In the study on 35 samples to identify the quality of breakfast butter in the Elazığ province, the average yeast-mold count of the samples was found to be 9.0x106 CFU/g (Patır et al., 1995). It was studied on 20 samples of butter offered for consumption in Ağrı and the average number of yeasts and molds in the samples was 2.6x103 CFU/g (Esis, 1997). Microbiological qualities of butter made from yoghurt and cream were analyzed in Malatya and the number of yeasts and molds in cream butter was found between 1.0x103 and 7.3x106 CFU/g (Hayaloğlu and Konar, 2001).

5. Conclusions

Variations in pH values were observed among the samples. Microbiological analyses revealed discrepancies in the counts of thermotolerant yeasts across the samples. Notably, cream, Tulum, and white cheeses exhibited an absence of thermotolerant yeasts, with counts falling below detectable limits (<2 log CFU/g). Contrarily, butter samples demonstrated the presence of thermotolerant yeasts.

These results indicate significant microbiological differences among the samples. The absence of thermotolerant yeast below the detectable limits in cream, Tulum, and white cheeses suggests that these products may be safer in terms of this particular characteristic. On the other hand, the presence of thermotolerant yeast in butter implies that the production or storage conditions of this product may be more conducive to yeast growth. These findings provide valuable insights for the assessment of the microbiological quality of various dairy products. Such information can assist producers in understanding potential improvements to make their products safer and enhance quality for consumers.

Declaration of Competing Interest

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

Author's Contributions

F. Ayer, F. Aygül Karadeniz, S. Yıldızhan, M. M. Polat: *Definition, Data Collection, Investigation Conceptualization, Methodology.*
İ. Öztürk (0000-0003-1434-4763): *Definition, Investigation Conceptualization, Writing, Editing, Methodology, Supervision.*

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International Journal of Gastronomy Research

Psychosocial Stressors Affecting Food Choices

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Abstract

Stress is defined as an individual's psychological and physical reaction to adapt to a mental or physical impact. When environmental stressors are added to a diet in which unhealthy food preferences are made, the negative effects of psychological stress on health are intensified. The food preferences of individuals are influenced by many factors including physiological, psychological, environmental, and sociocultural factors. The general tendency is that individuals who are exposed to stress reduce their intake of foods low in saturated fat and prefer to consume foods high in unhealthy fats in addition to healthy food groups. This study aims to comprehend the factors influencing individuals' dietary preferences, with a specific focus on delving deeper into how stress intricately affects these choices. Future research should focus on gaining a more comprehensive understanding of this intricate relationship, with the aim of revealing the effects of stress on eating habits in greater detail and contributing to more effectively guiding individuals towards healthier lifestyles.

Keywords: Food choice, Saturated fat, Health, Stress, Sugar.

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1. Introduction

Stress is a part of modern life and an increasing amount of evidence indicates that stress contributes to poor and unbalanced diets. Self-management theory suggests that when people are under stress, they are motivated to regulate their mood and deal with behavioral demands. As such, stress triggers various coping strategies, of which eating is a common one. It has been widely reported that stress and food consumption are related (Kim & Jang, 2017). It is known that while some people eat less when stressed, most people tend to eat more (Leng et al., 2017). In addition to its more general effects on appetite, stress can also cause poor health through unhealthy changes in diet (Mohamed et al., 2020). Besides aging-related diseases such as obesity, metabolic syndrome, type 2 diabetes (type 2 DM), cardiovascular disease, stroke, and Alzheimer's Disease (AD), chronic psychological stress also increases the risk of many common mental illnesses including depression and anxiety (Ginty et al., 2017; Kivimaki & Steptoe, 2018; Caruso et al., 2018). Attempts to decrease stress levels are usually not effective enough. Because it is difficult to control stressors and adapt to effective therapeutic treatments. Moreover, financial limitations of individuals may also reduce the impact of interventions. For these reasons, attempts to reduce the relationship between stress and health problems have not been successful. This situation implies that the factors that can positively affect the relationship between stress and health are not sufficiently understood (Hackett & Steptoe, 2017). The adverse health effects of psychological stress are intensified when environmental stressors are included in a diet of unhealthy food choices. Many individuals follow a Western-style diet with a high content of animal protein sources rich in saturated fat and ready-to-eat foods such as fast food, which are high in sugar and salt, leading to an increased risk of disease. However, observational studies have demonstrated that following the Mediterranean dietary pattern, which is characterized by a high intake of fruits, vegetables and vegetable protein, contributes to lower stress levels (Nguyen et al., 2017; Kye & Park, 2012; Crichton et al., 2013; Bonaccio et al., 2018). It has been determined that dietary habits with a high intake of simple sugars and saturated fats cause an increase in cortisol levels (Laugero et al., 2011; Jakulj et al., 2013).

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This study aims to review the literature on the effects of exposure to psychosocial stressors on food choices.

2. Stress Regulation

One of the most important causes of health problems in the 21st century is stress. Stress reactivity happens through multiple mechanisms. Stressors in humans refer to any threat to well-being or any real or perceived disruption of physiological homeostasis. Homeostasis is coordinated by multiple brainstem nuclei. Physiological stressors (for example injury, exercise) typically influence physiological set points such as temperature, blood volume, blood pressure, and pH. Psychosocial stressors (for example, public speaking) indirectly disrupt homeostasis by causing emotional instability, which then alters physiological responses (Davies, 2016).

Unlike disruptions in physiological homeostasis, responses to psychosocial stressors originate in brain regions such as the prefrontal cortex (PFC) and interconnected limbic nuclei. Despite this difference in origin, there is considerable overlap between the physiological systems and neurotransmitters that are involved in both physiological and psychosocial stress responses. Responses to stressors are produced by the sympathetic adrenomedullary (SAM) system and the hypothalamic-pituitary-adrenocortical (HPA) axis. The SAM system facilitates an immediate (within seconds) response to stressors through increased sympathetic nervous system (SNS) activation and decreased parasympathetic nervous system (PSS) activation. The SNS neurotransmitters most abundant in the body are norepinephrine (NE) and epinephrine (E), which activate adrenergic receptors and produce receptor subtype(s) and effector organ-dependent effects. Consistent acute responses include increased respiration, increased heart rate, blood pressure and pupil dilation. Unlike immediate SAM responses, HPA axis responses occur over minutes to hours. During HPA axis activation, glucocorticoids, particularly cortisol, are secreted from the adrenal cortex (Moses et al., 2023).

Cortisol is the main effector hormone of the HPA axis stress response system. Like the rest of the endocrine system, the HPA axis is also regulated by a negative feedback system, thanks to which the hypothalamus and pituitary gland have receptors that detect changes in cortisol levels. For instance, cortisol secretion is inhibited when circulating levels rise and when they rise, levels are lowered. But if the HPA axis is activated repeatedly, this triggers increased cortisol production and thus exposes body tissues to excessive concentrations of the hormone. Over time, this kind of repetitive activation can overload various body systems, including the HPA axis, resulting in tissue damage and contributing to future health problems (O'Connor et al., 2021). Long-term exposure to stressors leads to a sustained release of cortisol, causing a tense mood in individuals (Herhaus et al., 2020). With the stimulation of the hypothalamus, pituitary and adrenal (HPA) axis, the hormonal and metabolic process begins. Under stress, this axis increases the release of glucocorticoids. With the release of glucocorticoids, signaling through neuropeptides increases. Ghrelin, leptin and insulin are stimulated. Growth hormones, which act lipolytic, decrease with increased stress. In addition, there is a decrease in sex (gender) steroids. A decrease in lipolytic and sex hormones causes fat to accumulate and increase (Smith & Vale, 2022).

Another system activated in individuals under prolonged stress is the dopaminergic system, which is stimulated via the mesolimbic pathway. When the dopaminergic system is activated, the individual starts to feel a sense of reward for delicious foods. Corticosteroids increase dopamine synthesis through their peripheral effects. Stress in the brain caused by the effects of dopamine and glucocorticoids triggers an increase in dopamine. Consequently, the individual's food preferences and eating habits are shaped. When the dopamine receptors are stimulated, the individual's tendency towards delicious foods and consequently energy intake increases. But when combined dopaminergic receptors are stimulated, the opposite effect can be seen. Long-term stress leads to obesity by increasing unhealthy food preferences. A prolonged state of stress increases the choice of foods high in sugar and fat. In acute stress, not only overeating but also under-eating can be observed (Rasheed, 2017).

2.1. Acute and Chronic Stress

Acute stress influences cognition and behavior. In acute stress, excessive food consumption is initiated by stimulation of the hormone cortisol. Acute stress is a weak psychological emotion that stimulates the ego state of the individual. If this process is taken under control, the chronicization of stress is avoided by supporting the individual to motivate and adapt (Rasheed et al., 2010; Rasheed et al., 2012). Healthy food selection during the acute stress period reduces cortisol release and stress responses. In case the acute stress period cannot be managed, the risk of metabolic disorders increases with excessive food consumption (Razzoli et al., 2017).

The physiological response to acute stress that can affect food intake has two distinct, but interacting pathways. One is the activation of the HPA axis with subsequent stimulation of the secretion of glucocorticoids (including cortisol) as described above. The other is the pathway of the sympathetic nervous system, which leads to an increase in arousal parameters such as adrenaline secretion, high blood pressure and diversion of blood flow from the gastrointestinal tract to skeletal muscles and the brain. This response is also known as the "fight or flight" response and often leads to a reduction rather than an increase in food consumption. Nevertheless, if the stressor is perceived as threatening to the ego, i.e. a threat to self-esteem or the social self, cortisol is released, thereby stimulating appetite and food intake (Hyldelung et al., 2022).

Chronic stress is related to chronic stimulation of the HPA axis, which involves neuroendocrine neurons in the hypothalamus regulating the secretion of adrenocorticotropic hormone (ACTH) from the anterior pituitary and glucocorticoid secretion from the adrenal gland. Over-secretion of glucocorticoids is related to obesity on several levels. The consumption of high-energy foods suppresses the hyperactivity of the HPA axis, leading to the so-called emotional eating (Maier et al., 2015)

Glucocorticoids stimulate behaviors that are mediated by the dopamine reward pathway, resulting in an increased appetite for tasty foods. Moreover, stress releases endogenous opioids that potentiate the consumption of tasty food and promote non-homeostatic eating. On the contrary, comfort food intake decreases HPA axis activity. So, if stress becomes chronic, then eating becomes a coping strategy (Leng et al., 2017).

Chronic stress affects adipose tissue. With the stimulation of the peripheral mechanism, fat and sugar intake causes visceral adiposity. According to a study carried out in the work environment of a state university, the increase in social stressors leads to an increase in BMI, especially in the female gender (Özcan & Kızıl, 2020).

3. Food Choice

Consuming food is generally conceptualized as a food choice. It is a complex activity with many dimensions. Food choice is multidimensional as it involves where, when, for how long, how, why, with whom, for whom and under what conditions food will or will not be eaten. Since physical, biological, psychological and sociocultural factors operate and interact simultaneously, food choice is multi-layered. Food choice becomes integrated as people combine multiple considerations to form specific eating activities. Food choice is diverse due to the wide range of different and unique eating activities (Sobal et al., 2014).

While food choices are thought to be formed early in life and continue into adulthood, they can develop and change throughout life (Anzman-Frasca et al., 2018). High salt, sugar and unhealthy fats, especially industrially processed foods, are known to increase unhealthy food choices. Processed products are highly tasty and attractive, have a long shelf life and can be consumed anytime, anywhere. Their formulations, presentation and marketing often encourage overconsumption (Monteiro et al., 2018).

When compared to naturally occurring foods, processed foods may have fiber, protein and water removed during processing. Ingredients can be used to soften the food (making it more likely to melt in the mouth and requiring less chewing). This enables over-processed foods to be consumed more quickly and increases the rate at which highly rewarding ingredients, such as refined carbohydrates, are absorbed by the system (Chan, 2015). For this reason, processed foods are designed to optimize not only the magnitude of the reward signal in the brain through high doses of energetic nutrients and additives but also the speed at which the reward is delivered (Gearhardt & Schulte, 2021).

Food choices of individuals vary and are shaped by many factors, especially physiological, psychological, environmental and sociocultural factors.

These multilevel factors interact to influence attitudes and beliefs about food. The interaction of the individual with the social and physical environment influences food choices and dietary behaviors. Food choices are determined by neurobiology. Primary tastes (sweet, sour, salty, bitter, and umami) and smell contribute to the overall perception of food flavor and are influenced by genes, physiology and metabolism. Certain foods cause strong sensory pleasure responses. The oral sensation of fat is extremely rewarding, especially in the presence of sugar. A combination of sugar and fat is linked to the stimulation of pleasure receptors in the brain. The food industry has been criticized for producing sweet, salty and high-fat foods to take advantage of innate biological predispositions. Biological mechanisms that regulate food intake may not match the available food supply, which provides low-cost, tasty, energy-dense foods with high reward potential and limited nutritional value. Biological factors that control food intake can be moderated through learning, experience, or altered through disease states (Monterrosa et al., 2020). Research on the perceived taste intensity of salt, sour, bitter and sweet showed that the male gender perceived weaker taste intensity than the female gender. Participants who were older than younger individuals perceived stronger taste intensity (Fischer et al., 2013).

Interactions between the individual and food choices are important in shaping food choices. These interactions include familiarity and learned safety, conditioned food preferences and conditioned satiety. Specific foods that people like and their food acceptance patterns are learned largely through physiological conditioning acquired through the experience of exposure to foods. New foods gain preference through repeated exposure. Satiety feelings also change through physiological conditioning and emotional responses to the social context in which eating occurs. Parents largely shape the context in which children encounter food by providing, modeling, encouraging, restricting and rewarding food (Monterrosa et al., 2020). In one study, the aim was to systematically review empirical studies examining the influence of parents on children's food consumption behaviors in two contexts: One that is encouraging in nature (e.g., healthy food) and one that is preventive in nature (e.g., unhealthy food). It has been demonstrated that active guidance/education may be more influential for healthy foods, whereas restrictive guidance/rule-setting may be more influential for unhealthy foods. This study suggests that a range of parental behaviors have strong associations with child food consumption behavior (Yee et al., 2017).

Individual factors (e.g. attitudes, beliefs, motivations and values, personal meanings, knowledge and skills), social and cultural norms and interpersonal factors (e.g. family and social networks) also play an important role in shaping food choices. As individuals progress through life and are exposed to social and cultural norms, attitudes, beliefs, motivations and values, knowledge and skills develop. Such factors have an impact on the foods that individuals acquire and prepare for consumption. People adopt food-related identities, and this influences food choices. Family and social networks also shape food choices by observing what others choose, negotiating with others with whom food is shared, and the support or lack of support from others in making desirable food choices (Monterrosa et al., 2020). In one study, the eating choices of 12 low/middle-income mothers (26-53 years) were investigated. The mothers emphasized their identities related to food and eating when describing food-related decisions and activities. These identities influenced the food choices a mother made for herself and her children. Analysis showed that mothers with a more defined health identity made healthier choices for themselves and their children. They also displayed behaviors that positively influenced their children's food choices. On the other hand, mothers who had difficulty seeing themselves as healthy consumed more junk food and reported feelings of anxiety and guilt. The food choices of these mothers were found to be more disconnected from their children's choices. This emphasizes the importance of understanding how identities related to food and eating can influence food choices (Johnson et al., 2011).

Lastly, food supply, marketing, societal food and nutrition policies and programs cause broader environmental, mental and societal influences on food choices (Monterrosa et al., 2020). Genetic and environmental factors' contribution to individual differences in food preferences for different food clusters has been examined in 4 UK studies that represent 3 independent samples with sample sizes ranging from 331 to 2865 participants. Heritability of liking fruits and vegetables was found to be moderate, with estimates ranging from 36 to 54 participants. Estimates of heritability for meat and fish were slightly higher than for fruit and vegetable preference, ranging from 44 to 78. The heritability of snacks was reported to be low to moderate, ranging from 20 to 52 participants (Vink et al., 2020).

3.1. Food Choice and Stressors

It is known that energy intake increases in a large proportion of the population during stress. There are also health concerns that the higher intake is often due to unhealthy foods that are high in sugar and fat. This stress-induced change in food intake is likely a contributing factor to obesity. Actually, perceived stress is associated with higher BMI and several long-term studies have found that high psychological stress can lead to long-term weight gain (Mouchacca et al., 2013; Richardson et al., 2015; Roberts et al., 2014; Tryon et al., 2013).

Considering why energy intake increases during stress, many people presume that eating tasty, favorite foods relieves some of the negative aspects of stress. Based on pre-clinical studies, there is evidence that chronic exposure to high-fat foods suppresses the stress reaction. To be specific, rats that were given access to tasty, unhealthy food for about a week and then exposed to a laboratory stressor exhibited a blunted stress response (Maniam & Morris, 2010; Ortolani et al., 2011).

A similar effect is possible in humans. Participants who described themselves as having high chronic stress had a blunted stress response and a high BMI. Researchers have suggested, based on pre-clinical research, that the blunted stress response may result from long-term intake of unhealthy nutrients (Tomiyama et al., 2011; Tryon et al., 2013).

As a result of the decrease in physical activity with the effect of stressors, eating disorders such as binge eating, emotional eating and metabolic diseases occur. Eating desires of obese women with binge eating disorders increase with an increase in hedonic desire under stress (Klatzkin et al., 2018).

The examination of study samples with differences in the levels of reaction types shows that reactions to stress may show individual differences. People with high levels of anxiety and worried mood and low levels of social support have an increased risk of hyperphagic reactions. Furthermore, it has been found that the level of restriction of unhealthy foods in the diet of individuals also improves the response to work stress (Long et al., 2021).

The eating behaviors of men and women in response to stress differ. For instance, in a study carried out in Saudi Arabia, it was found that stressed women were more likely to eat sweets and junk food, while men showed an increased preference for fast food and meat (Mohamed et al., 2020).

Finch and Tomiyama (2015) investigated the relationship between stress and comfort food eating in a sample of 2,379 young adult women. Findings indicated that negative life events experienced in the previous year and self-reported levels of psychological stress in the previous month were positively associated with comfort food eating, defined as how often participants reported eating when they felt stressed, sad, anxious, angry, or bored (Finch & Tomiyama, 2015).

Likewise, in a sample of 561 women, Groesz et al. (2012) reported that both perceived stress and exposure to chronic stress (i.e., the number of endorsed stressors) were linked to higher consumption of appetizing, non-nutritious foods such as chips and hamburgers. Involvement in stressful tasks created in an experimental environment has been associated with a variety of eating outcomes, particularly increased consumption of unhealthy snack foods (Groesz et al., 2012).

Royal and Kurtz (2010) studied the intake of snack foods after exposure to stress in 52 female university students who were exposed to high or low stress. Participants with high stress consumed more of these foods than participants with low stress (Royal & Kurtz, 2010).

In studies that examined the biological indicators of stress, it has been found that women with high cortisol reactivity to stress consume more calories under stress than women with low cortisol reactivity to stress (Herhaus et al., 2020).

In another study, 59 pre-menopausal women completed three stressful tasks that included puzzles, mental math and conversation. The participants were then left alone in a room with a variety of snacks (chocolate granola bars, potato chips, rice cakes and pretzels) to eat at leisure. Compared to women who showed higher cortisol reactivity, women who showed lower cortisol reactivity had more energy following stressful tasks (Tomiyama et al., 2011).

Keren et al. (2015) explained that the high preference for snack foods in stressful situations is due to their fast availability and palatability. They stated that the second reason why individuals choose such foods when they are in a stressful mood is the effect of the stress hormone cortisol on metabolism (Karen et al., 2015).

Food intake and stress interact in a two-way way. In the same way that stress and mood can cause eating behavior to change, a change in mood can result from intentional or unintentional food choices. Selecting to eat certain foods can alter mood through sensory or hedonic effects, relevant social context, cognitive expectations, psychological distraction, changes in appetite, or nutritional modulation of brain function. For instance, high-sugar, high-fat foods, and low-protein foods may reduce stress through better functioning of the serotonergic system (Finch et al., 2019).

Pre-clinical studies have also demonstrated that sweet-tasting foods can provide analgesic effects during acute stressors, increasing pain threshold latency and pain tolerance. Collectively, these findings demonstrate that comfort food has a general capacity to elicit desirable emotional responses in humans, which may function to reinforce stress-induced eating behavior (Zhang et al., 2023; Nuseir et al., 2022).

In general, eating when hungry is both pleasurable and rewarding. Food intake stimulates the release of endogenous opiates and activates neural substrates similar to drugs of abuse (although there are important differences in degree). Conversely, opiate release may help protect an organism from the deleterious effects of stress by reducing the activity of the HPA axis and thus attenuating the stress response.

Within a reward-based model of stress eating, repetitive stimulation of reward pathways through stress-induced HPA stimulation, highly palatable food intake, or both, can lead to neurobiological adaptations that support the compulsive nature of overeating (Park et al., 2014).

As demonstrated by Maier et al. (2015), cortisol increases under acute stress are dually linked to a preference for palatable foods and reduced activation in brain regions associated with goal processing. Behavioral tendencies such as risk aversion may also interact with stress to increase these changes in brain activity. In the study, undergraduate students were shown photographs of food or nature during exam and non-exam periods and asked to answer questions about risk aversion using the Behavioral Inhibition Scale. Of the students studied, the exam period resulted in increased perceived stress, and for those who scored lowest on risk aversion, photos of high-energy foods were associated with increased activation in regions involved in reward processing and decreased activation in regions involved in goal processing (Maier et al., 2015).

Neurobiological research suggests that stress may increase sensitivity to the consumption of energy-dense, tasty foods by emphasizing hedonic rewards and reducing long-term consequences (Neseliler et al., 2017; Duff et al., 2018).

4. Conclusions

Stress can lead to unhealthy behaviors that create a risk of deterioration in mental health. The process becomes a vicious circle through mutually triggering factors such as stressful mood, cortisol reactivity, increased hunger, increased consumption of unhealthy foods, and increased BMI. Stress can affect mood as much as nutrients affect food preferences. It is believed that stress caused by various factors can affect the food choices of individuals and that this effect may be different in men and women in different ways and at different levels. To better understand the mechanisms between stress and food choices and to better manage the relationship between stress and nutrition, further studies are needed.

Declaration of Competing Interest

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

Author's Contributions

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

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Bioavailability and health effects of some carotenoids by different cooking methods

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Abstract

Humans lack the inherent capability to synthesize carotenoids, necessitating their acquisition through dietary sources or supplementation. Among the carotenoids prevalent in our daily nutritional intake are beta-carotene, lycopene, lutein, beta-cryptoxanthin, alpha-carotene, and zeaxanthin. They have antioxidant features thanks to their ability to capture ROS (reactive oxygen species) and free radicals. Particularly beta-carotene, lycopene and lutein are carotenoids with high antioxidant capacity. However, with the effects of factors, such as oxygen, high temperature, light exposure, and pH, they are oxidatively degraded and their bioavailability in the body changes. Among food processing methods, reducing food size and dietary fiber inhibits the absorption of carotenoids by micellization and inactivating pancreatic lipase, while monounsaturated fatty acids have been shown to increase bioavailability and absorption. In vitro studies on various vegetables and fruits with the effect of exogenous factors showed that the addition of oil, increase in lycopene processing, decrease in food particle size, increase in micellization with the breakdown of dietary fibers, and increase in bioavailability as a result of the destruction of cell walls with heat treatment. The addition of olive oil with heat treatment and the factors of decreasing food particle size have positive effects on health by transforming carotenoids into forms with high bioavailability in the body. This review endeavors to investigate the bioavailability of select carotenoids, namely lycopene, beta-carotene, and lutein, in light of various cooking methods and processes, as well as to elucidate their implications for health resulting from heat treatments.

Keywords: Cooking methods, Carotenoids, Health, Bioavailability.

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1. Introduction

Carotenoids were first obtained by Weckenroder in 1831 by isolating them from carrots, but studies on carotenoids began in 1837 when yellow compounds in autumn leaves were named xanthophylls (Erge & Karadeniz, 2010). Carotenoids are the second most common natural pigments worldwide, which are synthesized by some plants, algae, fungi and bacteria and give yellow-red colors to fruits and vegetables and are fat-soluble with more than 750 members. In general, carotenes are isoprenoids formed by the combination of eight isoprene units (Gökbulut & Şarer, 2008). In the structure of carotenoids, conjugated double bonds provide color formation. For color formation, at least seven conjugated double bonds must come together. While phytoene compound with five conjugated double bonds is colorless, lycopene compound with eleven conjugated double bonds is red. Thus, as the number of conjugated double bonds increases, the color concentration also increases. Carotenoids are categorized into four main groups according to their structures: Carotenes, Xanthophylls, Carotenoid ketones and Carotenoid acids. Carotenoids that contain oxygen in their structure are called 'xanthophylls,' and those that contain carbon in their structure are called 'carotenes' (Türkcan & Ökmen, 2012). Xanthophylls can be classified as lutein, zeaxanthin, astaxanthin and canthaxanthin and carotenes as alpha carotene, beta-carotene and lycopene (Gökbulut & Şarer, 2008).

Carotenoids are synthesized in the plastids of photosynthetic organisms, such as fruits, vegetables and flowers. They are composed of carotenoids and isoprenoids and IPP (isopentyl pyphosphate). Sources of IPP in plants are the MVA (cytosolic mevalonic acid pathway) and the MEP (methylerythritol 4-phosphate)

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pathway. In the cytosolic pathway, IPP is first isomerized to DMAPP (dimethylallyl diphosphate). From DMAPP, GGPP is formed by the enzyme GGPPsynthase. Phytoene is produced by phytoene synthase enzyme, and lycopene is formed in the last step (Erge & Karadeniz, 2010; Rosas-Saavedra & Stange, 2016).

Carotenoids cannot be synthesized by humans. They should be taken from foods or supplements (Eggersdorfer & Wyss, 2018). Carotenoids most commonly found in our daily food consumption are beta-carotene, lycopene, lutein, beta cryptoxanthin, alpha carotene and zeaxanthin (Desmarchelier & Borel, 2017). Although carotenoids cannot be synthesized by animals, they are also present in some animal-derived foods, such as eggs, fish, dairy products and chicken, in our daily consumption (Martini et al., 2022). Other than these foods, carotenoids are also found in vegetables, such as tomatoes, carrots, red peppers, zucchini, eggplants, broccoli, beans, and spinach and fruits and vegetables with yellow-red colors, such as raspberries, strawberries, blackberries and blueberries according to their different levels of carotenoid content (Erge & Karadeniz, 2010). Dark green plants are rich in lutein, tomatoes and their derivatives in lycopene, red fruits and vegetables in alpha and beta-carotene, and egg yolk in zeaxanthin and lutein. Although 40 natural carotenoids in the daily diet have been identified, 20 carotenoid species are measured in tissues and blood plasma. Approximately 90% of the 20% species are composed of alpha, beta-carotene, lycopene and lutein in in vivo studies (Rivera-Madrid et al., 2020; Yılmaz, İ. 2020). In one study, 62 prospective cohort studies and case controls were analyzed. Based on the study, plasma carotenoid levels and health outcomes were analyzed. Therefore, a carotenoid health index was obtained. In accordance with this index, a plasma carotenoid concentration of <1000 nmol/L poses a risk for metabolic diseases, such as cardiovascular disease and cancer, while ≥ 2500 mmol/L is protective (Böhm et al., 2021; Donaldson, 2011).

Thanks to their ability to capture ROS (reactive oxygen species) and free radicals, carotenoids have antioxidant properties. In particular, beta-carotene, lycopene and lutein are carotenoids with high antioxidant capacity. In addition, some carotenoid species show provitamin A activity. Especially beta-carotene is the carotenoid with the highest conversion activity to vitamin A (Desmarchelier & Borel 2017; Gökbulut & Şarer 2008; Yılmaz, 2020). By blocking the transylation of nuclear factor, carotenoids provide inhibition of inflammatory cytokines, such as IL-8 and prostaglandin E2. At the same time, they interact with the nuclear factor-associated factor 2 pathway and increase its translocation to the nucleus. Consequently, it activates phase enzymes, such as glutathione S transferase and suppresses oxidative stress by showing antioxidant activity (Kaulmann & Bohn, 2014). Because of these properties, they have positive effects on many diseases, such as degenerative skin diseases, cancer, Alzheimer's, cardiovascular disease, osteoporosis, age-related macular degeneration and cataract (Rivera-Madrid et al., 2020). There are certain factors affecting the antioxidant capacity of carotenoids, including concentrations of carotenoids, molecular structure, oxygen pressure, carotenoid sites of action, and interaction with other carotenoids and antioxidants (Gao et al., 2020)

Contents of carotenoids in foods change according to some factors. Among these factors are the type of food, seasonality, variety, maturity level, processing, storage conditions and climatic conditions (Martini et al., 2022). Also, carotenoids are stable and independent of cooking and storage. However, they are oxidatively degraded with the effects of factors, such as oxygen, high temperature, light exposure, and pH (Martini et al., 2022; Türkcan & Ökmen, 2012). However, the bioavailability of carotenoids in the body is also significant and is affected by some factors. These factors are classified as intrinsic and extrinsic. Intrinsic factors are dietary factors (plasma vitamin A concentration), presence of fat and fat-soluble micronutrients and food processing methods that may impair the bioaccessibility of foods. Especially among food processing methods, reducing food size and dietary fiber inhibits the absorption of carotenoids by micellization and inactivating pancreatic lipase while increasing the bioavailability and absorption of monounsaturated fatty acids. On the other hand, extrinsic factors include gender, age, presence of disease (hormonal status), lifestyle (drug use, smoking, alcohol intake), pregnancy and breastfeeding, and genetic variations. These factors may affect carotenoid bioavailability and metabolism positively or negatively (Moran et al., 2018). Thus, to increase the bioavailability of carotenoids, nutrition rich in unsaturated fatty acids, and terminal and mechanical treatments that will ensure cell wall degradation are effective (Yao et al., 2021).

This review aims to examine the bioavailability of some carotenoids (lycopene, beta-carotene and lutein) as a result of cooking methods and processes and their effects on health due to heat treatments.

2. Cooking Methods

Cooking is the process of applying controlled heat to foods for specific purposes. By doing so, it increases the value of the food, changes its taste, improves its digestibility and destroys harmful microorganisms. Different cooking methods are available. Traditional methods known as cooking methods are divided into two dry heat and wet heat. Dry heat cooking methods are cooking in a pan with little oil, frying in a pan with oil, frying in plenty of oil, cooking by applying heat from the top, grilling and baking in the oven. On the other hand, cooking methods in aqueous heat are cooking in hot water, cooking below boiling temperature, boiling, steaming and cooking in a small amount of liquid. There are also contemporary cooking methods and techniques. Some of them are sous vide, microwave and bleaching methods (Mutlu & Sandıkçı, 2018). Among the various cooking methods used in studies on carotenoids, boiling method, steaming method, frying, microwave, sous vide, cook vide methods are preferred.

The boiling method is based on the method of cooking foods in cold or hot water. With this method, foods can be placed in cold water and then boiled or cooked directly in boiling water (Mutlu & Sandıkçı, 2018). Steaming is one of the healthiest cooking methods. In this method, foods are cooked with the vapor of boiling water without contact with water (Kasar et al., 2021). The microwave cooking method plays a vital role in heating, cooking, drying and sterilization of foods. Due to the water molecules in the food, the food is cooked as a result of molecular friction by vibrating with the effect of microwaves (Ağagündüz & Bilici, 2016).

The frying method can be divided into pan-frying and deep-frying. Pan frying is done by evenly distributing the heat in a widespread, shallow, thick-bottomed pan. In the process of frying in plenty of oil, it is the method of cooking the foods thrown in oil at 160-180°C by immersing them in oil. Foods are cooked in a short time due to high heat contact (Mutlu & Sandıkçı, 2018).

Sous vide cooking method is a cooking method originated in France. In this method, foods are placed in vacuum bags with evacuated air and cooked in a controlled manner in a low temperature (<100°C) and water environment (Baltalı, 2019). Cook vide cooking method is cooking in <100°C boiling water on a low-pressure cooker without changing the atmospheric conditions (García-Segovia et al., 2007).

3. Cooking Effects on Carotenoid Bioavailability and Health

Consuming high amounts of fruits and vegetables rich in carotenoids (especially β-carotene and lycopene) has been associated with a reduced risk of developing cancer and cardiovascular problems, especially for lung and stomach cancer types. It is also suggested that lutein and zeaxanthin, among the carotenoids, have a protective role against the development of some eye diseases (Toydemir et al., 2022).

Previous studies show that cooking processes, such as microwave heating, canning, and baking, lead to an increase in (Z)-isomers at the expense of (all-E)-carotenoids. Literature data indicate that the consequences of E/Z isomerization are changes in bioavailability and physiological activity. Furthermore, literature data also show that each carotenoid exhibits a distinct pattern of absorption, plasma transport and metabolism. Overcooking may cause a decrease in carotenoid concentrations, which may result from thermal degradation or E/Z isomerization. The concentration of (9Z)/(9′Z)-carotenoid isomers increased with the increase in boiling time throughout the entire cooking process, probably due to E/Z isomerization. It is extremely important to be aware of the significant increase in (9Z)-β-carotene because it has the potential to inhibit tumor progression in humans (Kao et al., 2012). Lycopene bioavailability is lowest in raw sources, slightly increased in lightly processed foods, and highest in heat-processed food sources and purified fatty preparations (Caseiro et al., 2020). It was noted that serum lycopene levels were higher in humans after consuming heat-treated tomato juice but not after unprocessed juice. This enhanced bioavailability of lycopene in processed food has again been attributed to its release as a result of plant cell disruption during mechanical and thermal processing, as well as heat-induced trans-cis-isomerization (Gärtner et al., 1997).

Liu et al. (2004) compared the bioavailability of carotenoids in raw and cooked whole foods using an in vitro simulated gastrointestinal digestion model combined with an in vitro Caco-2 cell culture model. They determined that cooking (15 minutes at 100°C in a water bath) led to significant increases in the bioavailability of carotenoids (Liu et al., 2004). Mild heat treatment has also been suggested to increase carotenoid bioavailability from plant foods by weakening carotenoid-protein complexes and solubilizing cell wall pectin, subsequently softening the tissue. Thus, the absorption of the compounds becomes easier (Toydemir et al., 2022). Orlando et al.

investigated the human plasma bioavailability of β-carotene, lutein, and isothiocyanate after consumption of broccoli subjected to various cooking procedures, including steaming (100% relative humidity, 99°C, 13 min) and boiling (10 min). Lutein and β-carotene levels in serum did not change significantly with consumption of broccoli prepared with different cooking procedures (Orlando et al., 2022).

To predict the in-vivo bioavailability of lycopene and beta-carotene in different processed soups, a study on in-vitro models included 14 participants for study 1 and 72 participants for study 2. Blood samples were also taken from the participants. In study 1, broccoli and carrots were boiled at >85°C and, tomato paste was added and a soup containing 5% olive oil was made at 80°C. Fourteen participants consumed 300 ml/day of soup containing 3.9 mg carotene, 4 mg lycopene and 5% olive oil for four weeks. In study 2, 5% soup was prepared by boiling broccoli, tomato and carrot in a 1:1:1 ratio. Participants consumed reference soup containing 2.5% olive oil and prepared soup containing 5% olive oil for four weeks. The beta-carotene content for the prepared/reference soups was 4.10/2.90 mg and lycopene content was 3.90/2.71 mg, respectively. Carotenoids were determined from the soups by HPLC analysis. An in vitro digestion module was established to determine the bioavailability of carotenoids in soups. Caco-2 (human colon epithelial cells) cell experiments were performed. Micellization fractions of reference and prepared soups digested in vitro were examined. At the end of the model, the carotenoid content in the cells was analyzed within two weeks. The bioavailability ratio was calculated as the ratio between the increase in blood plasma carotenoid levels after consumption of the prepared soups and the rise after consumption of the reference soup. Bioaccessibility was calculated by comparing the number of carotenoids released from the food matrix or incorporated into the micelle phase after in vitro digestion of the prepared soup or uptake in Caco-2 cells with the amounts measured after in vitro digestion. The results of the study showed that both the release from the food matrix and the amount of beta-carotene were higher in the soup prepared after in vitro digestion than in the reference soup. In study 1, lycopene bioavailability was higher than in study 2. This is believed to be because the tomatoes were heat-treated and processed. When the Caco-2 cell uptake level was examined, beta-carotene micellization was higher in the prepared soup compared to the reference soup. Also, serum beta-carotene and lycopene levels increased by 141% and 132%, respectively, in the study 1 group at the end of four weeks. In the study, two groups, serum beta-carotene concentrations increased 139% and lycopene concentrations increased 54% compared to baseline. Consequently, it was concluded that while beta-carotene bioavailability and accessibility increased with easier micellization, more in vitro studies are needed to examine lycopene bioavailability and bioaccessibility (Alminger et al., 2012).

In a study in which corn carotenoids were analyzed by HPLC analysis, three different cooking methods were compared. In the first method, corn kernels boiled at 95C for 15 minutes were cooled and dried with filter paper. In the second method, the corn kernels were mixed into porridge after heating and carotenoids were determined in the cooled form. In the third method, after boiling at 95°C for five minutes, the grains were dried in an oven at 50°C for 48 hours, and tortillas were made. In the study, an in vitro digestion model was created, and the bioavailability of corn kernels was examined by examining micellization and bioaccessibility. According to the results of the study;

- Boiled corn has the highest total carotenoid content.
- Lutein and zeaxanthin content also increased after boiling.
- The carotenoid content of maize increased after heat treatment.
- The carotenoid content of oat porridge decreased by 76% compared to the crude form, and it was thought that this may be due to the exposure of the ground corn kernels to oxidation by air.
- The tortilla retained 78.4% of its raw state, but the beta-carotene content decreased by 0.45. The reason for this is beta-oxidation due to contact with oxygen during the drying process.
- Oxidation may be the main factor affecting carotenoid losses induced by light and heat.
- β-carotene was more sensitive and vulnerable to heat treatment.
- The micellization efficiency (6.66 ± 0.13%) and bioaccessibility (2.36 ± 0.10%) of total carotenoids in boiled kernels were the lowest among the three cooked products.
- The carotenoid in the boiling method is stable until the chewing stage.
- Cooking by grinding increases the bioaccessibility of carotenoids due to dietary fiber breakdown.
- During digestion, the carotenoid content in porridge is lowest in the cone.
- The β-carotene contents in porridge and tortilla were higher than the contents before digestion, indicating that the digestive stability of porridge

and tortilla β-carotene reached 104 ± 11% and 309 ± 63%, respectively.

- β -carotene digestive stability in tortillas increased 309-fold compared to porridge - the washing process removed pericarp and fibers and increased beta-carotene digestive stability
- In boiled kernels and tortillas, micellization efficiency of carotenoids, lutein>beta-carotene (Zhang et al., 2020).

Another study of freeze-dried vegetable snacks examined the bioavailability and bioaccessibility of onions, carrots, parsley and broccoli for carotenoids in in vitro models. A human bioavailability study was also conducted and included 19 healthy participants. The participants were divided into two groups. One group was offered a 75-gram snack while the other group was offered a comparator cooked vegetable meal. After consuming the test meals, blood and urine were analyzed to measure the bioavailability of the nutrients. In the study, the target dose for measurable levels of beta-carotene in plasma 15 mg. To reach the target, the vegetable contents of the products were 10.5% broccoli, 27.6% onion, 56.9% carrot and 5% parsley. While creating the snacks, three different processes were followed.

i. Combining freeze-dried broccoli, carrots and onions with flash-frozen parsley and cook in a hot air oven
ii. Cooking all flash-frozen vegetables in a hot air oven
iii. Combining frozen and microwaved broccoli, onions and carrots with frozen and baked parsley, cooked in the microwave and dried in the oven

Snacks that passed through the three processes were combined in different concentrations. Beta-carotene contents were 10.3 mg/100 grams in freeze-dried products, 2 mg/100 grams in frozen products and 5.7 mg/100 grams in freeze-microwave products. An in vitro human digestion model was established to determine bioavailability and bioaccessibility. According to the study results, the beta-carotene content in the dough content before cooking decreased after cooking. In the in vitro digestion model, there was no detectable beta-carotene content released from the food matrix in the snacks and vegetable dishes, while the lutein content was 0.4 mg. Based on fasting blood samples, plasma beta-carotene levels fluctuated between 13.6-447.9 nmol/L and 24.7-516.1 nmol/L in both groups after consumption of the test meal. The reason for this was thought to be transport from endogenous fat stores reflecting habitual carotenoid intake (Perez-Moral et al., 2018).

In a study on lutein and beta-carotene liberation and in vitro bioavailability of spinach after different treatments; the results of pureeing, steaming and oil addition were examined to improve carotenoid release. 75 grams of spinach leaves were steamed at 100°C for three minutes with the addition of 2.5 grams of oil (olive oil, butter, or peanut oil). The comparison of fresh spinach and cooked spinach leaves was made. Oral phase, gastric phase and intestinal phase were established with an in vitro digestion model. In the study, a decrease in both carotenoid types was observed due to steaming, with or without the addition of oil. It is thought that this is due to the oxidation and degradation of carotenoids as a result of steaming. However, in pureed spinach, no change was observed in both carotenoid types as a result of steaming. Nevertheless, lutein and beta-carotene in pureed and cooked spinach leaves were found to have higher release from the food matrix (minimum and maximum values of beta-carotene and lutein in raw state; 2.7-4.3, 6.3-8.1, 9-13.7, 21.7-25 in cooked state) and in vitro bioavailability (2-3.5, 5.3-6.4, 5.6-6.2, 16.8-21.7 in cooked state) compared to raw spinach leaves in both states with/without the addition of oil. This suggests that the chewing factor is one of the main factors affecting bioavailability through a decrease in tissue particle size. Following oil addition, lutein release and in vitro bioavailability decreased, while the opposite effect was observed for beta-carotene. In particular, as a result of the steaming process with the addition of oil, it was observed that there was a 35% increase in release compared to the raw state (Eriksen et al., 2017).

In a study in which the carotenoid bioavailability was evaluated in in vitro models as a result of different thermal processes applied on tomatoes, two different blanching processes were performed. The first blanching process lasted four minutes at 90°C and the second blanching process lasted 40 minutes at 60°C. Pre-bleaching process was applied. In addition, an in vitro digestion model was established to examine bioavailability. According to the results of the study, a significant decrease in beta-carotene was observed as a result of heat treatment, while lycopene remained relatively stable. According to the results of the in vitro digestion model, lycopene bioavailability rates increased from 5.1 mg/kg to 9.2 mg/kg at low temperature, while this rate was 9.7 mg/kg at high temperature (Svelander et al., 2010).

In a study on the effect of different heat treatments on the in vitro bioavailability of lycopene in tomato, microwave heat treatment and high-pressure homogenization were applied at 70, 90 and 120°C for

20 minutes. Three different 5% oils (coconut oil, fish oil, olive oil) were also added. An in vitro digestion model was established. No significant difference was found regarding bioavailability in the in vitro model in high pressure/no pressure and with/without oil addition. Among the three different microwave heat treatments applied, the total bioavailability rate increased only at 120°C. This was explained by the increase in micellization with the disruption of the cellular structure. In addition, lycopene bioavailability increased by increasing micellization in the function of heating at 70 and 90°C with 5% oil addition (Colle et al., 2013).

In a study on the bioavailability of lutein and zeaxanthin in vitro after boiling seven different types of yellow-fleshed potatoes, potatoes were boiled for 20-25 minutes and then frozen at -70°C. An in vitro digestion model was established to examine bioavailability. The lutein and zeaxanthin concentrations of undigested samples varied between 65.4-395 mcg/100 g and 51.1-1196 mcg/100 g, respectively. In the in vitro digestion model, lutein and zeaxanthin concentrations decreased during the digestion stages and showed the least stability in the gastric environment. The digestive stability of both carotenoids in the duodenum was high, ranging between 70-95% (Burgos et al., 2013)

In a study investigating the relationship between different cooking methods of broccoli and the health of human subjects, three male and four female participants aged 25-35 years with a BMI of 18.5-25 kg/m2 participated. In the study, broccoli was frozen at -20°C for 15 days before cooking. The effects of boiling for 10 minutes and steaming at 99°C for 13 minutes on carotenoid contents were compared. Simultaneously, the participants followed a cleansing diet for at least two weeks and then took 400 grams of broccoli or three capsules of BroccoMax supplement in the morning on an empty stomach. Blood samples were then analyzed. According to the results of the study, lutein and beta-carotene were 0.37mg /100 g in raw broccoli. Beta-carotene content increased 3.3 times as a result of boiling method and 0.9 times as a result of steaming method compared to its raw state. Lutein increased 2.4 times after boiling method and 1.3 times after steaming method. The reason for this effect was observed to be the tissue softening event triggering the release of matrix components with boiling. However, no difference was observed between blood plasma carotenoid levels in both cooking methods (Orlando et al., 2022).

In a study with three men and nine women aged 25-48 years, the effect of bioavailability of different tomato purees on blood values in humans was examined. The participants were divided into two groups. The first group received Rustic tomato puree (32 kcal, 6 grams CHO, 1.1 dietary fiber) and the second group received strained tomato puree (26 kcal, 4.6 grams CHO and 0 grams fiber). The tomato purees were boiled for 30 minutes and frozen at -20°C before consumption. Participants were given 500 ml of water and 150 grams of tomato puree accompanied by five slices of white bread. At the same time, fasting blood was taken from the participants and blood samples were taken again at two, four, six and 24 hours after the test meal. Following the procedures, it was observed that strained tomatoes had higher concentrations of trans- and 5-cis-lycopene isoforms than rustic tomatoes. At the same time, lycopene and beta-carotene concentrations increased as a result of 10, 20, 30 and 40 minutes of boiling, cooking time and olive oil addition. When lycopene plasma concentrations were analyzed in the participants, trans lycopene concentration in the group consuming strained tomato puree exceeded basal levels two hours after food consumption compared to the other group. In the group consuming rustic tomatoes, an increase in lycopene levels was observed two and four hours after meal consumption. In conclusion, an increase in the bioavailability of lycopene was observed with the addition of olive oil and an increase in the cooking process (Vitucci et al., 2021).

Daniella tomatoes (Licopersicon esculentum Mill. cv) were treated with olive oil at 95-96°C at two different concentrations, 5% and 10%. The tomato was cooked for 15, 30, 45 or 60 minutes. The amounts of 13-, 5- and 9-(Z) lycopene increased by 31%, 18% and 15% in the tomato sauce obtained after cooking. In addition, 85.5 mg/kg in the form of all-E lycopene and 85.5 mg/kg in the form of all-E lycopene as a result of the addition of 5% olive oil in the cooking process for 15-30 minutes. As a result of the addition of 10% olive oil, it increased by 140.09 mg/kg. The findings obtained in the study suggest that as a result of this increase in carotenoid levels, lipid peroxidation may decrease, HDL may increase, and as a result of these effects, the incidence of chronic neurodegenerative diseases, such as cancer and cardiovascular diseases, may decrease (Vallverdú-Queralt et al., 2015).

In a study that investigated the changes in carotenoid concentrations of fresh leaves of Spinacia oleracea (oriental spinach) as a result of frying and non-frying process; the leaves were fried in 500 grams of sunflower oil at 250°C for 15, 30, 45 and 60 minutes. As a result of frying, the amount of beta-carotene increased from 1.44 mg/100 g to 6.64 mg/100 g. All-e-lutein content increased from 19.1 mg/100 g to 37.5, 44.2, 47.8 and 50 mg/100 g at 15, 30, 45 and 60 minutes, respectively (Zeb & Nisar, 2017).

A study examined the changes in blood lycopene concentrations of cooking and fresh forms of tomatoes in nine men and nine women aged 25-75 years; crushed tomatoes, crusted tomatoes with olive oil added and cooked tomatoes with olive oil added were compared. Blood samples were taken from the participants. The results of the study showed that blood lycopene levels increased less in crushed tomatoes (0.17 mmol/L) than in tomatoes with added olive oil (0.21 mmol/L). Cooked and olive-oil added tomatoes showed an increase in blood lycopene levels. Age and gender did not play a role in the effect on plasma lycopene levels (Perdomo et al., 2012).

4. Conclusions

Common cooking techniques include boiling, microwaving, frying, and steaming. It can enhance flavor, neutralize anti-nutritional compounds and toxic substances by softening the food matrix after foods are cooked. However, cooking may or may not affect the bioavailability of carotenoids. While some studies suggest that carotenoid contents increase after cooking, others have shown a detrimental effect on these compounds. These variable results may depend on the cooking method applied, the duration of heat exposure, and the type of food used in cooking. Carotenoid contents differ according to various factors, such as food type, seasonality, variety, maturity level, processing, storage conditions and climatic conditions. However, some factors increase or decrease the bioavailability of crude amounts of carotenoid concentrations in foods. One of them is heat treatment, which may decrease or increase according to the type of carotenoid. It was observed that there were changes in the bioavailability of lycopene, lutein and beta-carotene carotenoids in the body as a result of heat treatments, such as boiling, microwave, frying, steaming, sous vide and cook vide. According to the results of in vitro studies investigated various vegetables and fruits with the effect of exogenous factors as a result of the literature review, it was observed that the bioavailability increased as a result of the addition of oil, increase in lycopene processing, decrease in food particle size, increase in micellization with the breakdown of dietary fibers, and destruction of cell walls with heat treatment. Besides, the addition of olive oil with heat treatment and the decrease in food particle size had positive effects on health by transforming carotenoids into forms with high bioavailability in the body.

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): *Study design, Methodology, Draft preparation, Critical review, Final approval.*

İ. Helvacıoğlu (0000-0002-7741-2324): *Literature review, Writing.*

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