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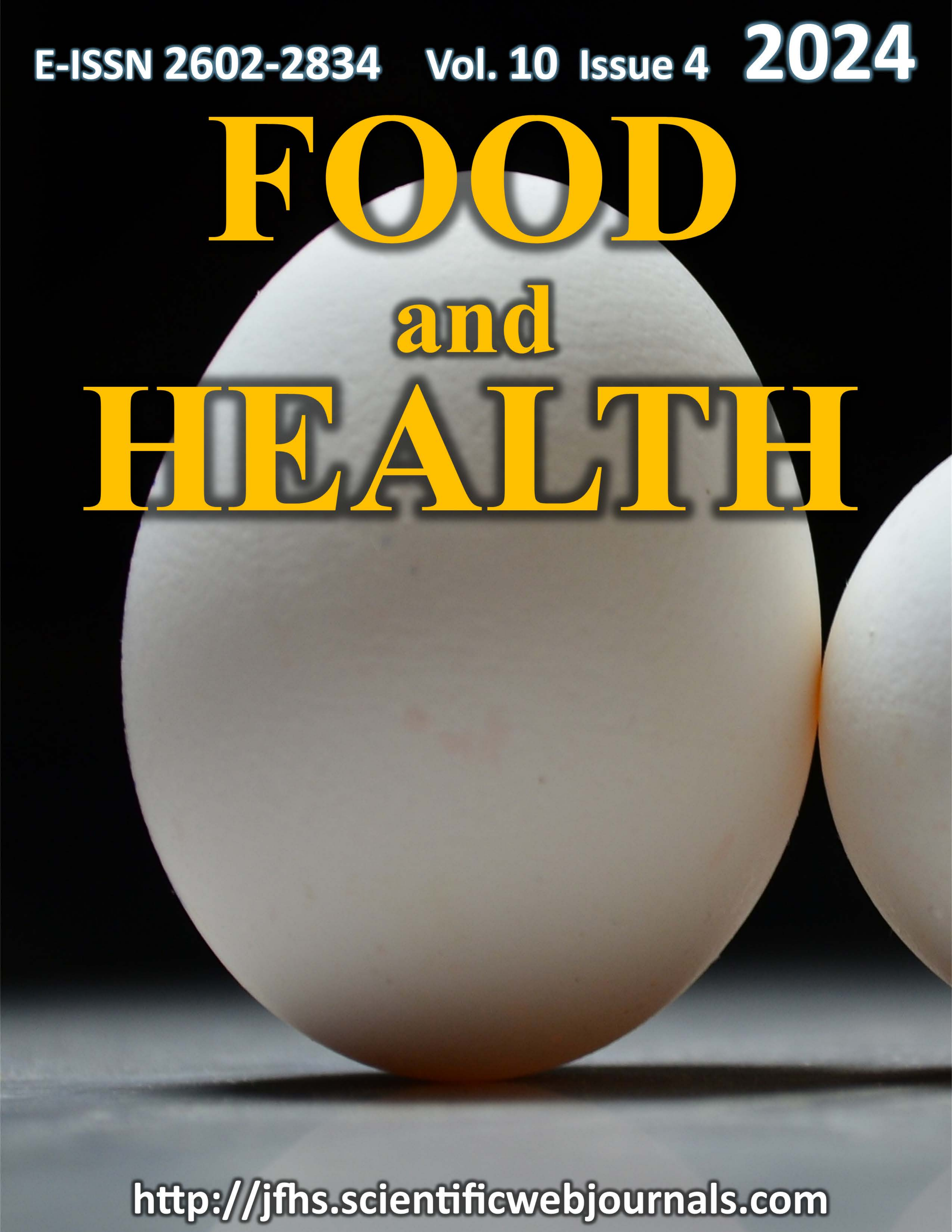
# FOOD and HEALTH



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FOOD and HEALTH

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## Aims and Scope

### FOOD and HEALTH

Abbreviation: **FOOD HEALTH**

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**"Food and Health"** journal will publish peer-reviewed (double-blind) articles covering all aspects of **food science and their health effect** in the form of original research articles (full papers and short communications), and review articles. Their team of experts provides editorial excellence, fast publication processes, and high visibility for your paper.

Food / Seafood / Food Technology / Food Chemistry / Food Microbiology/Food Quality/Food Safety/Food Contaminant / Food Allergen / Food Packaging / Modified Food / Functional Food / Dietary Supplements / Nutrition and their health effect is the general topics of the journal.

Manuscripts submitted to the "**Food and Health**" journal will go through a double-blind peer-review process. Each submission will be reviewed by at least two external, independent peer reviewers who are experts in their fields in order to ensure an unbiased evaluation process. The editorial board will invite an external and independent editor to manage the evaluation processes of manuscripts submitted by editors or by the editorial board members of the journal. Our journal will be published quarterly in English or Turkish language.

The journal's target audience includes specialists and professionals working and interested in all disciplines of food and Nutrition Sciences.

The editorial and publication processes of the journal are shaped in accordance with the guidelines of the International Committee of Medical Journal Editors (ICMJE), World Association of Medical Editors (WAME), Council of Science Editors (CSE), and Committee on Publication Ethics (COPE), European Association of Science Editors (EASE), and National Information Standards Organization (NISO). The journal is in conformity with the Principles of Transparency and Best Practice in Scholarly Publishing (doaj.org/bestpractice).

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# Content

## Research Articles



## Review Articles

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Research Article

# Physical changes in hen eggs stored at different temperatures

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**ABSTRACT**

Eggs are among the most nutritious foods, but they are perishable. Immediately after they are laid, ageing processes begin in shell eggs, altering their chemical, physical and functional properties. This study aimed to determine the effect of storage temperature on the shelf life of hen eggs according to changes in some important physical properties (weight, pH, Haugh Unit, Albumen Index, and Yolk Index). The studied temperatures were selected as possible refrigerator and room temperatures (10, 20 and 30°C). It was revealed that temperature significantly influenced egg quality, with the most significant effects observed in the Haugh unit and pH due to weight changes. The highest quality loss occurred at 30°C. The activation energies for each quality parameter were determined using the Arrhenius equation. The pH of the fresh egg was 7.6 ± 0.1 and increased to over 8.5 – 9.0 during storage, depending on the temperature. Haugh unit, albumen index, and yolk index decreased, and the area of both yolk and albumen increased during storage.

**Keywords:** Hen egg, Temperature, Physical properties, Shelf life, Egg quality

## Introduction

The egg is a kind of important animal protein resource obtained from fowl. There are different egg types, such as duck, bird and turkey. However, in Codex Alimentarius, egg refers to common hen eggs, which are easier to produce and more nutritious. Hen eggs contain high-quality protein, important vitamins, and minerals (Afacan, 2023). The product comprises 65.6% water, 12.1% proteins, 10.5% lipid, 0.9% carbohydrates and 10.9% minerals. Chicken eggs are used as the basic ingredient in many products due to their high nutritional value and multifunctional properties, such as emulsification, foaming, gelling, thickening and flavouring, which improve the textural and sensory development of foodstuffs (Rossi et al., 2010). Egg composition may vary, not only in terms of genetic heritage but also in the chicken's feeding method. Housing conditions are another factor that affects this. Egg composition may vary depending on the hen's feeding method and genetic heritage. Housing condition is also another factor that affects the egg structure. The determination of shelf life and its relation to storage temperature is important. In order to determine shelf-life, the most important parameter has to be selected. There are some useful methods to determine the change in the quality of eggs' external and internal qualities. Chemical (protein content, lipid content, and solid content) and physical (colour, weight of egg, and height of albumen) are the most commonly used. In addition, the age and breeding environment of the hen have an important impact on the level and quality of egg components (Suk & Park, 2001). Traditional cages, free range and barns are examples of breeding methods for chicken animals. Instead of using standard feed for their chickens, some egg producers prefer to supplement the feed with chia seeds, fish oil, etc., to increase their nutritional value. In addition to this housing system, they have been feeding supplemented with several nutrients (such as chia, fish oil, flaxseed, and grape pomace) to improve the nutrition level (such as omega 3 fatty acids) of the egg (Sherwin et al., 2010; Kara et al., 2016). Also, egg quality can be affected by environmental conditions such as humidity, temperature and storage times (Akyurek & Okur, 2009). The good quality of the egg still corresponds to the consumer's expectation. Knowledge of typical egg structure, good quality characteristics, and deterioration stages is necessary for effective egg quality parameter testing. On the other hand, knowing the effect of shelf life and temperature on food structure is necessary. Environmental conditions on the farm, in the warehouse and at home become important in deciding which process features to apply (Feddem et al., 2017).

Studies in the literature have examined the impact of storage duration on hen egg quality. However, the other most important parameter, storage temperature efficiency, has not been examined in detail. Therefore, the main objective of this research was to investigate the effect of three different storage temperatures on the shelf life of the egg according to changes in physical properties.

## Materials and Methods

One of the most important preference parameters when choosing the eggs used in this study was their freshness. Therefore, 150 freshly laid chicken eggs were supplied simultaneously from a previously informed local farm in Gaziantep. The laying hen was kept constant to ensure the homogeneity of the eggs used in the study (*Gallus gallus var. domesticus)*. Bought eggs were rested in the room until they reached room temperature. After the suitable temperature was reached, the surface of the egg samples was checked for cracks, contamination or foreign matter and the defective ones were separated. Intact eggs were grouped according to weight and size differences. As a result, 130 eggs were used as the representative samples for analyses. The selected temperatures were possible for refrigerator and room temperatures, such as 10, 20, and 30 °C. At each temperature condition, samples were divided into two lots (30 eggs for each lot); weight and colour changes of the same eggs in the first lot were followed periodically. The five eggs from the second lot determined the other physical characteristics for each test time. All chemicals used were reagent grade.

### *Weight Change Determination*

Firstly, the egg samples were equilibrated at room conditions. After that, their initial weight values were recorded. Ten eggs were numbered and placed at three instead four different temperatures (refrigerator's door temperature (10°C), incubator (20°C), and incubator (30°C)) to test their weight changes (Feddern, 2017). The selected storage temperatures were determined by considering the conditions of commercial sales places. A precision balance (Precisa, 163 XB 220A, Dietikon, Switzerland) was used to weigh the egg samples periodically.

### *Colour Determination*

The eggshell colour was measured from the same side of the samples, and a Hunter Lab Color Flex (A60-1010-615 Model Colorimeter, Hunter Lab, Reston VA) was used for detection. The L (Lightness), a (redness) and b (yellowness) values of the samples were obtained with the CIE Lab colour scale, and the average value of three readings was reported.

### *Changes in pH, Weight, Area and Height Determination*

Five trials were conducted for each temperature group. An apparatus was set up using a precision balance to determine the weight change of shell eggs, whole eggs, whites and yolks. A glass material (190 x 190 mm) was put on the balance and calibrated with a spirit level. The board was placed in front of the balance to stabilize the height and distance of the photo taken. Lastly, the mechanism consisted of a small box that displayed the height during the image analysis process. At first, glass was put on the precision balance and tare weight was taken. Once the shell was weighed, it was carefully broken on plate glass, preserving the membranes between the yolk and white. After five minutes, a picture of the eggs was taken using a digital camera (Kodak, EasyShare, C713). The weight of the whole egg was then recorded. Both front and top photographs of the whole egg were taken to measure the height of the yolk and the area of the yolk and white. A pH meter (Eutech, EcoScan) was used to test the pH of the whole egg (Afacan, 2023). Before pH measurement, the egg yolk and white were mixed with a magnetic stirrer until they became completely homogeneous. The area and height of the yolk, and also an area of the albumin values, were detected by image analysis software (UTHSCSA Image Tool for Windows, Version: 3.00). A pin box was placed near the whole egg and photographs were taken to obtain the height of the egg yolk. System calibration measurement (from pixels to millimetres) was made by taking the initial height value of the box. The defined program determined the yolk height. A similar system was utilized to measure egg yolk and albumen areas. In this stage, the flat glass, which the egg was broken, was the material and its length was measured. Calibration from pixel to millimetre was done using the predetermined value. Then, the albumen surface, which spread on the flat glass, was pointed. When marking was made to create a closure, the program automatically calculated the albumen area. The same steps were applied to yolk area calculations.

### *Haugh Unit and Other Parameters*

The Haugh Unit shows the internal quality of the egg. This approach was a correlation of albumen quality between the height of the thick albumen (in millimetres) and the weight of the egg (in grams) (Akyurek, 2009; Kirikçi et al., 2003). The Haugh Unit equation was given as follows:

Haugh Unit (HU) = $(100 \log (h - 1.7w^{0.37} + 7.6))$ (1)

Where h shows the height of the albumen (mm), and w is the weight of the egg (grams).

Equations 2 and 3 were used to calculate albumen and yolk indexes, respectively:

Albumen index (%) =

((height of the albumen / diameter of the albumen) x 100) (2)

Yolk index (%) =

((height of the yolk / diameter of the yolk) x 100) (3)

### *The Shelf Life and Activation Energy*

By definition, a product's shelf life is the amount of time it can remain on the store shelf without any negative reaction from the consumer (Labuza, 1982). Egg quality parameter changes were found to obey zero order rate expression:

$$A = A_0 - kt \quad (4)$$

Where "A" refers to the amount left after the time of t, "$A_o$" refers to initial quality, k is the rate constant and " t" refers to time. If the A is selected as the endpoint, t is to be shelf-life. It is explained in the literature that the steeper the slope, the more sensitive it will be to temperature fluctuations.

Arrhenius type equation can be used to determine temperature-dependent degradation reactions, given as:

$$k = k_o e^{-EA/RT} \quad (5)$$

Where ko is the pre-exponent constant, EA is the activation energy (cal/mole), R refers to the gas constant (1.987 kcal / (mole) (K)), and T refers to temperature (K). ln (k) values of each parameter determined were drawn concerning the inverse of absolute temperature (1/T); the activation energies were calculated from the slopes of these lines since the slope is equal to $-E_A/R$.

### *Statistical Calculation*

Analysis of variance (ANOVA) was performed using SPSS software (v.15.0.0) to investigate some parameter effects (temperature and time) on the Haugh unit, weight change, and pH of the egg. A univariate linear model was utilized, and the Tukey multiple comparison test was selected as a post hoc test.

## Results and Discussion

### *The Results of Egg Weight Change*

Figure 1 shows the weight change determinations of the analyzed samples at three different storage temperatures. According to the results, it was determined that there was an inverse proportion between egg quality and egg weight. This means that the rate of weight loss increases with the increase in storage temperature. In the study, it was understood that the highest weight loss was detected in egg samples placed at the highest temperature (30°C), as seen in Figure 1. The main reason for the loss of not only weight but also quality of eggs is the loss of $CO_2$ and $H_2O$ through the shell pores (Suk & Park, 2001). The weight change continues on the market shelf, and after a while, the egg becomes stale, and the product reaches the end of its shelf life. Therefore, one of the most important quality parameters determining eggs' shelf life can be expressed as weight loss.

### *Colour Change of the Egg Shell*

This research investigated changes in colour properties during storage to determine whether there is a relationship between eggshell colour and the shelf life of hen eggs. The L (Lightness), a (redness) and b (yellowness) values of the studied egg samples stored at 10, 20 and 30°C are given in Table 1. It was observed that the "L value" had a decreasing tendency during the storage period. This behaviour caused the final colour of the eggshells to be darker than the initial colour. Similarly, the other colour parameters of "a" showed a decreasing trend with increasing storage time. This means that the last colour of the egg changes from reddish to greenish. However, the "b value" showed an unstable change during the storage period.

### *Determination of Haugh Unit*

Haugh unit (HU) is the most useful data for estimating egg freshness (Ahmadi & Rahimi, 2011). The variation of HU at 10°C, 20°C and 30°C was determined and given in Figure 2. The observations showed that a steady decrease in HU occurred during storage. HU is the correlation between egg weight and the height of the albumin. Therefore, this situation can be expected. In this study, it was understood that if the eggs were to be stored for a longer period of time, they would continue to lose weight. Similar trends were observed in the literature (Kahraman Dogan and Bayindirli, 1996). The decomposition rate constants (k) for each storage temperature were calculated from the line slopes and demonstrated in Table 2. The highest storage temperature (30°C) was found to have the highest k value in direct proportion. After 20 days of storage at 30°C, the acceptability of egg samples was lost due to the highest rates of white height and weight decrease. A decrease in the strength of the yolk vitelline membrane and the inner shell membrane can relate to this decreasing trend in white height. Another reason was the increase in the viscosity of the egg yolk (Karoui et al., 2006). The increase in the moisture content of the yolk explained these situations.

**Table 1.** Colour change of egg samples at 10, 20 and 30°C

| Time (day) | 10°C | | | 20°C | | | 30°C | | |
|---|---|---|---|---|---|---|---|---|---|
| | L | a | b | L | a | b | L | a | b |
| 0 | 46.67 | 0.20 | 1.25 | 50.87 | 0.30 | 2.13 | 49.06 | 0.20 | 1.76 |
| 4 | 47.57 | 0.23 | 1.26 | 50.94 | 0.24 | 2.65 | 49.45 | 0.10 | 1.78 |
| 6 | 47.52 | 0.22 | 1.81 | 51.07 | 0.19 | 1.90 | 50.10 | 0.03 | 1.87 |
| 9 | 47.57 | 0.24 | 2.86 | 50.99 | 0.20 | 2.31 | 49.55 | 0.06 | 3.14 |
| 12 | 47.98 | 0.17 | 1.28 | 51.31 | 0.15 | 2.18 | 49.89 | 0.01 | 1.59 |
| 14 | 47.99 | 0.20 | 1.14 | 51.66 | 0.17 | 2.44 | 50.12 | 0.02 | 2.48 |
| 16 | 48.02 | 0.19 | 1.32 | 51.23 | 0.16 | 2.77 | 50.18 | 0.02 | 2.27 |
| 19 | 47.79 | 0.16 | 1.32 | 51.16 | 0.15 | 1.81 | 50.07 | -0.01 | 1.98 |
| 21 | 48.02 | 0.13 | 2.32 | 50.93 | 0.13 | 2.06 | 50.12 | -0.03 | 2.05 |
| 23 | 47.71 | 0.15 | 1.63 | 51.28 | 0.13 | 1.93 | 49.83 | -0.03 | 2.00 |

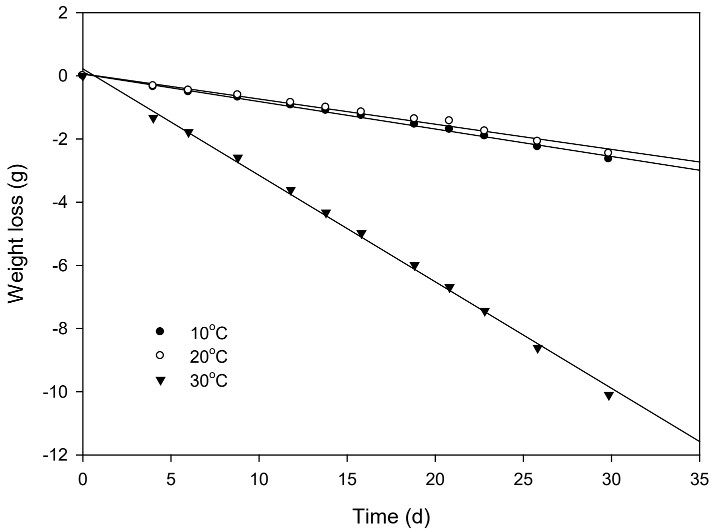


**Figure 1.** Weight loss of egg samples stored at 10, 20 and 30°C

**Table 2.** The deterioration rate constants (k) for quality parameter change at the studied temperature range

| Quality parameters | Storage temperature°C | | |
|---|---|---|---|
| | 10 | 20 | 30 |
| Weight Change (gr) | 0.086 | 0.199 | 0.335 |
| Haugh Unit | 0.076 | 0.533 | 2.201 |
| pH | 0.019 | 0.030 | 0.048 |
| Albumen Area ($mm^2$) | 159.433 | 297.060 | 465.456 |
| Yolk Area ($mm^2$) | 5.334 | 12.697 | 99.340 |
| Albumen Index | 0.105 | 0.416 | 0.487 |
| Yolk Index | 0.074 | 0.512 | 1.508 |

### *Determination of pH*

The pH results of the studied egg specimens are illustrated in Figure 3. The pH value of fresh eggs was 7.6. During storage of shell eggs, pH increased to a maximum of around 8.2. Close values were reported by Karauri et al (2006), but the authors only investigated the pH of egg white in their study (Karoui et al., 2006). The eggshell can breathe, meaning this material is moisture and gas (carbon dioxide) permeable (Caner, 2005). When carbon dioxide gas is released from the egg, the acidity in the egg matrix decreases. Additionally, the evaporation of water from the eggshell surface due to pores reduces acidity. Deterioration rate constants according to pH changes are shown in Table 2. As the storage temperature increased, gas solubility decreased, and the water evaporation rate increased. Increasing constants with increasing storage temperature indicate an increase in quality loss. It was seen that deterioration rate and quality loss reached the highest values at 30°C (Table 2). However, a non-linear pH increase was detected. Albumin buffering ability against pH changes is the weakest and appears to rapidly increase in the first few days of storage, as reported by other researchers (Karoui et al., 2006).

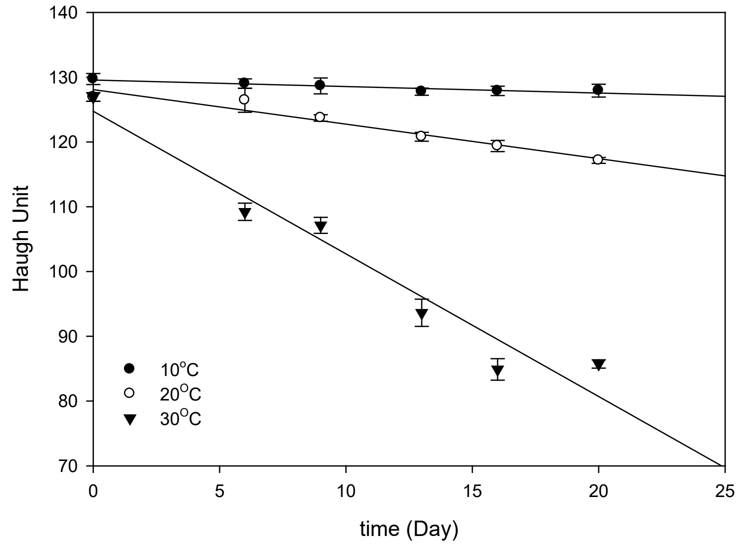


**Figure 2.** Haugh unit results of the egg samples stored at 10, 20 and 30°C

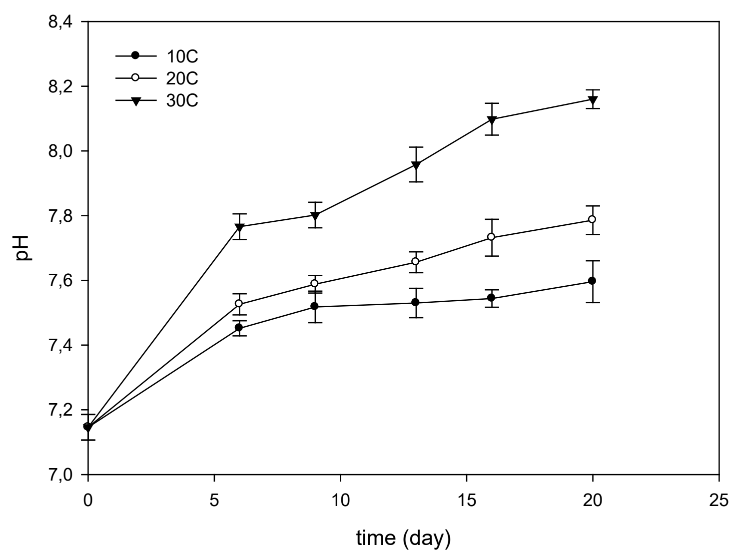


**Figure 3.** pH changes of egg samples stored at 10, 20 and 30°C

### *Area Change Results of the Egg Albumen and Yolk*

When a stale egg is cracked, the yolk flattens out, usually gathering on one side, and the thick albumin around it thins out, causing a large area of albumin to collapse and flatten, forming a wider arc of liquid (Egg, 2000). Area variations of egg white and egg yolk samples were examined and shown in Figures 4 and 5, respectively. Degradation rate constants for albumin and yolk areas, determined using the zero-order rate equation, are tabulated in Table 2. Another study also detected the same increasing results for albumin (Karoui et al., 2006). The rate of increase was directly proportional to the temperature change. The highest degradation rate was recorded at a storage temperature of 30°C in both the albumin and yolk areas.

### *Albumen Index and Yolk Index Determination*

After the egg was broken on a flat surface, the albumin and yolk index were determined and graphed using the height and diameter of the albumen and yolk (Figure 6 - 7). Both white and yolk indexes had a decreasing pattern. This may be attributed to the inverse relationship between index values and yolk and albumin area during storage. However, there was a direct proportionality between yolk and albumin height and index values. Similar observations were also stated by some other authors (Kahraman Dogan and Bayindirli, 1996).

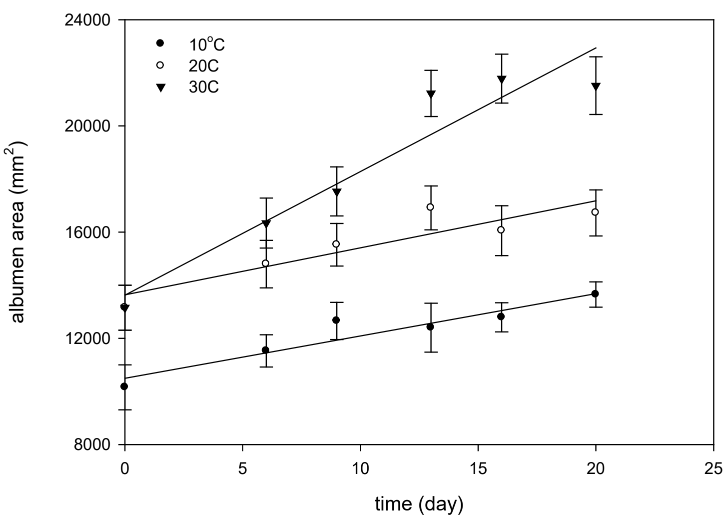


**Figure 4.** Changes in albumen area of egg samples stored at 10, 20 and 30°C

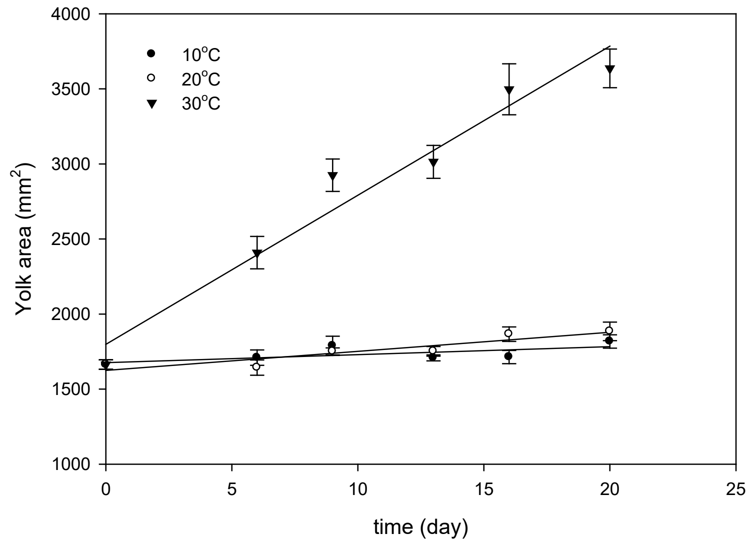


**Figure 5.** Changes in the yolk area of egg samples stored at 10, 20 and 30°C

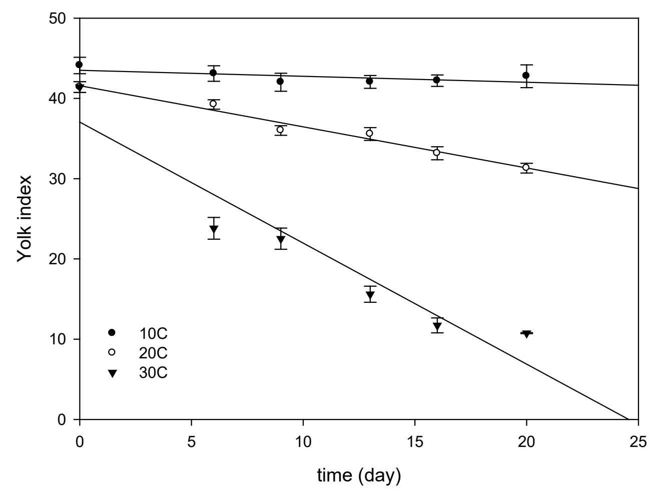


**Figure 6.** The yolk index of egg samples at 10, 20 and 30°C

### *Temperature Effect on Egg Quality*

First, the natural logarithms of the rate constants were plotted against the inverse of absolute temperature, and then the straight-line relationship gave an Arrhenius-type behaviour. Table 3 shows egg samples' calculated activation energies (EA) for different quality parameters (weight change, Haugh Unit, pH, albumen and yolk area, albumen and yolk index). In the literature, activation energy is defined as the evaluation of the sensitivity of foodstuffs to temperature (Labuza, 1982). It was determined that the sensitivity of egg quality parameters to temperature decreased in the order of Haugh Unit, yolk index and area, white index and area, pH and weight. Haugh Unit is the most sensitive among all these because Haugh Unit is a relationship between the weight of the eggshell and flux height; also, both parameters are affected by storage temperature. Egg yolk is more affected by temperature changes than white. This may be due to the higher solids concentration in the egg yolk. Therefore, as the egg ages, water enters the white, causing the yolk to increase in size and become less viscous.

**Table 3.** Calculated activation energies of the egg samples at each test parameter

| Quality Parameter | Activation Energy (kcal/mole) | $R^2$ |
|---|---|---|
| Weight Change | 3190.630 | 0.921 |
| Haugh Unit | 48467.396 | 0.933 |
| pH | 7472.829 | 0.996 |
| The Area of Albumen | 9136.013 | 0.994 |
| The Area of Yolk | 24776.768 | 0.938 |
| Albumen Index | 13216.958 | 0.841 |
| Yolk Index | 25722.170 | 0.979 |

($R^2$: coefficient of determination)

### *Shelf-life Determination Due to Different Quality Parameters*

Two important parameters were determined according to the temperature dependence on the activation energy. Haugh unit is the most sensitive parameter to temperature (Kemps et al., 2006; Kul & Şeker, 2004). Yolk index, yolk area, albumen index, and albumen area are the next sensitive parameters after the Haugh unit. However, when the indices and Haugh unit parameters were checked, the same parameter, height, was observed. Therefore, if the Haugh unit is chosen as a shelf-life determination parameter, the area, height, and weight values should be considered simultaneously. Since pH is an important indicator of egg deterioration (Kemps et al., 2006), the changes in pH values were chosen as the second important parameter for measuring the egg's shelf life.

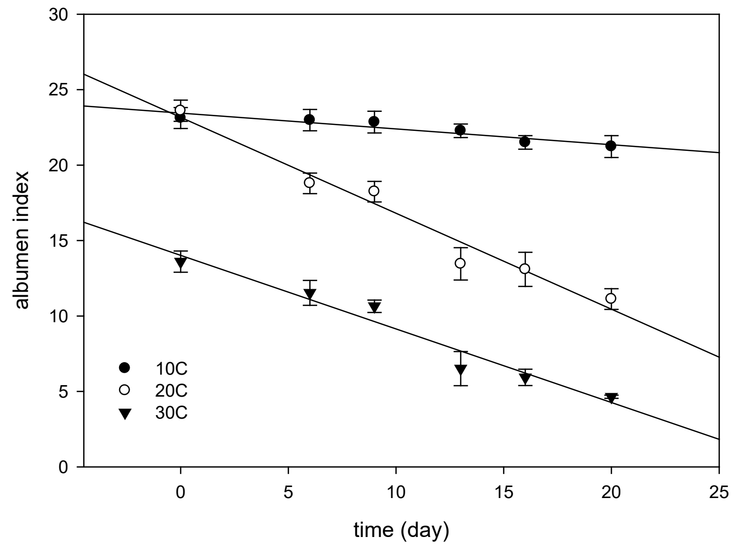


Figure 7. Albumen index of egg samples at 10, 20 and 30°C

If the end of the experiment is considered the end of the consumer's acceptance of the egg, the remaining quality parameters appear to be different in percentage. In order to decide the shelf life, an endpoint value must be assigned. Since there was no criterion for any egg quality parameter or egg shelf-life determination, it was assumed that 14% of the Haugh unit values were lost and 86% remained. For the case of pH value, a similar approximation was used also. Hence, the final quality parameter "A" in Equation 4 for the Haugh unit can be considered as "0.86Ao", and the final quality parameter "A" for the pH parameter can be considered as "(1/0.86) $A_o$". Because the samples' pH increased during storage, the highest pH value for our sample was calculated as 8.3 (≈ 7.14*1/0.86) and used in the calculation of values in Table 4. The shelf life of the egg samples at different temperatures was determined by substituting the new values obtained into the expression of the zeroth order ratio (Table 4-A). It was found that according to the Haugh Unit, at 10°C, the shelf life of the egg studied was found to be 238 days (Table 4-A). It was questionable to accept. Hence, it is clear that the most important step in shelf-life estimation for any food is assigning the most important parameter that must be followed and then assigning an endpoint at which the food is no longer acceptable. Then, instead of 0.86, 0.90 was inserted in the calculations, and the obtained shelf-life values were also listed in Table 4-B. It was found that a change from 0.86 to 0.9 caused such a huge change in shelf life.

**Table 4.** Calculated shelf-life values of the eggs using changes in Haugh Unit and pH values at 10, 20 and 30℃

| | Shelf life (d) | | | | | |
|---|---|---|---|---|---|---|
| | A Temperature (℃) | | | B Temperature (℃) | | |
| | 10 | 20 | 30 | 10 | 20 | 30 |
| Haugh Unit | 238.9 | 28.9 | 6.9 | 167.2 | 24.3 | 5.9 |
| pH | 58.3 | 38.7 | 24.2 | 38.2 | 25.3 | 15.8 |

## Conclusion

In this study, the following results were obtained by investigating egg quality parameters, their temperature sensitivity and egg shelf life: It was understood from the results that as shell eggs age, significant physical changes occur in the yolk, white, egg weight and shell colour. During the ageing process, the flocked area and pH of the whole egg increased, while the weight and flock height of the shell egg decreased. Some of the egg quality parameters, such as egg weight, pH, Haugh Unit, colour, white area and white height, showed zero order of degradation kinetics. Lightness (L) and redness (a) can indicate colour quality. While HU was found to be the most sensitive parameter to temperature, weight change was the least affected parameter. It has been understood that pH is an important parameter in determining shelf life. Egg shelf life decreased as the storage temperature increased. In order to estimate shelf life, especially for perishable food products, the most critical step is defining the value of the deterioration mechanism causing food not to be consumable. Any misleading in the calculation will cause either the loss of food itself, though it still has value, or the loss of food safety.

### Compliance with Ethical Standards

**Conflict of interest:** The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** The authors declare that this study does not include experiments with human or animal subjects, so ethics committee approval is not required.

**Data availability:** Data will be made available on request.

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**Disclosure:** -

## References

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Research Article

# The relationship between dietary polyphenol intake and adherence to the Mediterranean diet, mental health, and sleep quality among Turkish adults: A cross-sectional study

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## ABSTRACT

A high intake of polyphenols has been shown to benefit health, protect against the risk of mental disorders, and improve sleep quality. This study aimed to determine the relationship between polyphenol intake, sleep quality, depression, stress, and anxiety in Turkish adults. This cross-sectional study was conducted with adults aged 18-64 between December 5, 2023, and May 12, 2024, in Istanbul, Türkiye. Participants completed a questionnaire with demographic characteristics, the Mediterranean Dietary Adherence Screener (MEDAS), the Depression Anxiety Stress Scale, the Pittsburgh Sleep Quality Index, and a 7-day food consumption record. Data were analyzed using SPSS 24.0. One hundred nineteen adults (73.1% female, mean age 23.69 ± 3.76 years) participated. There was a statistically significant difference in MEDAS classification across tertiles of polyphenol intake (p: 0.015). After controlling for confounders, the depression score significantly decreased across tertiles of polyphenol intake (OR: 0.990, p: 0.001). Similar results were observed for the anxiety score (OR: 1.006, p< 0.001). MEDAS scores showed a statistically significant difference across tertiles in unadjusted and all adjusted models (p: 0.049, p: 0.030, p: 0.020, and p: 0.015, respectively). Our findings revealed that dietary polyphenols may have a beneficial effect on depression and anxiety.

**Keywords:** Anxiety, Depression, Dietary polyphenol, Sleep quality, Mediterranean diet

## Introduction

Many people around the world suffer from mental health disorders. According to the World Health Organization (WHO), there has been a 13% increase in mental health disorders in recent years, making them the leading cause of disability worldwide (WHO, 2022).

Depressive disorder (also known as depression) involves a persistent depressed mood or a loss of enjoyment or interest in activities over a long period (WHO, 2023). Up to 350 million people worldwide suffer from depressive disorders (Skonieczna-Żydecka et al., 2018). Anxiety, while a normal feeling in various situations, can become a permanent problem in individuals with anxiety disorder. Anxiety is a leading cause of disability, alongside depression (WHO 2022, 2023).

Not much is known about the aetiology of depression. However, it has been observed that its aetiology is similar to inflammatory diseases such as cardiovascular disease, diabetes and cancer. These include reduced insulin sensitivity, endothelial dysfunction and increased proinflammatory cytokine production (Behl et al., 2022). Additionally, depression and obesity have a bidirectional relationship, with obese individuals being more likely to experience depression (Mannan et al., 2016). Evidence suggests that depression and obesity are related to inflammation (Kivimäki et al., 2014), impaired glycemic control (Kivimaki et al., 2009) and genetic predisposition (Harbron et al., 2014).

Sleep is essential for maintaining homeostasis, circadian rhythm, metabolism, organ function, and other physiological functions. It is known that sleep disorders result in psychological disorders, physical dysfunction and decreased quality of life (Hibi, 2023). Moreover, sleep deprivation is strongly related to an increased risk of depression among all age groups (Ouyang & Sun, 2019; Short et al., 2020; Liu et al., 2021). A regular sleep pattern has been linked to better diet quality, potentially mediated by body weight status and obesity-related disorders (Manna & Jain, 2015; Mousavi et al., 2022).

Over the past few years, food ingredients have been shown to affect mental health disorders and the quality of sleep. Dietary intake has been shown to affect sleep quality and depression in previous studies (Bremner et al., 2020). Fruit and vegetable intake, rich in anti-inflammatory compounds such as carotenoids and polyphenols, is inversely associated with depression (Bayes et al., 2020). Polyphenols are defined as secondary metabolites that are abundant in fruit and vegetables as well as coffee, tea, red wine and dark chocolate (Bayram et al., 2021) and may regulate oxidative stress, neuroinflammation and gut microbiota to reduce depressive behaviours (Bayes et al., 2020; Tayab et al., 2022). However, only one study has evaluated polyphenol intake and sleep quality, showing that high polyphenol intake is negatively associated with depression, stress, and sleep quality among overweight and obese women (Golmohammadi et al., 2023).

The Mediterranean diet, rich in polyphenols, has numerous health benefits, including reduced risk of chronic diseases and depression and improved sleep quality (Castro-Barquero et al., 2018). However, no study has examined how polyphenols, Mediterranean diet adherence, sleep quality, and risk of depression, stress, and anxiousness are associated with polyphenols in Turkish adults. This study aimed to calculate the average daily polyphenol intake and to determine the relationship between polyphenol intake and sleep quality, depression, stress and anxiety in Turkish adults.

## Materials and Methods

### *Participants*

This cross-sectional study was conducted on adults aged 18-64 between December 5, 2023, and May 12, 2024, in Istanbul, Turkey. A power analysis was performed for sample selection. A prevalence of 20%, a type 1 error rate ($\alpha$) of 0.05, a type 2 error rate ($\beta$) of 0.20 and a power ($1-\beta$) of 0.80 were calculated. The minimum total number of participants was, therefore, set at 100.

The participants were administered a face-to-face questionnaire that included demographic characteristics, the Mediterranean Dietary Adherence Scale (MEDAS), the Depression Anxiety Stress Scale (DASS-21), the Pittsburgh Sleep Quality Index (PSQI), and a 7-day food consumption record. The participants' height and body weight values were taken in accordance with their statements. Body mass index (BMI) was calculated as body weight (kg) / height $(m)^2$.

The study's inclusion criteria were adults aged 18 and 64 with a normal BMI (18.5-24.9 $kg/m^2$) and no history of chronic disease. Exclusion criteria included adults with diabetes, cardiovascular disease, kidney or liver disease, thyroid disorders, cancer, those following a special diet, chronic alcohol consumers, menopausal women, and pregnant or lactating women. The study received ethical approval, and informed consent was obtained from the participants.

### Mediterranean Dietary Adherence Screener

Schröder et al. (2011), and Martínez-González et al. (2012) developed the Mediterranean Dietary Adherence Screener (MEDAS). Pehlivanoğlu et al. (2020) established the Turkish validity and reliability of the scale. The scale consists of 14 questions, each scoring 0 or 1 point based on consumption amounts, and the total score is calculated. The interpretation of the total MEDAS score is as follows: $< 7$ indicates low Mediterranean diet adherence (MDA), $\geq 7$ indicates moderate MDA, and $\geq 9$ indicates high MDA.

### Pittsburgh Sleep Quality Index

Sleep quality was determined using the Pittsburgh Sleep Quality Index (PSQI) developed by Buysse et al. (1989). The PSQI consists of seven items, each measured at one-month intervals and scored between 0 and 3. The PSQI total score ranges from 0 to 21, with higher scores indicating poorer sleep quality. Poor sleep quality is indicated by a score above five (Buysse et al., 1989).

### Depression, Anxiety, and Stress Scale Short Form

Depression, Anxiety and Stress Scale Short Form (DASS-21) is a 4-Likert-type scale developed by Lovibond and Lovibond (1995). The Turkish version's validity and reliability were evaluated by Sarıçam (2018). The questionnaire was designed to assess levels of depression, anxiety and stress levels and consisted of seven items for each of the three scales. Items 3, 5, 10, 13, 16, 17, and 21 represent the depression score; and according to the total score, 0 to 4 is normal, 5 to 6 is mild depression, 7 to 10 is moderate depression, 11 to 13 is severe depression and >13 is extremely severe depression. Items 2, 4, 7, 9, 15, 19, and 20 represent the anxiety score, and total scores between 0 to 3 mean normal, between 4 and 5 of mild anxiety, between 6 and 7 of moderate anxiety, between 8 and 9 of severe anxiety, and >9 of extremely severe anxiety. Additionally, items 1, 6, 8, 11, 12, 14, and 18 represent the stress score, and the total scores between 0 and 7 mean normal, between 8 and 9 of mild stress, 10 and 12 of moderate stress, 13 and 16 of severe stress, and >16 are indicative of extremely severe stress (Sarıçam, 2018).

### 7-Day Food-Record Method

The 7-day food recall method assessed the participants' polyphenol and nutrient intakes. Participants wrote the foods they ate for 7 days and their quantities on the food consumption record form. A photographic atlas showing the portion size of the food was used for the quantities of the foods (Rakıcıoğlu et al., 2009). Additionally, participants were contacted for each food for which quantities were not specified. Packaged products were written as brand and weight, and the contents were checked again to minimise the margin of error. The Nutrient Database (BeBIS Pro for Windows, Willstätt, Germany; Turkish version BeBiS 9) determined daily energy and nutrient intakes.

### Assessment of Total Polyphenol Intake

We used a tool developed by (Hinojosa-Nogueira et al., 2021) to assess total polyphenol intake. This tool contains 302 foods, and the total polyphenol values were obtained from the Phenol Explorer database (http://phenol-explorer.eu/). Food products were classified into 16 groups: oils and olives, cocoa and derivatives, fruits and derivatives, vegetables, nuts, cereals and derivatives, legumes, soy and derivatives, infusions, tubers, processed foods, herbs, juices, alcoholic drinks, coffee, and condiments. Total polyphenol intake was divided into tertiles: <25th percentile (Tertile 1, T1), 25th-75th percentile (Tertile 2, T2), and >75th percentile (Tertile 3, T3): T1: <853.88 mg/d, T2: 853.88-1418.41 mg/d, and T3: >1418.41 mg/d.

### Statistical Analyses

SPSS 24.0 was used to analyse the data. Categorical data are presented as numbers (n) and percentages (%), while quantitative data are presented as means ($\bar{X}$) and standard deviations (SD). The distribution of variables was verified using the Kolmogorov–Smirnov test. The chi-squared test was used for categorical variables, and ANOVA was used for quantitative variables. The associations between tertiles of polyphenol intake and mental health, sleep quality and MEDAS scores were assessed using multivariate logistic regression analysis. A p-value $\leq 0.05$ was considered statistically significant.

## Results and Discussion

Table 1 shows the general characteristics of the participants. The study included 119 adults (73.1% female; the mean age was 23.69 ±3.76 years). Most participants (50.4%) were graduated from university, and 68.9% were employed. It was found that 83.2% of the participants did not exercise regularly, and 9.2% had no regular sleep patterns.

Table 2 presents the relationship between tertiles of polyphenol intake of depression, anxiety, stress, PSQI and MEDAS scores and classification. There was no statistically significant difference in depression, stress, anxiety, PSQI and MEDAS scores by tertile of polyphenol intake. However, the difference between MEDAS classifications was statistically significant across tertiles of polyphenol intake (p: 0.015).

**Table 1.** General characteristics (n: 119)

| Parameters | Total (n: 119) n | % |
|---|---|---|
| **Age (Mean ± SD)** | 23.69 ±3.76 | |
| **Gender** | | |
| Woman | 87 | 73.1 |
| Male | 32 | 26.9 |
| **Education Levels** | | |
| Primary School | 1 | 0.8 |
| Secondary School | 1 | 0.8 |
| High School | 49 | 41.2 |
| University | 60 | 50.4 |
| MA or PhD | 8 | 6.7 |
| **Employment status** | | |
| Employee | 82 | 68.9 |
| Unemployed | 37 | 31.1 |
| **Regular Physical exercise** | | |
| No | 99 | 83.2 |
| Yes | 20 | 16.8 |
| **Regular sleeping** | | |
| No | 11 | 9.2 |
| Yes | 108 | 90.8 |
| **Height (cm)** | 168.99 ±8.76 | |
| **Body weight (kg)** | 65.32 ±14.22 | |
| **BMI ($kg/m^2$)** | 22.75 ±3.85 | |

MA: Master's degree, PhD: Doctoral degree, BMI: Body mass index

Table 3 shows the total polyphenol, energy, macro and micronutrient intake among tertiles of polyphenol intake. Participants in T3 had significantly higher energy (p< 0.001), carbohydrate (p< 0.001), protein (p: 0.002), total fat (p: 0.014), fibre (p< 0.001), and MUFA (p< 0.001) intakes compared to participants in other tertiles. Additionally, significant differences were observed in micronutrient intakes, including beta-carotene (p: 0.001), vitamin A (p: 0.004), vitamin E (p: 0.030), vitamin C (p< 0.001), thiamine (p: 0.001), riboflavin (p: 0.002), vitamin $B_6$ (p: 0.003), folate (p< 0.001), pantothenic acid (p: 0.003), sodium (p: 0.046), potassium (p< 0.001), iron (p< 0.001), magnesium (p< 0.001), zinc (p: 0.004), and phosphorus (p: 0.006). Additionally, caffeine intake was higher in T3, with a statistical difference (p: 0.001).

There were statistical differences between tertiles in coffee, cocoa and derivatives (p: 0.004), condimental (p: 0.002), nuts (p: 0.008), infusions (p: 0.007), legumes (p< 0.001), vegetables (p< 0.001) (Figure 1).

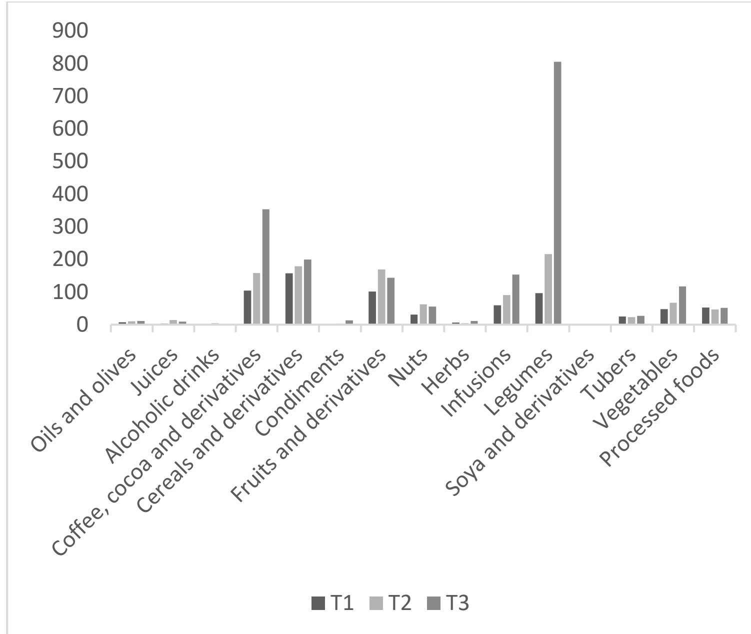


Figure 1. Total polyphenol intake (mg/d) is classified into fifteen food groups for over polyphenol tertiles

Table 4 shows the relationship between polyphenol tertiles and participants' mental health, sleep quality and Mediterranean diet adherence. In all three adjusted models, depression scores decreased significantly among tertiles of polyphenol intake (p< 0.001, p< 0.001 and p: 0.001, respectively). A similar pattern was observed for the anxiety scores (p< 0.001). MEDAS scores showed a statistically significant difference between tertiles both unadjusted (OR: 1.298, p: 0.049) and in all adjusted models for T3 (OR: 1.412, p: 0.030 for Model 1, OR: 1.472, p: 0.020 for Model 2, and OR: 1.534, p: 0.015 for Model 3, respectively) (Table 4).

A high intake of polyphenols has been shown to benefit health and protect against the risk of mental disorders. According to our results, total polyphenol intake was negatively correlated with both depression and anxiety levels, but there was no relationship between polyphenol intake and sleep quality. On the other hand, there was a significant relationship between polyphenol intake and MEDAS.

The antioxidant properties of polyphenols play a crucial role in mental health by positively affecting the brain and potentially alleviating depressive symptoms (Bayes et al., 2020; Tayab et al., 2022). The importance of dietary polyphenols in controlling pathways involved in neurogenesis and neuroprotection has been highlighted by studies that may have implications for the improvement of mental health, including depression (Huang et al., 2019; Bayes et al., 2020). Observational studies have indicated that higher dietary polyphenol intake is associated with a reduced risk of depression (Mofrad et al., 2019; Sangouni et al., 2022; Golmohammadi et al., 2023). Additionally, interventional studies have suggested that polyphenols may help decrease depressive symptoms (Fisk et al., 2020; Lin et al., 2021; Kabra et al., 2022). While our initial analysis showed no relationship between depression and tertiles of total polyphenol intake, the results changed when we adjusted for confounders. After these adjustments, we observed a significant decrease in depression scores across tertiles of polyphenol intake. This indicates that polyphenols may have a beneficial effect on depression, but this effect is only apparent when other influencing factors are taken into account. These findings highlight the significance of considering confounders in nutritional research to uncover potential health benefits.

**Table 2.** Relationship between tertiles of polyphenol intake of depression, anxiety, stress, PSQI and MEDAS scores and classification

| | Total polyphenol intake (mg/d) | | | |
|---|---|---|---|---|
| | T1 (n: 30) (<853.88 mg) | T2 (n: 60) (853.88-1418.41 mg) | T3 (n: 29) (>1418.41 mg) | p-value |
| Depression score | 7.97 ±5.49 | 5.73 ±4.58 | 7.70 ±5.72 | 0.232 |
| Anxiety score | 6.07 ±5.20 | 5.10 ±4.51 | 4.67 ±4.15 | 0.611 |
| Stress score | 8.24 ±5.33 | 6.67 ±4.67 | 7.43 ±4.65 | 0.290 |
| PSQI Score | 6.63 ±2.55 | 6.45 ±2.92 | 6.97 ±2.81 | 0.655 |
| MEDAS Score | 5.70 ±1.70 | 6.17 ±1.97 | 6.76 ±2.46 | 0.227 |
| **Stress classification** | | | | 0.128 |
| Normal (0-7 scores) | 19 (63.3) | 36 (60.0) | 11 (37.9) | |
| Mild (8-9 scores) | 3 (10.0) | 8 (13.3) | 10 (34.5) | |
| Moderate (10-12 scores) | 2 (6.7) | 10 (16.7) | 4 (13.8) | |
| Severe (13-16 scores) | 4 (13.3) | 5 (8.3) | 2 (6.9) | |
| Extremely severe (>16 scores) | 2 (6.7) | 1 (1.7) | 2 (6.9) | |
| **Anxiety classification** | | | | 0.773 |
| Normal (0-3 scores) | 16 (53.3) | 25 (41.7) | 10 (34.5) | |
| Mild (4-5 scores) | 3 (10.0) | 10 (16.7) | 5 (17.2) | |
| Moderate ( 6-7 scores) | 2 (6.7) | 8 (13.3) | 6 (20.7) | |
| Severe (8-9 scores) | 4 (13.3) | 6 (10.0) | 2 (6.9) | |
| Extremely severe (>9 scores) | 5 (16.7) | 11 (18.3) | 6 (20.7) | |
| **Depression classification** | | | | 0.286 |
| Normal (0-4. scores) | 10 (33.3) | 26 (43.3) | 9 (31.0) | |
| Mild (5-6 scores) | 6 (20.0) | 9 (15.0) | 5 (17.2) | |
| Moderate (7-10 scores) | 5 (16.7) | 17 (28.3) | 5 (17.2) | |
| Severe (11-13 scores) | 3 (10.0) | 4 (6.7) | 6 (20.7) | |
| Extremely severe (>13 scores) | 6 (20.0) | 4 (6.7) | 4 (13.8) | |
| **PSQI classification** | | | | 0.530 |
| Good sleep quality (<5 scores) | 9 (30.0) | 25 (41.7) | 10 (34.5) | |
| Poor sleep quality (≥ 5 scores) | 21 (70.0) | 35 (58.3) | 19 (65.5) | |
| **MEDAS classification** | | | | **0.015*** |
| Low MDA (<7 scores) | 26 (86.7) | 47 (78.3) | 16 (55.2) | |
| Moderate MDA (7-9 scores) | 4 (13.3) | 11 (18.3) | 8 (27.6) | |
| High MDA (≥9 scores) | - | 2 (3.3) | 5 (17.2) | |

*p<0.05, PSQI: Pittsburgh Sleep Quality Index, MEDAS: Mediterranean Dietary Adherence Screener, MDA: Mediterranean diet adherence

**Table 3.** Total polyphenol, energy, macro and micronutrient intake among tertiles of polyphenol intake

| | Total polyphenol intake (mg/d) | | | |
|---|---|---|---|---|
| | **T1 (n: 30) (<853.88 mg)** | **T2 (n: 60) (853.88-1418.41 mg)** | **T3 (n: 29) (>1418.41 mg)** | **p-value** |
| Total polyphenol intake (mg) | 692.28 ±129.19[a,b] | 1047.21 ±160.46[a,c] | 1953.18 ±404.60[b,c] | **<0.001**** |
| Energy (kcal) | 1264.69 ±206.71[b] | 1321.06 ±234.07 | 1583.00 ±366.41[b] | **<0.001*** |
| Protein (g) | 51.55 ±11.38[a,b] | 60.03 ±10.55[a] | 62.01 ±16.50[b] | **0.002*** |
| Protein (E %) | 16.90 ±4.19[a] | 18.93 ±3.88[a,c] | 16.14 ±2.91[c] | **0.002*** |
| Carbohydrate (g) | 136.00 ±30.70[b] | 141.54 ±30.88 | 176.56 ± 45.05[b] | **<0.001**** |
| Carbohydrate (E %) | 43.73 ±4.65 | 43.87 ±5.11 | 45.69 ±5.96 | 0.529 |
| Total fat (g) | 55.85 ±10.98[b] | 55.33 ±14.64[c] | 66.80 ±17.25[b,c] | **0.014*** |
| Total fat (E %) | 39.23 ±3.96 | 36.98 ±4.98 | 37.62 ±5.06 | 0.093 |
| Fibre (g) | 14.88 ±4.30[b] | 16.59 ±3.78[c] | 19.56 ±4.39[b,c] | **<0.001**** |
| SFA (g) | 19.17 ±3.76 | 18.70 ±5.20 | 21.43 ±5.95 | 0.113 |
| MUFA (g) | 18.31 ±3.76[b] | 18.47 ±4.98 | 24.13 ±5.80[b] | **<0.001**** |
| PUFA (g) | 13.02 ±5.20 | 12.74 ±5.28 | 15.37 ±5.60 | 0.190 |
| Cholesterol (mg) | 257.97 ±108.72[a] | 314.74 ±104.49[a] | 274.41 ±106.17 | **0.030*** |
| n-3 (g) | 1.28 ±0.63 | 1.48 ±0.58 | 1.25 ±0.49 | 0.091 |
| Linolenic acid (mg) | 0.98 ±0.46 | 1.06 ±0.50 | 1.06 ±0.45 | 0.688 |
| n-6 (g) | 11.45 ±5.27 | 10.92 ±5.00 | 13.75 ±5.72 | 0.116 |
| Sodium (mg)[¥] | 1823.72 ±540.03[b] | 1997.65 ±644.54 | 2333.45 ±807.37[b] | **0.046*** |
| Potassium (mg) | 1636.92 ±287.70[b] | 1851.68 ±307.80[c] | 2222.69 ±647.16[b,c] | **<0.001**** |
| Vitamin A (mcg) | 543.90 ±168.94[b] | 642.75 ±503.39 | 1057.99 ±472.52[b] | **0.004*** |
| Beta carotene (mg) | 1.64 ±0.93[b] | 1.80 ±1.16 | 3.05 ±2.37[b] | **0.001**** |
| Vitamin C (mg) | 48.48 ±17.61[b] | 60.98 ±22.19 | 82.84 ±38.09[b] | **<0.001**** |
| Calcium (mg) | 473.07 ±170.23[a] | 599.72 ±205.89[a] | 508.50 ±133.57 | **0.007*** |
| Iron (mg) | 7.49 ±1.65[b] | 8.39 ±1.76[c] | 10.42 ±3.30[b,c] | **<0.001**** |
| Vitamin E (mg) | 12.27 ±6.80[b] | 11.87 ±5.38[c] | 17.02 ±8.29[b,c] | **0.030*** |
| Thiamine (mg) | 0.64 ±0.14[b] | 0.74 ±0.17 | 0.84 ±0.27[b] | **0.001**** |
| Riboflavin (mg) | 1.01 ±0.34[a,b] | 1.27 ±0,32[a] | 1.12 ±0.41[b] | **0.002*** |
| Niacin (mg) | 19.56 ±4.14[a] | 22.11 ±4.11[a] | 24.44 ±8.37 | **0.008*** |
| Vitamin B6 (mg) | 0.97 ±0.24[a,b] | 1.13 ±0.24[a] | 1.27 ±0.42[b] | **0.003*** |
| Folate (mcg) | 175.62 ±41.40[b] | 207.66 ±46.05[c] | 256.04 ±97.84[b,c] | **<0.001**** |
| Vitamin $B_{12}$ (mcg) | 3.63 ±2.26 | 4.91 ±2.20 | 4.40 ±5.26 | 0.181 |
| Biotin (mcg) | 30.51 ±9.54[a,b] | 38.14 ±10.97[a] | 38.01 ±14.11[b] | **0.004*** |
| Pantothenic acid (mg) | 3.40 ±0.75 [a,b] | 3.98 ±0.75[a] | 4.23 ±1.37[b] | **0.003*** |
| Vitamin K (mcg) | 47.33 ±24.76[b] | 61.72 ±40.63[c] | 90.85 ±66.51[b,c] | **0.002*** |
| Magnesium (mg) | 192.26 ±39.01[a,b] | 217.01 ±36.78[a,c] | 257.12 ±62.61[b,c] | **<0.001**** |
| Zinc (mg) | 7.46 ±2.05[a,b] | 8.78 ±1.70[a] | 9.23 ±2.38[b] | **0.004*** |
| Phosphorus (mg) | 837.88 ±215.36[a,b] | 994.69 ±206.56[a] | 970.75 ±233.13[b] | **0.006*** |
| Caffeine (mg) | 27.56 ±26.16[b] | 41.57 ±3.033 | 68.14 ±63.31[b] | **0.001**** |

*p<0.05, **p< 0.001. ANOVA test was used. [a]Differences between T1 and T2, [b] Differences between T1 and T3, [c] Differences between T2 and T3. [¥] only from foods. SFA: Saturated fatty acids, MUFA: Monounsaturated fatty acids, PUFA: Polyunsaturated fatty acids, n-3: Omega-3, n-6: Omega-6.

**Table 4.** The relationship between polyphenol intake and mental health, sleep quality, and adherence to Mediterranean diet in participants

| | Tertiles | UOR (95% CI) | p-value | Model 1 AOR[a] (95% CI) | p-value | Model 2 AOR[b] (95% CI) | p-value | Model 3 AOR[c] (95% CI) | p-value |
|---|---|---|---|---|---|---|---|---|---|
| **Depression score** | T1 | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | |
| | T2 | 0.943 (0.864-1.029) | 0.140 | 0.933 (0.848-1.026) | 0.247 | 0.939 (0.854-1.033) | 0.196 | 0.946 (0.856-1.046) | 0.282 |
| | T3 | 1.027 (0.933-1.130) | 0.584 | 1.009 (0.900-1.130) | **<0.001**** | 0.994 (0.883-1.119) | **<0.001**** | 0.990 (0.873-1.123) | **0.001**** |
| **Anxiety score** | T1 | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | |
| | T2 | 1.023 (0.924-1.132) | 0.661 | 1.024 (0.919-1.141) | 0.669 | 1.033 (0.925-1.154) | 0.125 | 1.048 (0.930-1.181) | 0.442 |
| | T3 | 1.108 (0.954-1.197) | 0.249 | 1.105 (0.977-1.273) | **<0.001**** | 1.103 (0.965-1.265) | **<0.001**** | 1.006 (0.956-1.283) | **<0.001**** |
| **Stress score** | T1 | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | |
| | T2 | 0.996 (0.881-1.060) | 0.467 | 0.966 (0.878-1.063) | 0.480 | 0.971 (0.882-1.070) | 0.551 | 0.977 (0.885-1.079) | 0.649 |
| | T3 | 1.034 (0.932-1.146) | 0.532 | 1.054 (0.937-1.186) | 0.383 | 1.034 (0.915-1.169) | 0.593 | 1.031 (0.909-1.172) | 0.633 |
| **PSQI score** | T1 | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | |
| | T2 | 0.976 (0.833-1.144) | 0.767 | 0.991 (0.837-1.173) | 0.913 | 0.998 (0.840-1.184) | 0.169 | 1.033 (0.862-1.239) | 0.723 |
| | T3 | 1.044 (0.868-1.255) | 0.647 | 1.072 (0.869-1.324) | 0.516 | 1.036 (0.831-1.290) | 0.755 | 1.089 (0.861-1.377) | 0.477 |
| **MEDAS score** | T1 | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | | 1.000 (referans) | |
| | T2 | 1.122 (0.901-1.398) | 0.305 | 1.141 (0.892-1.460) | 0.294 | 1.150 (0.893-1.480) | 0.278 | 1.175 (0.903-1.529) | 0.230 |
| | T3 | 1.298 (0.999-1.685) | **0.049*** | 1.412 (1.034-1.927) | **0.030*** | 1.472 (1.063-2.040) | **0.020*** | 1.534 (1.086-2.167) | **0.015*** |

*p< 0,05, **p< 0,001. Model 1: adjusted for age, BMI, gender and energy, Model 2: Model 1 + education level + physical activity, Model 3: Model 2 + linolenic acid + caffeine intake. The reference group was tertile 1 of polyphenol intake.

Anxiety disorders are very common and have been associated with an increased risk of coronary heart disease. However, the link between diet and anxiety has received less attention. Vegetarian and traditional diets rich in phytochemicals are related to a lower prevalence of anxiety (Jacka et al., 2010; Mofrad et al., 2019). Contrary to these findings, Golmohammadi et al. (2023) reported no relationship between polyphenol intake and anxiety. Our findings revealed a noteworthy relationship between anxiety and polyphenol intake after adjusting for confounders. This suggests that polyphenol consumption may have a positive impact on reducing anxiety levels, but this effect becomes evident only when other influencing factors are controlled for. These results suggest that dietary polyphenol intake positively affects mental health and emphasise the importance of considering confounding variables in such studies to reveal true associations.

The risk of mental disorders such as depression can be increased by stress. A study reported that a higher dietary phytochemical index was associated with a decreased risk of stress in women (Mofrad et al., 2019). Similarly, Golmohammadi et al. (2023) found that higher dietary polyphenol intake was negatively associated with stress after adjusting for various factors. However, our findings showed no association between stress and polyphenol intake. In previous studies, the effects of stress and polyphenol intake were observed in women (Mofrad et al., 2019; Golmohammadi et al., 2023). Including both men and women in this study may have influenced the results in this way. Furthermore, polyphenols might not have a direct mechanism of action affecting stress levels, or the effects may not be significant enough to produce observable changes.

Additionally, polyphenols, commonly found in the Mediterranean diet, have been linked to a lower prevalence of mental disorders, especially depression and anxiety (Bayes et al., 2020; Dominguez et al., 2021; Melguizo-Ibáñez et al., 2023). Furthermore, polyphenol-rich foods have been associated with improvements in depressive symptoms (Fisk et al., 2020). According to our study, the difference between MEDAS classification was statistically significant in tertiles of polyphenol intake. In both unadjusted and adjusted models, MEDAS scores showed a statistically significant difference between tertiles. This suggests that dietary polyphenol intake may be important in influencing MEDAS scores, potentially impacting overall dietary quality and health outcomes.

Short sleep duration is associated with obesity, hypertension, type 2 diabetes, cardiovascular disease, and all-cause mortality compared to normal sleep duration (Yin et al., 2017). These associations are thought to be partly mediated by changes in nutritional intake, including fruit and vegetables, which affect body weight and risk of chronic disease (Noorwali et al., 2018). Total polyphenol intake was reported to be inversely associated with sleep duration (Noorwali et al., 2018). Similarly, Golmohammadi et al. (2023) found that higher dietary polyphenol intake was inversely associated with sleep quality after adjusting for multiple factors. Additionally, it has been shown that individuals following the Mediterranean diet are less likely to experience poor sleep quality, insufficient sleep duration, excessive daytime sleepiness or insomnia symptoms (Scoditti et al., 2022; Godos et al., 2024). We found no relationship between sleep quality and polyphenol intake despite investigating the potential link. This suggests that, within the scope of our research, polyphenol consumption does not appear to significantly impact sleep quality, and factors other than polyphenol intake may play a more important role in influencing how well people sleep.

There are several limitations to the study. Firstly, the study was cross-sectional, meaning we cannot establish a cause-and-effect relationship or the direction of the findings. Second, the sample size is small and predominantly female, which may limit the generalizability of the results to the entire population. Third, residual confounders in our study, including categorical variables (employment status, marital status, educational status, physical activity, etc.), may have been a factor. Despite these limitations, the study has several strengths. First, we used the 7-day Food Record Method, considered the best method for analysing food consumption (FAO, 2018). Second, the study controls for a wide range of confounders. Third, the Phenol Explorer database accurately calculated total polyphenol intake.

## Conclusion

After controlling for confounders in this study, depression and anxiety scores were significantly reduced across tertiles of polyphenol intake, but no association was found between polyphenol intake and sleep quality. Furthermore, there was a significant association between polyphenol intake and MEDAS. In conclusion, our findings revealed that dietary polyphenols may have a beneficial effect on mental health disorders such as depression and anxiety. However, dietary polyphenols were not associated with sleep quality. Future prospective studies with larger sample sizes are needed compared with current results.

**Compliance with Ethical Standards**

**Conflict of interest:** The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** The Istanbul Gelisim University Ethics Committee approved the study during meeting number 2023/09 on 20.11.2023.

**Data availability:** Data will be made available on request.

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Research Article

# Evaluation of textural and sensorial properties of burger patties produced with plant-based protein alternatives

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## ABSTRACT

Recently, there has been a growing interest in alternative protein sources. This study aimed to determine the textural and sensory properties of vegan burger patties produced with plant-based (soy and pea) protein sources instead of meat protein. For this purpose, 14 different vegan burger patties produced with soy and pea-based protein alternatives were obtained from different brands in the İstanbul market. Burger patties were analysed in terms of moisture content, cooking properties, instrumental colour, texture profile, and sensory properties. According to the results, pea-based burger patties have a higher moisture content and cooking loss and a lower cooking yield than soy-based patties. The $L^*$ and $a^*$ values of the pea-based patties tended to be higher than those of the soy-based patties, while the $b^*$ values were generally higher. In addition, the texture profile analysis of soy and pea-based burger patties shows differences in texture attributes that may affect consumer preference and overall eating experience. In the sensory evaluation, a significant difference between soy and pea-based burger patties was observed only for juiciness and spicy taste characteristics. The research findings shed light on alternative proteins' textural and sensorial properties and their role in the food industry, particularly in developing vegan burger patties. These differences in sensory attributes and colour and texture analysis between soy and pea-based burger patties highlight the importance of ingredient selection and formulation in developing plant-based protein products.

**Keywords:** Pea-based burger patties, Sensorial properties, Soy-based burger patties, Textural properties

## Introduction

Meat, the highest quality protein source among animal-originated food, has an excessively savoury taste and nutritional attributes. Meat proteins are classified into two groups. Some of them have all amino acids essential for the human body, whereas the rest conduce to the food industry via their functional features (Asgar et al., 2010; Piazza et al., 2015; Xiong, 2004). An increasing acceleration has been recorded in global meat production, reaching 357 million tons in 2021 (FAOSTAT, 2023). It is possible to say that this situation occurred initially due to developments in the industry, followed by a hectic work pace and personal preferences (Joseph et al., 2020). On the other hand, the world population seems to be growing rapidly and is estimated to be almost 9 billion by 2050. This means that people will need much more meat resources than humans consume. For this reason, food factories have developed alternative products that can replace meat. However, consumers have become aware of the negative aspects of conventional meat, such as health effects, environmental impacts, animal welfare, ethnical and religious beliefs, personal preferences and habits.

In terms of health impact, the high-fat content of meat, which contains saturated fatty acids, causes serious health problems such as cholesterol, stroke, diabetes type 2, colorectal cancer, cardiovascular (CV) and cerebrovascular diseases (Cengiz & Gokoglu, 2005; Muguerza et al., 2004; Profeta et al., 2021; Richi et al., 2015; Simopoulos, 2002). Excessive intake of red meat and meat products in routine diets seriously threatens human health (Apostolidis & McLeay, 2019). For this reason, the World Health Organization (WHO) recommends that fat is between 15% and 30% of the calories in the diet, while saturated fat should take place less than 10%. Also, it defends that cholesterol intake must be limited to 300 mg/d in protective activity for CV diseases (WHO, 2003).

Livestock are a major part of the ecosystem, and the ecosystem's functional movement relates to these animals' presence. Raising livestock and meat production in recent years seems to have vital effects on the environment, such as greenhouse gas emissions and water pollution, leading to decreased biodiversity and increased climate change (Katare et al., 2022). From this point of view, it is evaluated as a situation that triggers meat consumers to experience anxiety (de Vries et al., 2011; Erisman et al., 2011; Escribano et al., 2021; Profeta & Hamm, 2019).

Animal welfare is another major reason for rejecting meat consumption. The idea of protecting animal rights also supports it. This situation significantly affects people's choice to abandon animal protein and look for new alternatives (Thavamani et al., 2020). Because of this, humans may tend to a flexitarian or vegetarian diet or veganism (Profeta et al., 2021). Moreover, according to ethnic and religious beliefs, meat consumption differs in some geographies. The prohibition of different animal meat products in Muslims, Jews, and Hindus alternative protein sources will fulfil the needs of consumer communities (Asgar et al., 2010). High meat prices are also one of the main reasons forcing food plants to switch to other protein sources (Bhat & Karim, 2009; Boye et al., 2010).

Alternative protein sources are divided into five groups: plant-based alternative proteins, pulses, single-cell protein (algae, mycoprotein) insects, and cultured meat (Onwezen et al., 2021). Plant-based protein sources have the most widespread production and consumption network. Legumes such as soy, peas, beans, lentils, and chickpeas are used for this purpose.

Soybean proteins are the largest source for manufacturing texturized protein products worldwide. Soybean contains 35% to 40% protein, which is high quality due to its relatively well-balanced composition of amino acids, especially lysine (Dubois & Hoover, 1981; Golbitz & Jordan, 2006; Klein et al., 1995). Also, they play a major role in food functionality via some features such as gelling/textural capabilities, water absorption, fat absorption, emulsification, elasticity, and colour control (Singh et al., 2008). Pea protein has become an increasingly preferred protein source in recent years because it is a non-genetically modified organism (GMO), gluten-free, highly nutritious, and low-allergenic (Lam et al., 2018). Pea protein exhibits a balanced amino acid profile, characterized by high levels of the amino acid lysine (Lu et al., 2020). Pea seeds comprise approximately 23.4% protein, 21.2% total dietary fibre and 49.0% starch (Tulbek et al., 2024).

Plant-based meat alternatives reduce the burden by producing less greenhouse gas emission, using less water (Keoleian & Heller, 2018; Tilman & Clark, 2014) and leaving several times less environmental footprint than industrial meat production (Reijnders & Soret, 2003). The fact that it has beneficial aspects in terms of health also causes people to tend towards this direction. Even if consumers are still cautious about the taste and edibility of these products, this can be considered an important transition to sustainable food consumption (Szenderák et al., 2022).

Based on this information, this study was carried out to determine the textural and sensory qualities of vegan burger patties produced with plant-based protein sources such as soy and pea instead of meat protein.

## Materials and Methods

### *Sampling*

Fourteen vegan burger patties produced with plant-based protein alternatives (soy and pea) from different brands commercially available in İstanbul, Türkiye were collected from September 2023 – May 2024.

Seven soy-based (SB) and seven pea-based (PB) burger patties from three different batches were obtained from the markets at different times and delivered immediately to the laboratory in their original packaging (-18°C).

### *Physical and Cooking Properties*

The moisture content of burger patties was determined by drying 2 g of homogenised sample in a digital moisture analyzer (Sartorious MA45, Germany) at 105°C to constant weight.

The cooking properties (cooking loss [CL], cooking yield [%], reduction in the diameter of the burger [%], and reduction in burger thickness [%]) of burger patties were calculated using the following equations (Murphy et al., 1975).

Immediately after opening, the raw burger patties were cooked in an electric cooker at 150-170°C for 6 minutes (applying heat to both patty's faces for an average of 3 minutes).

Cooking loss = Weight of raw burger – Weight of cooked burger

Cooking yield % = (Weight of cooked burger / Weight of raw burger) × 100

Reduction in the diameter of the burger % = (Diameter of raw burger – Diameter of cooked burger) / (Diameter of raw burger) × 100

Reduction in burger thickness % = (Thickness of raw burger – Thickness of cooked burger) / (Thickness of raw burger) × 100

### *Instrumental Colour Analysis*

CIE $L^*$ (lightness), $a^*$ (redness) and $b^*$ (yellowness) values of burger patties were determined using the HunterLab Color Flex Colour Measurement System (Hunter Associates Laboratory, Inc., USA). All colour measurements were evaluated in "daylight" mode using diffuse illumination (D65 2° observer) with a viewing aperture of 8 mm and a port size of 25 mm. Five measurements were taken from each sample, and the arithmetic means of the results were calculated (AMSA, 2012).

### *Texture Profile Analysis*

The textural profiles of the vegan burger patties were determined by Instron (Model 3343, Instron, UK) texture profile analyser. For the evaluation of the texture profile analysis (TPA) of the samples, 6 measurements were performed for each burger sample and the arithmetic averages were calculated. Hardness (N), cohesiveness, springiness (mm), chewiness (J), gumminess (N) and adhesiveness (J) properties were used to determine the texture profile of the analysed burger samples. The values of these properties were calculated using the following areas and distances and their related equations (Bourne, 1978).

### *Sensory Analysis*

Twelve trained panellists (5 females and 7 males, aged between 25 and 55) evaluated the sensory properties of the vegan burger patties, serving each one raw or cooked (ISO 8586, 2023).

Raw burger samples were subjected to sensory evaluation immediately after the packages were opened, and cooked burger samples were subjected to sensory evaluation after being cooked in an electric cooker at 150-170°C for 6 minutes.

The samples were evaluated in terms of appearance, colour, odour, texture (both raw and cooked samples) and flavour (cooked samples only) attributes using a 10-point bipolar scale (0: extremely weak; 10: extremely strong) and arithmetic averages were recorded.

### *Statistical Analysis*

The statistical differences between and within soy and pea-based vegan burger patties groups were determined using ANOVA (one-way analysis of variance). Duncan's test was used to control the significance of differences between the groups (SPSS, 2017). The trial was conducted with three replicates at different times.

## Results and Discussion

In the last decade, several types of new generations of non-meat protein alternatives with meat-like texture, aspect, dietary facts, aroma, and taste have entered the market (Hu et al., 2019; Lu et al., 2020). With the unique imitation of meat, they are expected to positively impact vegetarians and traditional meat-eaters (Szejda et al., 2020). In this context, the present study aimed to evaluate the textural and sensory qualities of vegan burger patty samples produced with plant-based protein sources such as soy and peas.

The component information given in the label of vegan burgers is given in Table 1. Although the products were produced with the same plant base, it was observed that there were differences in nutrient values from producer to producer. The protein values of soy-based burger patties varied between 12 and 21%. On the other hand, the protein values of pea-based burger patties were detected in a much wider range of 12 to 44%. Despite the differences between the components, the energy values of the products were close to each other, while the energy amount increased in parallel with the increase in protein level.

The moisture content and cooking properties of vegan burger patties are shown in Table 2. Pea-based burger patties' moisture content and cooking loss were higher than soy-based ones. However, the cooking yield of pea-based vegan burger patties was lower than soy-based burger patties. The average moisture content varied between 40-62% (n: 7, ~50%) in pea-based burger patties, while it was around 41-57% in soy-based samples. Since the moisture loss caused by the cooking process was higher in pea-based samples, hardness was observed with increased binding in the products. Meanwhile, the preservation of the raw product form was higher in soy-based vegan burger patties with higher cooking yields. Similarly, Bakhsh et al. (2021) reported the average moisture content of the plant-based meat analogue examined in their study as 51.53±0.54%. Simard et al. (2021), who compared plant-based patties' physicochemical and cooking properties with animal-based burger patties, determined that the proportions of the specified parts were lower in plant-based ones. The same study reported that moisture loss was lower in plant-based burger samples; high protein content and low fat and starch content in the meatball composition helped the product retain water. Studies have shown that moisture retention and cooking loss percentage are inversely proportional. Likewise, Chin et al. (2004) confirmed with their data that soy is another plant-based ingredient that reduces cooking weight loss. It is stated that reduced cooking loss is emphasized in product development to attract consumers who appreciate juicier products (Yi et al., 2012).

**Table 1.** Label information of proximate properties of soy and pea-based vegan burger patties (n=14)

| Origin | Sample | Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| | | Protein (%) | Fat (%) | Carbohydrate (%) | NaCl (%) | Energy (kcal) | Dietary fibre (%) |
| Soy-based vegan burger patties | SB1 | 13.82 | 13.47 | 10.9 | 1.19 | 227.48 | 3.72 |
| | SB2 | 21.4 | 13.5 | 6.7 | 0.9 | 235 | - |
| | SB3 | 14.2 | 14.9 | 2.9 | 1.14 | 207 | - |
| | SB4 | 13.5 | 4.1 | 73.4 | 0.3 | 339 | - |
| | SB5 | 14.6 | 13.5 | 10.9 | 1.2 | 231 | 3.7 |
| | SB6 | 16.9 | 12.32 | 9.37 | 1,77 | 224.4 | 4.22 |
| | SB7 | 20.59 | 14.07 | 8.07 | 0.8 | 241 | |
| Pea-based vegan burger patties | PB1 | 12 | 12 | 8 | 1.5 | 197 | 4 |
| | PB2 | 17.5 | 13.9 | 7.6 | 2.6 | 225.5 | 4.4 |
| | PB3 | 12.7 | 13.7 | 8.5 | 2 | 209 | - |
| | PB4 | 34.73 | 8.44 | 41.64 | 2 | 393.12 | - |
| | PB5 | 36.16 | 8.23 | 43.2 | 1.8 | 391 | - |
| | PB6 | 18 | 8 | 6 | 1.2 | 168 | - |
| | PB7 | 44.1 | 7 | 33.2 | 0.6 | 234.8 | 9.8 |

**Table 2.** Instrumental colour (CIE *L*, a*, b**) and cooking parameters of soy and pea-vegan burger patties (n=14)

| Origin | Sample | Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *L** | *a** | *b** | Moisture (%) | Cooking Loss | Cooking Yield (%) | Reduction in diameter (%) | Reduction in thickness (%) |
| Soy-based vegan burger patties | SB1 | 43.10$^{c}$±0.27 | 8.41$^{e}$±0.05 | 15.14$^{e}$±0.23 | 54.82$^{b}$±0.04 | 23.64$^{b}$±0.04 | 76.45$^{e}$±0.20 | 11.88$^{a}$±0.02 | 16.67$^{c}$±0.04 |
| | SB2 | 32.55$^{g}$±0.61 | 13.33$^{c}$±0.24 | 17.79$^{d}$±0.42 | 50.75$^{e}$±0.11 | 5.44$^{d}$±0.02 | 93.84$^{b}$±0.06 | 3.26$^{f}$±0.01 | 7.14$^{e}$±0.02 |
| | SB3 | 56.49$^{a}$±0.44 | 7.37$^{f}$±0.16 | 27.19$^{a}$±0.17 | 52.71$^{d}$±0.09 | 5.00$^{d}$±0.04 | 94.91$^{a}$±0.03 | 6.17$^{c}$±0.02 | 25.00$^{a}$±0.44 |
| | SB4 | 44.52$^{b}$±0.27 | 17.35$^{a}$±0.31 | 15.48$^{e}$±0.35 | 56.97$^{a}$±0.13 | 9.29$^{c}$±0.04 | 90.07$^{d}$±0.03 | 2.33$^{g}$±0.09 | 13.33$^{d}$±0.15 |
| | SB5 | 40.16$^{e}$±0.56 | 10.06$^{d}$±0.18 | 16.96$^{d}$±0.22 | 53.60$^{c}$±0.13 | 27.90$^{a}$±0.45 | 71.67$^{f}$±0.08 | 10.00$^{b}$±0.09 | - |
| | SB6 | 36.17$^{f}$±0.68 | 13.25$^{c}$±0.28 | 25.20$^{b}$±0.53 | 54.52$^{b}$±0.18 | 3.67$^{e}$±0.09 | 94.66$^{a}$±0.15 | 4.11$^{e}$±0.05 | 20.00$^{b}$±0.45 |
| | SB7 | 41.64$^{d}$±0.35 | 14.02$^{b}$±0.13 | 22.52$^{c}$±0.72 | 41.17$^{f}$±0.08 | 3.79$^{e}$±0.09 | 93.39$^{c}$±0.09 | 5.41$^{d}$±0.04 | - |
| | P | *** | *** | *** | *** | *** | *** | *** | *** |
| Pea-based vegan burger patties | PB1 | 50.76$^{a}$±0.46 | 10.16$^{e}$±0.66 | 18.50$^{b}$±0.35 | 51.48$^{e}$±0.13 | 17.60$^{c}$±0.27 | 81.62$^{e}$±0.13 | 7.69$^{a}$±0.05 | - |
| | PB2 | 39.79$^{e}$±0.44 | 12.88$^{c}$±0.19 | 18.17$^{b}$±0.55 | 49.75$^{f}$±0.11 | 21.77$^{a}$±0.04 | 75.53$^{g}$±0.13 | 4.17$^{b}$±0.08 | 20.00$^{a}$±0.89 |
| | PB3 | 44.39$^{c}$±0.29 | 18.65$^{a}$±0.09 | 13.92$^{d}$±0.14 | 59.11$^{b}$±0.05 | 3.78$^{e}$±0.09 | 89.46$^{c}$±0.09 | 1.00$^{e}$±0.13 | 1.67$^{c}$±0.09 |
| | PB4 | 41.77$^{d}$±0.29 | 11.38$^{d}$±0.25 | 17.30$^{b}$±0.55 | 40.76$^{g}$±0.09 | 18.51$^{b}$±0.09 | 79.26$^{f}$±0.12 | 2.15$^{d}$±0.07 | 6.25$^{b}$±0.11 |
| | PB5 | 45.21$^{c}$±0.32 | 14.97$^{b}$±0.29 | 15.64$^{c}$±0.35 | 58.06$^{c}$±0.03 | 5.58$^{d}$±0.13 | 94.42$^{b}$±0.19 | 3.45$^{c}$±0.13 | 20.00$^{a}$±0.34 |
| | PB6 | 48.49$^{b}$±0.69 | 18.09$^{a}$±0.33 | 22.05$^{a}$±0.45 | 51.89$^{d}$±0.04 | 17.96$^{c}$±0.01 | 83.64$^{d}$±0.06 | 4.30$^{b}$±0.13 | 5.38$^{b}$±0.17 |
| | PB7 | 44.44$^{c}$±0.45 | 7.37$^{f}$±0.15 | 22.47$^{a}$±0.34 | 62.09$^{a}$±0.04 | 1.82$^{f}$±0.05 | 96.00$^{a}$±0.45 | - | - |
| | P | *** | *** | *** | *** | *** | *** | *** | *** |

a-g Values within a column with different superscripts differ significantly at $p<0.001$(***)

The instrumental colour values of soy and pea-based burger patties are given in Table 2. The lightness (*L**), redness (*a**), and yellowness (*b**) values of soy-based burger patties ranged between 32.55-56.49, 7.37-17.35 and 15.14-27.19, respectively. *L**, *a** and *b** values of pea-based burger patties ranged between 39.79-50.76, 9.37-18.65 and 13.92-22.47, respectively. The mean *L** and *a** values of pea-based burger patties were higher than soy-based burger patties, while the mean *b** values of soy-based burger patties were higher than pea-based ones (Figure 1). The difference between soy and pea-based samples was significant only in the lightness value. This was due to the darker colour of pea-based burger patties compared to soy-based ones. Bakhsh et al. (2021) reported that the yellowish colour in products is due to the soy protein content. Kyriakopoulou et al. (2019) reported that a yellowish-brown colour directly affects the final product quality. Also, the reason why plant-based burgers showed lesser green-red (*a**) and blue-yellow (*b**) colour is because of the compound which is called "leghemoglobin", known as symbiotic haemoglobin (De Marchi et al., 2021). However, most plant-based burgers on supermarket shelves have soy or pea protein as ingredients, which help create the impression of 'bleeding' to imitate meat better, making these products more attractive to consumers (Slade, 2018).

The texture profile analysis of soy and pea-based vegan burger patties is shown in Tables 3 and 4. The differences in the ingredients of soy and pea-based burger patties with different commercial formulations provided a significant difference in the texture profile analyses of the samples ($p<0.05$). The hardness, cohesiveness, springiness, adhesiveness, gumminess and chewiness properties of vegan burgers were similar in some patty formulations. At the same time, a significant difference was observed in the rest of the vegan burger patties (Table 3-4). The adhesiveness properties of pea-based vegan burger patties were equivalent ($p>0.05$). At the same time, significant differences were observed in all textural properties for both based on vegan burger patties ($p<0.05$). However, the variation in tenderness and juiciness properties depending on the ingredients used in the formulations also affected the chewiness properties of the products ($p<0.001$). Meanwhile, the differences in hardness, springiness, gumminess and chewiness were significant in the raw samples of soy and pea-based burger groups. In contrast, there were significant differences in springiness, adhesiveness and cohesiveness after cooking ($p<0.05$, Figure 2-3). The hardness and chewiness values of cooked soy and pea-based samples that lost moisture after cooking started showing similar characteristics ($p>0.05$). In the study of Forster et al. (2024), most plant-based burger samples were evaluated as high in terms of cohesiveness. Also, all plant-based burgers generally received lower scores for the attributes meaty, sweetness, and umami and showed higher scores for bitterness and lingering spice flavours. Samard et al. (2021) also reported that the adhesiveness, chewiness and hardness of the samples were weaker than the meat-based samples due to the presence of a weaker protein network compared to the structure of meat. In the present study, a significant difference was recorded in the adhesiveness of soy-based burger patties. Mabrouki et al. (2023) also stated that chewing before swallowing was necessary for patties made from beef rather than patties-originated peas. This difference is due to the different binding components used in the product formulation. When considering sensory parameters, no statistical difference was observed in the appearance and colour characteristics of vegan burgers of different brands produced by adding peas. In contrast, a significant difference was found in colour intensity between patties produced with soy. This is thought to be because of different additives or spices used in the composition of the patties, which affect the product's colour.

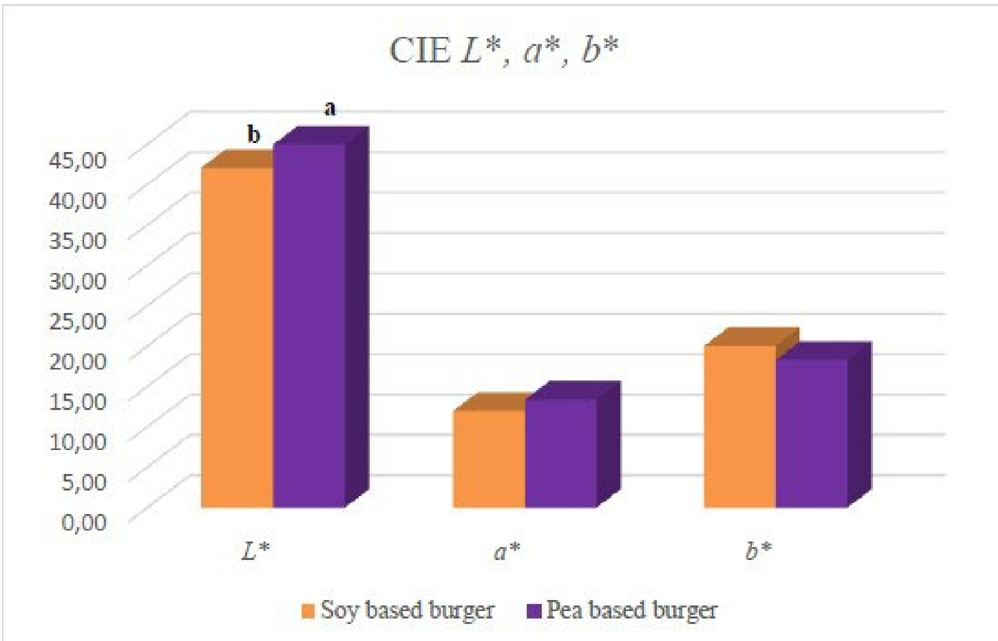


**Figure 1.** Comparison of instrumental colour values of soy and pea-based burger patties

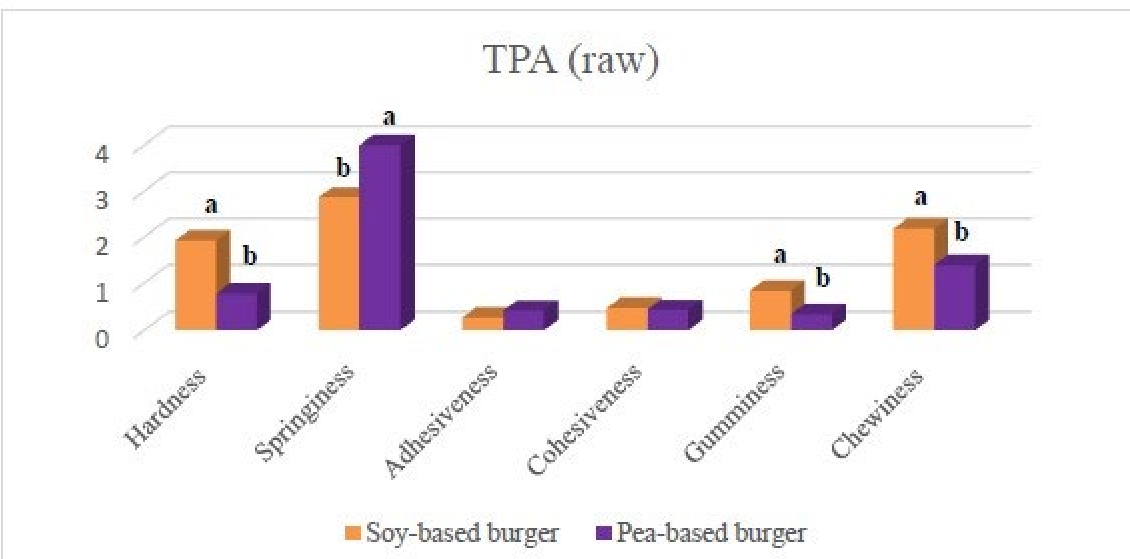


**Figure 2.** Comparison of texture profiles of raw soy and pea-based burger patties

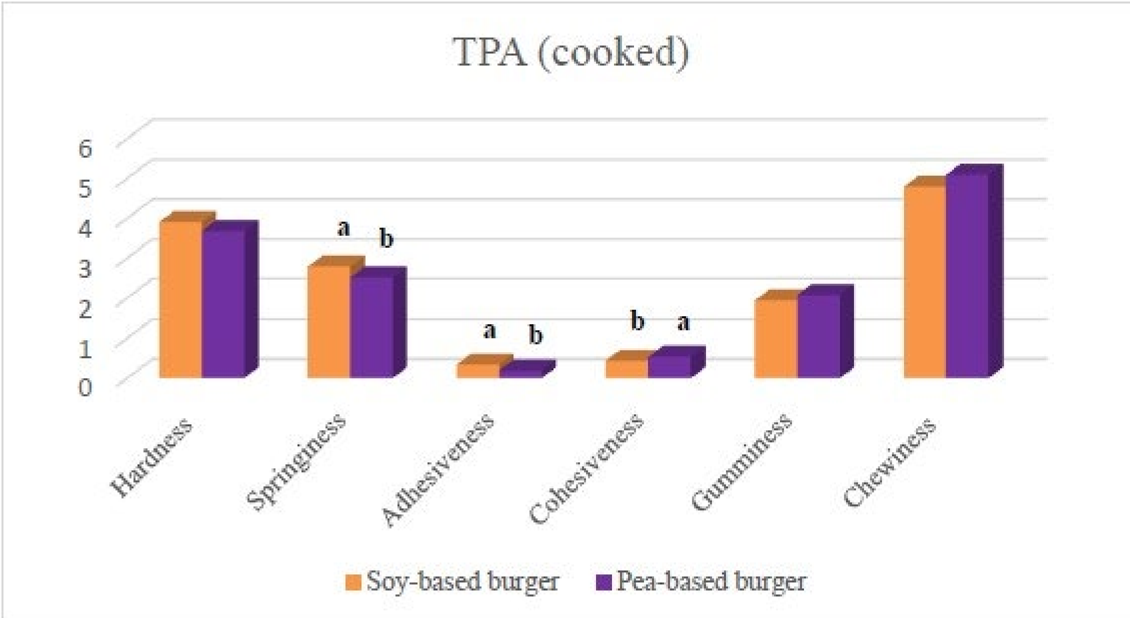


**Figure 3.** Comparison of texture profiles of cooked soy and pea-based burger patties

**Table 3.** Means and standard errors (SE) of textural properties of soy-based vegan burger patties (raw/cooked)

| Soy-based vegan burger patties | | n | HARDNESS | | SPRINGINESS | | ADHESIVENESS | | COHESIVENESS | | GUMMINESS | | CHEWINESS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| RAW | SB1 | 3 | $1.078^{de}$ | 0.007 | $2.583^{cd}$ | 0.112 | $0.080^{b}$ | 0.025 | $0.621^{a}$ | 0.008 | $0.669^{bc}$ | 0.010 | $1.729^{bcd}$ | 0.079 |
| | SB2 | 3 | $1.742^{c}$ | 0.049 | $3.500^{b}$ | 0.190 | $0.225^{b}$ | 0.028 | $0.388^{d}$ | 0.011 | $0.677^{bc}$ | 0.034 | $2.367^{bc}$ | 0.163 |
| | SB3 | 3 | $0.806^{ef}$ | 0.011 | $2.209^{cd}$ | 0.081 | $0.312^{b}$ | 0.159 | $0.339^{d}$ | 0.005 | $0.273^{c}$ | 0.008 | $0.604^{d}$ | 0.033 |
| | SB4 | 3 | $2.894^{b}$ | 0.349 | $2.749^{c}$ | 0.449 | $0.828^{a}$ | 0.309 | $0.372^{d}$ | 0.036 | $1.128^{b}$ | 0.241 | $3.088^{b}$ | 0.727 |
| | SB5 | 3 | $1.349^{cd}$ | 0.026 | $2.042^{d}$ | 0.032 | $0.041^{b}$ | 0.011 | $0.646^{a}$ | 0.008 | $0.871^{b}$ | 0.019 | $1.778^{bcd}$ | 0.052 |
| | SB6 | 3 | $0.545^{f}$ | 0.034 | $4.580^{a}$ | 0.201 | $0.241^{b}$ | 0.046 | $0.456^{c}$ | 0.015 | $0.249^{c}$ | 0.020 | $1.138^{cd}$ | 0.083 |
| | SB7 | 3 | $5.027^{a}$ | 0.243 | $2.375^{cd}$ | 0.081 | $0.169^{b}$ | 0.014 | $0.528^{b}$ | 0.023 | $1.983^{a}$ | 0.413 | $4.556^{a}$ | 0.906 |
| | P | 21 | *** | | *** | | ** | | *** | | *** | | *** | |
| COOKED | SB1 | 3 | $4.754^{c}$ | 0.045 | $1.667^{d}$ | 0.140 | $0.139^{c}$ | 0.046 | $0.625^{a}$ | 0.008 | $2.972^{b}$ | 0.040 | $4.959^{c}$ | 0.440 |
| | SB2 | 3 | $2.896^{d}$ | 0.175 | $3.209^{a}$ | 0.110 | $0.253^{bc}$ | 0.076 | $0.358^{d}$ | 0.007 | $1.036^{c}$ | 0.062 | $3.334^{d}$ | 0.246 |
| | SB3 | 3 | $1.289^{e}$ | 0.059 | $3.084^{ab}$ | 0.227 | $0.416^{abc}$ | 0.183 | $0.241^{e}$ | 0.015 | $0.315^{d}$ | 0.032 | $0.980^{e}$ | 0.128 |
| | SB4 | 3 | $9.173^{a}$ | 0.154 | $2.750^{bc}$ | 0.220 | $0.646^{a}$ | 0.139 | $0.469^{c}$ | 0.016 | $4.303^{a}$ | 0.142 | $11.723^{a}$ | 0.700 |
| | SB5 | 3 | $7.574^{b}$ | 0.356 | $2.458^{c}$ | 0.033 | $0.508^{ab}$ | 0.140 | $0.568^{b}$ | 0.010 | $4.289^{a}$ | 0.158 | $10.536^{b}$ | 0.381 |
| | SB6 | 3 | $0.986^{ef}$ | 0.059 | $3.083^{ab}$ | 0.083 | $0.204^{bc}$ | 0.042 | $0.453^{c}$ | 0.009 | $0.447^{d}$ | 0.032 | $1.384^{e}$ | 0.120 |
| | SB7 | 3 | $0.632^{f}$ | 0.044 | $3.250^{a}$ | 0.083 | $0.207^{bc}$ | 0.017 | $0.372^{d}$ | 0.021 | $0.191^{d}$ | 0.054 | $0.607^{e}$ | 0.164 |
| | P | 21 | *** | | *** | | * | | *** | | *** | | *** | |

n: number of analyzed samples. *: $p<0.05$. **: $p<0.01$. ***: $p<0.001$.
a-f Values within a column with different superscripts differ significant.

**Table 4.** Means and standard errors (SE) of textural properties of pea-based vegan burger patties (raw/cooked)

| Pea-based vegan burger patties | | n | HARDNESS | | SPRINGINESS | | ADHESIVENESS | | COHESIVENESS | | GUMMINESS | | CHEWINESS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | SE | Mean | SE | Mean | SE. | Mean | SE | Mean | SE. | Mean | SE |
| RAW | PB1 | 3 | 0.509$^{e}$ | 0.013 | 3.750$^{b}$ | 0.935 | 0.361$^{bc}$ | 0.053 | 0.500$^{b}$ | 0.008 | 0.254$^{de}$ | 0.009 | 0.988$^{c}$ | 0.263 |
| | PB2 | 3 | 0.978$^{b}$ | 0.037 | 1.958$^{c}$ | 0.193 | 0.132$^{c}$ | 0.036 | 0.448$^{c}$ | 0.015 | 0.440$^{b}$ | 0.027 | 0.857$^{c}$ | 0.087 |
| | PB3 | 3 | 0.667$^{d}$ | 0.015 | 4.875$^{ab}$ | 0.161 | 0.481$^{b}$ | 0.177 | 0.442$^{c}$ | 0.014 | 0.294$^{cd}$ | 0.007 | 1.436$^{b}$ | 0.074 |
| | PB4 | 3 | 0.546$^{e}$ | 0.023 | 4.083$^{ab}$ | 0.250 | 0.289$^{bc}$ | 0.024 | 0.364$^{d}$ | 0.019 | 0.197$^{ef}$ | 0.006 | 0.802$^{c}$ | 0.045 |
| | PB5 | 3 | 0.816$^{c}$ | 0.025 | 5.167$^{a}$ | 0.264 | 0.942$^{a}$ | 0.104 | 0.419$^{c}$ | 0.025 | 0.339$^{c}$ | 0.010 | 1.764$^{b}$ | 0.145 |
| | PB6 | 3 | 1.235$^{a}$ | 0.050 | 4.542$^{ab}$ | 0.170 | 0.511$^{b}$ | 0.026 | 0.585$^{a}$ | 0.011 | 0.725$^{a}$ | 0.041 | 3.258$^{a}$ | 0.087 |
| | PB7 | 3 | 0.654$^{d}$ | 0.029 | 3.626$^{b}$ | 0.178 | 0.252$^{bc}$ | 0.053 | 0.285$^{e}$ | 0.023 | 0.186$^{f}$ | 0.016 | 0.682$^{c}$ | 0.078 |
| | P | 21 | *** | | *** | | *** | | *** | | *** | | *** | |
| COOKED | PB1 | 3 | 3.842$^{c}$ | 0.150 | 1.750$^{e}$ | 0.064 | 0.176 | 0.043 | 0.566$^{b}$ | 0.013 | 2.181$^{b}$ | 0.126 | 3.854$^{d}$ | 0.376 |
| | PB2 | 3 | 3.909$^{c}$ | 0.133 | 2.417$^{cd}$ | 0.124 | 0.184 | 0.059 | 0.585$^{ab}$ | 0.010 | 2.282$^{b}$ | 0.057 | 5.533$^{c}$ | 0.371 |
| | PB3 | 3 | 2.662$^{d}$ | 0.216 | 2.292$^{d}$ | 0.122 | 0.106 | 0.035 | 0.505$^{c}$ | 0.009 | 1.336$^{c}$ | 0.087 | 3.035$^{d}$ | 0.192 |
| | PB4 | 3 | 3.581$^{c}$ | 0.147 | 2.792$^{ab}$ | 0.122 | 0.223 | 0.053 | 0.566$^{b}$ | 0.019 | 2.034$^{b}$ | 0.130 | 5.639$^{c}$ | 0.345 |
| | PB5 | 3 | 5.718$^{a}$ | 0.459 | 2.750$^{bc}$ | 0.135 | 0.207 | 0.066 | 0.570$^{b}$ | 0.005 | 3.260$^{a}$ | 0.264 | 8.903$^{a}$ | 0.716 |
| | PB6 | 3 | 4.901$^{b}$ | 0.244 | 2.459$^{bcd}$ | 0.062 | 0.173 | 0.027 | 0.620$^{a}$ | 0.009 | 3.041$^{a}$ | 0.171 | 7.516$^{b}$ | 0.596 |
| | PB7 | 3 | 1.112$^{e}$ | 0.083 | 3.125$^{a}$ | 0.153 | 0.275 | 0.118 | 0.333$^{d}$ | 0.027 | 0.381$^{d}$ | 0.058 | 1.164$^{e}$ | 0.148 |
| | P | 21 | *** | | *** | | NS | | *** | | *** | | *** | |

n: number of analyzed samples. NS: Not significant.
a-f Values within a column with different superscripts differ significantly at p<0.001(***)

The sensory properties (appearance, colour, odour, texture and flavour) of soy and pea-based vegan burger patties are shown in Figures 4 and 5. A significant difference was observed in colour intensity between the soy-based burger patties. However, there was no significant difference in the appearance and colour characteristics of pea-based vegan burger patties belonging to different brands. This is thought to be because of different additives or spices used in the composition of burger patties on the product's colour. There was no difference between the odour characteristics of vegan burger patties produced with soy and peas. When soy and pea-based burger patties were compared with each other in terms of odour characteristics, the mealy odour characteristics of pea-based samples were determined to be more intense than soy-based samples, and this difference was found to be significant ($p<0.05$, Fig 4). There was a significant difference in adhesiveness attributes between the vegan burger patties produced with soy ($p<0.01$). This difference is due to the different binding components used in the product formulation (e.g. pea starch, potato starch, methylcellulose, carrageenan). Different spice ratios used in the formulation provided a statistical difference between soy-based vegan burger patties. The difference between pea-based burger patties was significant only in tenderness and juiciness ($p<0.05$). In comparison between the soy and pea-based burger patties, a significant difference was observed in only juiciness and spicy taste attributes ($p<0.01$). Pea-based burger patties were juicier than soy-based ones, while soy-based patties had a more spicy flavour than pea-based patties (Figures 4-5). The difference in juiciness observed between the pea-based vegan patties produced with different ingredients caused the pea-based products to be perceived as juicier than soy-based ones. The soy-based product was reported as a factor that negatively affected the juiciness (Chin et al., 2024). In comparing the taste characteristics of the soy and pea groups, only the difference in spicy taste characteristics was found to be significant. Different spice ratios used in the formulation created a statistical difference between soy-based burger patties. Briefly, food scientists are investigating strategies to improve the quality parameters of meat analogues. In parallel with the increasing consumer demand, all efforts are focused on developing formulations and cooking methods to improve alternative protein sources' colour, flavour, and texture. In this context, it should be noted that the choice of protein source is an important factor to consider, as it can affect the sensory characteristics of the final product (Fiorentini et al., 2020). Also, the textural quality is influenced by many factors. Smaller particles create a smoother texture, while larger particles create a more granular texture. The particle organisation plays an important role in texture perception (Ilic et al., 2024).

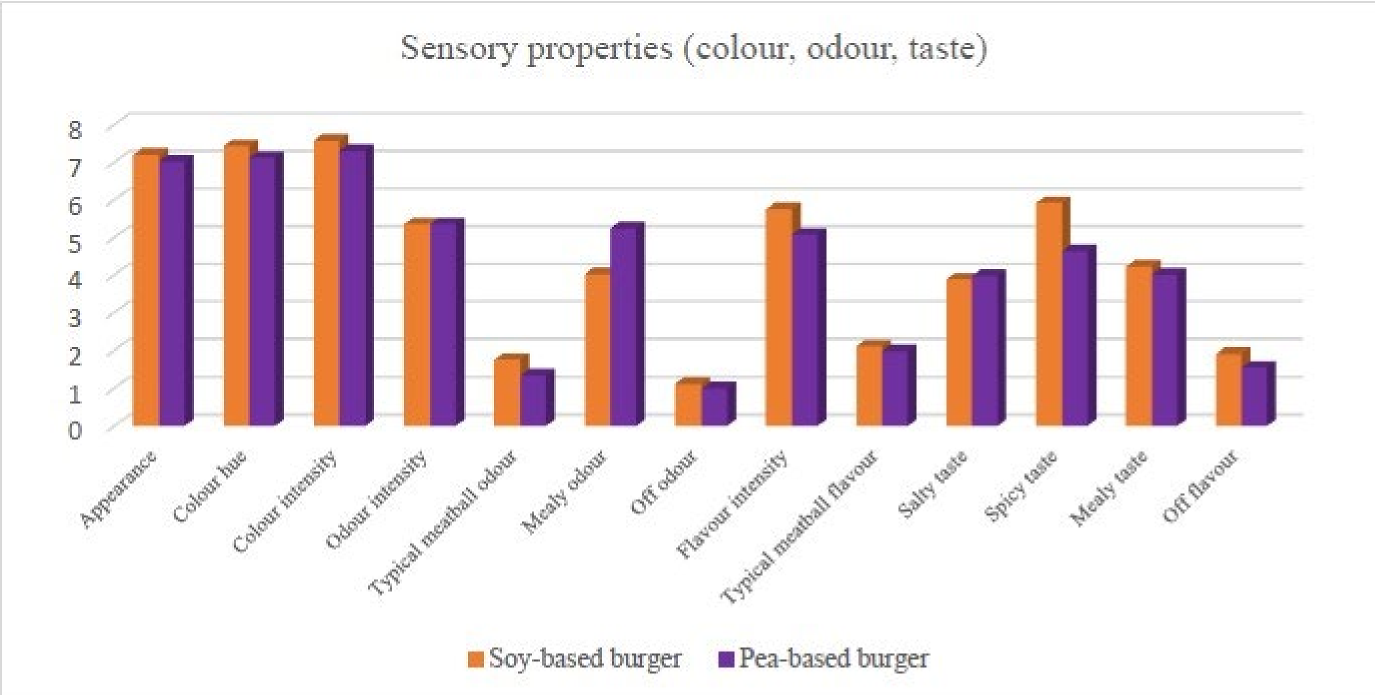


**Figure 4.** Comparison of sensory properties (colour, odour, taste) of soy and pea-based burger patties

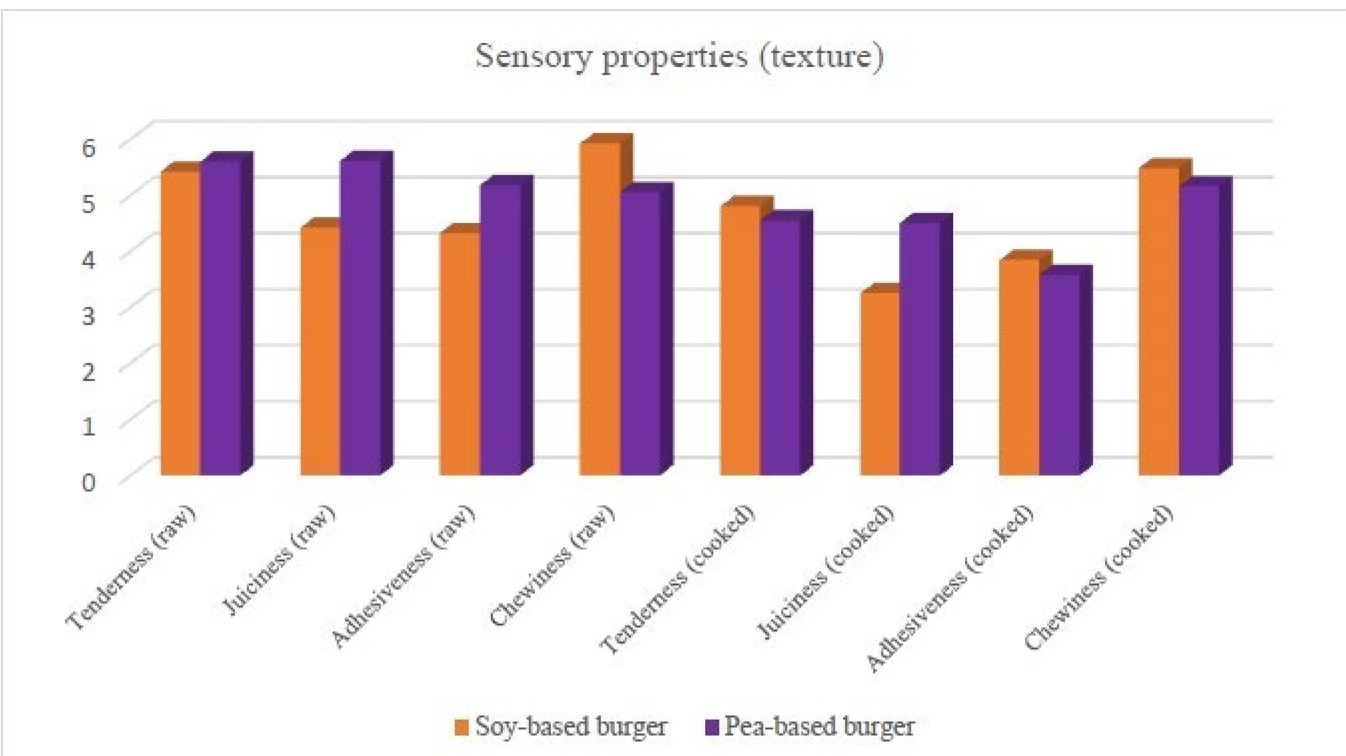


**Figure 5.** Comparison of sensory properties (texture) of soy and pea-based burger patties

## Conclusion

There is a growing trend towards plant-based protein sources due to animal welfare, health effects, environmental impact, and ethnic and religious beliefs. Therefore, patties produced with plant-based protein alternatives can be a good alternative to animal-based patties. To successfully produce meatless plant-based protein patties with a texture that is as close as possible to that of a meat-based burger patty, the textural and sensorial properties of the patties must be well understood. In the present study, texture profile analyses of soy and pea-based burger patties showed differences in texture characteristics, which may affect consumer liking and preferences. Among the sensory characteristics of soya and pea-based burger patties, only the difference in juiciness and spicy flavour was significant. The differences in textural and sensorial attributes between soy and pea-based burger patties highlight the importance of ingredient selection and formulation in developing plant-based protein products. In conclusion, the research findings remark on plant-based protein sources' textural and sensorial quality profiles to understand and meet consumer expectations and demands for these products. Also, it should be added that protein source is an important factor which is decisive over the sensory characteristics of the final product.

#### Compliance with Ethical Standards

**Conflict of interest:** The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** The authors declare that this study does not include experiments with human or animal subjects, so ethics committee approval is not required.

**Data availability:** Data will be made available on request.

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Research Article

# Investigation of nutrition literacy and quality of life in adults

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**ABSTRACT**

This study aimed to investigate the relationship between nutrition literacy (NL) score and quality of life (QoL) score for adults aged 19-64. The study included 430 adults. Data were collected through a questionnaire, the Evaluation Instrument of Nutrition Literacy on Adults (EINLA), and the European Health Impact Scale (EUROHIS). Sociodemographic data, anthropometric measurements, and biochemical parameters of adults were collected. The data were interpreted by T-test, One-Way Analysis of Variance (ANOVA), Chi-squared Test, and Pearson correlation analysis through the SPSS 21.0 IBM package program. 59.8% of participants had sufficient NL. Participants with enough EINLA scores had significantly lower body weight, body fat mass, fasting blood glucose, and triglyceride. The mean EUROHIS scores of participants with bachelor/postgraduate degrees were considerably higher than those with primary school graduates. A negative correlation was found between the age and BMI of the participants and their NL scores. It has been shown that there is a very weak positive correlation between the NL score and the QoL level of adults. As the NL level of adults increases, the QoL is expected to improve. According to the findings obtained from the research, it is necessary to increase the community's level of NL.

**Keywords:** Literacy, Nutrition, Nutrition literacy, Quality of life.

## Introduction

According to the World Health Organization (WHO), health is a state of complete physical, mental, and social well-being (WHO, 1948). Although many factors affect health, nutrition is a critical part of health (WHO, 2018). Among the reasons that prevent sufficient and balanced nutrition, the low nutrition literacy (NL) level of adults is an important factor (Kadıoğlu, 2019).

Nutrition literacy is an adult's ability to access, understand and interpret food and nutrition information and to apply this information to his/her life. Increasing the level of NL contributes to accessing accurate information about nutrients, making and implementing healthy nutritional decisions, and protecting and maintaining an adult's health (Aktaş & Özdoğan, 2016).

Quality of life (QoL) is defined as how a person perceives his/her place in life in terms of the culture and values in which he/she lives within the framework of his/her life goals and expectations (WHO, 2012). The prolonged life expectancy of the public has made QoL more important (Eser, 2014). Adults need to be nutritionally literate at a sufficient level for the prevention and management of nutrition-related diseases that negatively affect QoL (T.C. Sağlık Bakanlığı, 2015).

There is a strong relationship between nutrition and QoL. A better QoL can be maintained with a sufficient and balanced diet (Şahin, 2014). It is thought that the QoL can be improved with an increase in the level of NL of the public (Rochman et al., 2018). The study aimed to determine the relationship between NL levels and adult QoL.

## Materials and Methods

### *Objective and Type*

This cross-sectional study was conducted with 124 males and 306 females between May 6, 2019, and January 6, 2020, at Kütahya Evliya Çelebi Training and Research Hospital to determine the relationship between NL levels and QoL in adults.

### *Sample of the Study*

GPOWER 3.1 package program was used to determine the sample size. As a result of the calculations made by taking the 95% confidence level, 0.05 margin of error and the power of the test (1-β) 0.80 (effect size=0.2447225), the minimum sample size was determined as 416 people. Four hundred thirty voluntary adults between the ages of 19-64 years, who were at least in primary school, not pregnant and not wearing a pacemaker and who applied to the diet outpatient clinic for the first time, participated in the study.

### *Data Collection*

Data were obtained using a personal information questionnaire, the Evaluation Instrument of Nutrition Literacy on Adults (EINLA) and the European Health Impact Scale (EUROHIS) (Cesur, 2014; Eser et al., 2011). Necessary permissions were obtained from the scale owners. The personal information questionnaire includes gender, age, education, health status, general characteristics, anthropometric measurements, dietary habits, physical activity status and blood tests (fasting blood glucose (FBG), total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL) and triglycerides) performed in the last 6 months.

The height of the participants was measured with a Mesilife brand height meter. Body weight, body fat mass and fat percentage were measured using a Jawon X-Contact bioelectrical impedance analyser (BIA). Body mass index (BMI) was calculated according to the formula "body weight (kg) / height$^2$ (m$^2$)" using body weight and square meters of height. World Health Organization values were taken as a reference in the evaluation of the BMI of the participants (WHO, 2023).

### *Instruments*

***Evaluation instrument of nutrition literacy on adults (EINLA):*** The EINLA, the validity and reliability of which was performed by Cesur, Kocoglu and Sumer (2015), consists of five subsections and a total of 35 questions. The first sub-section consists of 10 questions on general nutrition information, the second sub-section consists of 6 questions on reading comprehension, and the third sub-section consists of 10 questions on food groups. The fourth sub-section consists of 3 questions on portion sizes, and the fifth sub-section consists of 6 questions on food labelling and numerical literacy (Cesur et al., 2015). Each correct answer is worth one point. In total, scores between 0-11 were reported as insufficient, 12-23 as borderline, and 24-35 as sufficient (Cesur, 2014). Cronbach's alpha on this scale was 0.76 in this study.

***European health impact scale (EUROHIS):*** EUROHIS is a QoL scale comprising eight questions. Responses to survey items were based on a five-point Likert type (1 = not at all; 5 = completely). The EUROHIS total score is formed by a simple summation of scores on the eight items.

As the scale score increases, the QoL increases. Eser et al. (2011) performed its validity and reliability. In this study, Cronbach's alpha on this scale was 0.77.

***Statistical Analysis***

The data obtained in this study was evaluated through SPSS 21.0 IBM (Statistical Program for Social Sciences) program. The Kolmogorov-Smirnov test was utilised to assess the normal distribution conformity of the quantitative data. Since the sample group was normally distributed, parametric tests were used. Descriptive statistical methods were used to analyse sociodemographic data: T-test (t), One-Way Analysis of Variance (ANOVA) (F), and Chi-squared test ($X^2$) were used to compare groups. The Pearson Correlation analysis (r) method was used to determine the relationship between variables. The results were considered statistically significant for $p<0.05$.

***Ethical Dimension of the Research***

Permission was obtained from Kütahya Health Sciences University Non-Interventional Clinical Research Ethics Committee (Decision no: 2019/04, Date: 19.03.2019). Institutional permission was obtained from the Kütahya Evliya Çelebi Training and Research Hospital administration. This study was conducted by the guidelines outlined in the Declaration of Helsinki. Data collection started after informed consent was obtained from all participants.

## Results and Discussion

Among the adults who participated in the study, 71.2% were female, 35.6% were between the ages of 34 and 48, and 35.1% had bachelor/ postgraduate degrees. Participants with at least one chronic disease diagnosed by a doctor comprised 63.5% of the sample. The BMI distribution of the participants showed that 37.7% were obese and 30.7% were overweight (Table 1).

When the scores obtained from the EINLA are analysed, 59.8% of the adults are at the sufficient NL level. While 62.1% of the participants were inadequate for the fifth section and 44.9% for the fourth section (Table 2). Nutrition literacy is one of the most important points for adults in public to exhibit sufficient and balanced nutrition behaviours (Ünal, 2017). In this study, the NL of 59.8% of the participants was sufficient. In various studies, the rate of sufficient NL varies between 32.1% and 94.4% (Cesur, 2014; Özdenk & Özcebe, 2018; Pınarlı, 2019; Uzun, 2019; Ünal, 2017). This may be due to methodological differences in the studies, the scales used, and the dates of the studies. Similar to the finding in this study, Son's study on adults in Afyonkarahisar reported that 61.4% of the participants were nutritionally literate at a sufficient level (Son, 2023). Unal showed that 94.4% of adults had sufficient NL. Unal's study was conducted with adults who applied to the obesity counselling unit (Ünal, 2017). Therefore, it is thought that adults may have a high level of awareness about nutrition and, therefore, a high level of NL. In another recent study, 81.8% of adults were nutritionally literate. Since the study by Demirer and Yardımcı (2023) was conducted on adults working at universities, this rate may have been high. In the study conducted in Kırşehir, the percentage of adults with a sufficient level of NL (32.1%) (Özdenk & Özcebe, 2018) was lower than in this study, which may be due to the difference in the socio-economic development levels of the cities where the research was conducted.

Participants were analysed in three groups: sufficient, borderline, and insufficient regarding EINLA scores. While no significant difference was found between genders (p=0.142), a significant difference was found in terms of age groups, education level, disease and BMI group (p<0.001) (Table 3). Participants with sufficient EINLA scores are mostly distributed in the 19-33 age group (45.1%) and bachelor/ postgraduate degrees (52.5%). In contrast, those with insufficient scores are mostly distributed in those with disease (85%) and obese people (60%).

Supporting the finding in this study, Unal also found no difference between genders (Ünal, 2017). In many studies, the NL of women was found to be higher (Kalkan, 2019; Michou et al., 2019; Son, 2023; Demirer & Yardımcı, 2023). The lack of difference between genders in this study may be because men are now involved in cooking and food shopping in our public.

In this study, in parallel with the literature, the distribution of people with sufficient NL level was in the group of bachelor/postgraduate degrees (Cesur, 2014; Spronk et al., 2014; Ünal, 2017; De Vriendt, Matthys, Verbeke, Pynaert & De Henauw, 2019; Michou et al., 2019). As an adult's educational level increases, nutritional knowledge increases (Cesur, 2014; Zoellner et al., 2019).

The nutritional knowledge level of an adult may be effective in preventing nutrition-related diseases (Madalı et al., 2017). In this study, it was noted that adults with chronic diseases exhibited inadequate NL levels. A low level of NL may make a person more vulnerable to developing the disease. Cesur showed no relationship between chronic disease status and NL level (Cesur, 2014). Unal stated that adults with chronic diseases had higher NL levels (Ünal, 2017).

Based on their EINLA scores, Table 4 shows the participants' mean anthropometric measures and biochemical parameters. It was determined that there was a significant difference between the groups in terms of body weight (F=14.579, $p<0.001$), body fat mass (F=14.798, $p<0.001$), FBG (F=17.170, $p<0.001$), and triglyceride (F=3.701, $p<0.05$) values. Participants with sufficient EINLA scores had significantly lower body weight, body fat mass, FBG, and triglyceride values than those with insufficient and borderline scores.

In this study, participants with sufficient EINLA scores had significantly lower body weight, body fat mass, fasting blood glucose and triglyceride values than insufficient and borderline scores. Mearns et al. showed a positive correlation between NL and high-density lipoprotein value (Mearns et al., 2017). Another study reported that people who received nutrition education had significantly lower fasting blood glucose levels, low-density lipoprotein and total cholesterol (Malek, 2010). It has been shown that NL may affect blood glucose and blood lipid profile.

When the QoL was compared according to the participants' general characteristics, no significant difference was observed in EUROHIS scores regarding gender, age group, disease status and BMI. There was a significant difference in EUROHIS total scores according to the education level of the participants ($p<0.05$). It was shown that participants in primary school had significantly lower EUROHIS total scores than those with bachelor/ postgraduate degrees (Table 5).

In this study, there was a significant difference in EUROHIS total scores according to the educational status of the participants. Akbal found that university graduates had higher EUROHIS scores (Akbal, 2010). Similarly, Eser et al. showed that adults with lower education levels had lower EUROHIS scores (2011). In parallel with the increase in an adult's education level, his/her economic income increases, and he/she can lead a better-quality life.

Table 6 shows the positive correlation between the total score and the first, second, and fifth subscale scores of the EINLA and EUROHIS total scores (r=0.166, p=0.001; r=0.187, $p<0.001$; r=0.172, $p<0.001$; r=0.102, $p<0.05$, respectively).

A negative correlation was discovered between age, all subsections, and the total scores of the EINLA. In parallel with this result, some studies have reported that the NL level decreases with age (Lassetter et al., 2015; Michou et al., 2019). This may be related to the fact that the elderly have more difficulty with math calculations, reading food labels, and portion calculations than younger people.

There was an inverse correlation between BMI and the first, second, third and fifth subsections and total scores of the EINLA. In parallel with the findings in this study, various studies have also shown a negative correlation between BMI and NL (Erem & Bektaş, 2023; Lassetter et al., 2015; Mearns et al., 2017; Pınarlı, 2019; Ünal, 2017). At the same time, it was found that adults with sufficient NL had lower body weight and fat mass. Mearns et al. (2017) and Pınarlı (2019) found a negative correlation between NL and body fat percentage in their studies. NL has the necessary knowledge about sufficient and balanced nutrition and contributes to an adult making the right food choices in this direction (Ünal, 2017).

This study demonstrated a weak positive correlation between the EINLA and EUROHIS scores. Some studies have shown a positive correlation between QoL and NL (Cesur, 2014; Erem & Bektaş, 2023). Sufficient and balanced nutrition improves QoL by preventing nutrition-related diseases and providing the best health status (Amarantos et al., 2001). People with sufficient knowledge about nutrition can pay more attention to their diets, read more food labels, and make more effort to choose healthy food when shopping for food. Thus, they can be protected from nutrition-related diseases and have a higher QoL.

***Limitations***

The study's limitations include the fact that only adults living in Kütahya were included in the sample, and the results cannot be generalised to the population. In addition, the study was conducted in a hospital and was based on self-report.

**Table 1.** Sociodemographic Characteristics and BMI Classification of the Participants (n:430)

| | n | % |
|---|---|---|
| **Gender** | | |
| Male | 124 | 28.8 |
| Female | 306 | 71.2 |
| **Age group** | | |
| 19-33 | 149 | 34.7 |
| 34-48 | 153 | 35.6 |
| 49-64 | 128 | 29.7 |
| **Education level** | | |
| Primary school | 123 | 28.6 |
| Secondary school | 42 | 9.8 |
| High school | 114 | 26.5 |
| Bachelor/ Postgraduate degree | 151 | 35.1 |
| **Profession** | | |
| Housewife | 135 | 31.4 |
| Government employee | 118 | 27.4 |
| Self-employment | 64 | 14.9 |
| Labourer | 53 | 12.3 |
| Retired | 23 | 5.3 |
| Not working | 37 | 8.7 |
| **History of disease** | | |
| Yes | 273 | 63.5 |
| No | 157 | 36.5 |
| **Diseases** *,† | | |
| Obesity | 162 | 34.0 |
| Diabetes mellitus | 83 | 17.4 |
| Hypertension | 75 | 15.7 |
| Digestive System Diseases | 53 | 11.1 |
| Kidney Diseases | 46 | 9.6 |
| Cardiovascular Diseases | 41 | 8.6 |
| Other (Liver Diseases, Neurological Diseases) | 17 | 3.6 |
| **BMI Group** | | |
| Underweight | 15 | 3.5 |
| Normal | 121 | 28.1 |
| Overweight | 132 | 30.7 |
| Obese | 162 | 37.7 |
| | **mean±SD** | |
| Age (years) | 40.23±12.46 | |

*Participants marked more than one option. †Patient adults answered.

**Table 2.** Distribution of the Total and Subsection Scores of the Participants in the EINLA

| | Insufficient | | Borderline | | Sufficient | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| EINLA total | 20 | 4.7 | 153 | 35.6 | 257 | 59.8 |
| **EINLA Sub-section** | | | | | | |
| 1. General Nutrition Information | 11 | 2.6 | 135 | 31.4 | 284 | 66.0 |
| 2. Reading Comprehension | 36 | 8.4 | 118 | 27.4 | 276 | 64.2 |
| 3. Food Groups | 31 | 7.2 | 71 | 16.5 | 328 | 76.3 |
| 4. Size of Servings | 193 | 44.9 | 169 | 39.3 | 68 | 15.8 |
| 5. Food Label and Numerical Literacy | 267 | 62.1 | 110 | 25.6 | 53 | 12.3 |

EINLA: Evaluation Instrument of Nutrition Literacy on Adults

**Table 3.** Comparison of the General Characteristics of the Participants According to Their Scores in the EINLA

| | Insufficient | | Borderline | | Sufficient | | | |
|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | $X^2$ | p |
| **Gender** | | | | | | | | |
| Male | 5 | 25.0 | 53 | 34.6 | 66 | 25.7 | 3.902 | 0.142 |
| Female | 15 | 75.0 | 100 | 65.4 | 191 | 74.3 | | |
| **Age group** | | | | | | | | |
| 19-33 | 1 | 5.0 | 32 | 20.9 | 116 | 45.1 | | |
| 34-48 | 5 | 25.0 | 47 | 30.7 | 101 | 39.3 | **70.275** | **<0.000*** |
| 49-64 | 14 | 70.0 | 74 | 48.4 | 40 | 15.6 | | |
| **Education level** | | | | | | | | |
| Primary school | 17 | 85.0 | 77 | 50.3 | 29 | 11.3 | | |
| Secondary school | 1 | 5.0 | 24 | 15.7 | 17 | 6.6 | **142.981** | **<0.000*** |
| High school | 1 | 5.0 | 37 | 24.2 | 76 | 29.6 | | |
| Bachelor/ Postgraduate degree | 1 | 5.0 | 15 | 9.8 | 135 | 52.5 | | |
| **History of disease** | | | | | | | | |
| Yes | 17 | 85.0 | 116 | 75.8 | 140 | 54.5 | **23.032** | **<0.000*** |
| No | 3 | 15.0 | 37 | 24.2 | 117 | 45.5 | | |
| **BMI Group** | | | | | | | | |
| Underweight | - | - | 2 | 1.3 | 13 | 5.0 | | |
| Normal | 1 | 5.0 | 26 | 17.0 | 94 | 36.6 | **45.508** | **<0.000*** |
| Overweight | 7 | 35.0 | 42 | 27.5 | 83 | 32.3 | | |
| Obese | 12 | 60.0 | 83 | 54.2 | 67 | 26.1 | | |

Chi-squared test. *p<0.001

**Tablo 4.** The Mean Anthropometric Measurements and Biochemical Parameters of the Participants According to the EINLA Scores.

| Insufficient | | | Borderline | | Sufficient | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | F | p |
| **Body weight (kg)** | 84.22 | 15.46 | 80.04 | 15.36 | 72.35 | 15.97 | **14.579**** | **<0.000** |
| **Body fat mass (kg)** | 28.10 | 11.23 | 25.84 | 10.99 | 20.85 | 9.20 | **14.798**** | **<0.000** |
| **FBG (mg/dl)** | 118.90 | 38.55 | 116.25 | 45.32 | 97.10 | 24.06 | **17.170**** | **<0.000** |
| **Total cholesterol (mg/dl)** | 202.20 | 29.51 | 196.10 | 46.67 | 187.51 | 39.22 | 2.756 | 0.065 |
| **Triglycerides (mg/dl)** | 177.75 | 111.09 | 172.40 | 129.33 | 141.26 | 113.11 | **3.701*** | **0.025** |
| **HDL (mg/dl)** | 46.90 | 6.68 | 47.75 | 10.45 | 49.79 | 10.56 | 2.262 | 0.105 |
| **LDL (mg/dl)** | 122.90 | 26.05 | 117.51 | 38.74 | 112.68 | 32.90 | 1.480 | 0.229 |

ANOVA test. **p<0.05,**p<0.001*

**Table 5.** Distribution of EUROHIS Total Scores According to General Characteristics of Participants

| | EUROHIS total score (Mean ±SD) | t/F | p |
|---|---|---|---|
| **Gender**† | | | |
| Male | 29.02±5.11 | 1.408 | 0.160 |
| Female | 28.26±4.77 | | |
| **Age group**‡ | | | |
| 19-33 | 28.32±4.47 | | |
| 34-48 | 29.08±4.84 | 2.037 | 0.132 |
| 49-64 | 27.95±5.31 | | |
| **Education level**‡ | | | |
| Primary school | 27.47±5.61 | | |
| Secondary school | 28.00±5.55 | 3.247 | **0.022*** |
| High school | 28.76±4.79 | | |
| Bachelor/ Postgraduate degree | 29.23±4.22 | | |
| **History of disease**† | | | |
| Yes | 28.18±4.97 | 1.749 | 0.081 |
| No | 29.01±4.66 | | |
| **BMI group**§ | | | |
| Underweight | 28.27±3.84 | | |
| Normal | 28.93±4.39 | 6.807 | 0.078 |
| Overweight | 29.08±4.78 | | |
| Obese | 27.68±5.28 | | |

EUROHIS: European Health Impact Scale
*p<0.05, †T-Test, ‡One-Way ANOVA

**Table 6.** Correlation Between Age, BMI, EUROHIS, and Sub-section and Total Scores of the Participants in the EINLA

| EINLA Sub-section | Age r | BMI r | EUROHIS Total score r |
|---|---|---|---|
| 1. General Nutrition Information | **-0.374†** | **-0.333†** | **0.187** |
| 2. Reading Comprehension | **-0.296†** | **-0.250†** | **0.172** |
| 3. Food Groups | **-0.264†** | **-0.229†** | 0.081 |
| 4. Size of Servings | **-0.141†** | -0.058 | 0.063 |
| 5. Food Label and Numerical Literacy | **-0.430†** | **-0.400†** | **0.102** |
| **EINLA total score** | **-0.453†** | **-0.394†** | **0.166** |

Pearson Correlation. BMI; Body mass index, EINLA; Evaluation Instrument of Nutrition Literacy on Adults, EUROHIS; European Health Impact Scale
*p<0.05, †p<0.01

**Conclusion**

It is thought that the prevalence of obesity can be reduced by increasing the NL level of adults in the public. In this context, some policies should be established, and various training programs should be organised to increase the NL levels of adults in our country. Since the NL level of middle-aged and older adults and adults with chronic diseases is insufficient, nutrition training should be organised for these groups. Although the readability levels of the materials used in nutrition education should be considered, they must appeal to all individuals in the public. Nutrition education should be aimed at individuals applying what they have learned. It is important to increase the educational status of individuals to increase the public's QoL. As the NL level of the public increases, the QoL is also predicted to increase. It is recommended that experts should organise necessary training and conferences on nutrition. Thus, it is thought that the QoL of individuals in the public can increase. This study contributed to the literature as a study investigating the relationship between NL and QoL and shows that further studies with different populations are needed.

**Compliance with Ethical Standards**

**Conflict of interest:** The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** Permission was obtained from Kütahya Health Sciences University Non-Interventional Clinical Research Ethics Committee (Decision no: 2019/04, Date: 19.03.2019).

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*Review Article*

# Effects of several culinary herbs and spices on gut microbiota

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## ABSTRACT

The microbiome of human beings, especially the gut microbiota, appears to be the most potent element of the human body responsible for health and disease. Various herbs and spices often used in cooking and exceptionally high in bioactive substances like polyphenols, terpenes, and flavonoids are getting more attention for their proposed effect on gut health. This study aims to examine the links between culinary herbs and spices and the gut microbiome and to review the latest research findings. Human microbiota has a variable number of bacteria, and the composition and properties of their microbiomes depend on diet, lifestyle, and environmental factors. The current literature demonstrates that phytochemicals in spices and herbs can modify gut microbiota, which may result in lower inflammation, better digestion, and prevention of non-communicable diseases. It has been proven with further studies that herbs such as cinnamon, ginger, turmeric and rosemary are beneficial for the intestines and have shown positive results in animal and human studies. In conclusion, adding culinary herbs and spices to the diet provides a straightforward but powerful means to preserve a healthy gut microbiota, and supports overall better health.

**Keywords:** Culinary herbs, Gut microbiota, Prebiotic, Spices

## Introduction

Bacteria are among the most important microorganisms that inhabit the human body, although viruses, protozoa, fungi, and archaea are also present. All together, they are known as the human microbiome. The bacteria in the digestive system are known as the gut flora or gut microbes. The human body contains more bacterial cells than human cells, with around 40 trillion bacterial cells compared to 30 trillion human cells (Sasso et al., 2023). The collective genome of gut bacteria is more than 100 times larger than the human genome. Given the microbiota's tremendous genetic potential, it is expected to play a role in almost every physiological activity in the human body (Cénit et al., 2014; Hasan & Yang, 2019). The human microbiome is critical for both health and disease. It works close to the digestive tract significantly (Jandhyala, 2015). The gastrointestinal tract is regularly influenced by various environments, significantly affecting the structure, functioning and metabolism of each individual's gut microbiome (Kolodziejczyk et al., 2019). Diet is the main factor in the development of the environment in the human gut. Hence, host diet changes are responsible for microbiome alterations. Gut bacteria perform these functions by digesting complex carbohydrates and amino acids, fermenting food, digesting proteins and lipids, and producing Short-chain fatty acids (SCFAs) – acetate, propionate, and butyrate (Cani et al., 2021).

Using spices and herbs in cooking and medicine can benefit the stomach and other health issues. They have recently gained attention in assessing gut microbes because of their high concentrations of polyphenols, antioxidants, and anti-inflammatory properties. These components provide scope for positive health impacts, which may include a reduction in inflammatory disorders, proper for cardiovascular diseases and obesity in some cases, and prevent incidents of dementia (Kim et al., 2017; Vamanu et al., 2019). The plant leaf is a culinary herb, and any other dried part of the plant is termed a spice. Spices can come from various parts of plants: buds like cloves, bark like cinnamon, roots like ginger, berries like peppercorns, seeds like cumin, and even the stigma of flowers like saffron (Tapsell et al., 2006). Ancient medical systems like Ayurveda, traditional African medicine, and traditional Chinese medicine combine medicinal plants for enhanced biological effects over individual herbs (Mussarat et al., 2021).

The primary goal of this paper is to review recent research on gut microbiota and culinary herbs and spices. This review focuses on cinnamon, ginger, turmeric, and rosemary due to their well-documented bioactive properties and widespread culinary and medicinal use. Cinnamon is known for its antimicrobial and anti-inflammatory properties, ginger for its digestive benefits, turmeric for its anti-inflammatory and antioxidant effects, and rosemary for its antioxidant and mood-enhancing effects. By exploring these herbs, the paper aims to provide insights into how they can influence gut health and overall well-being.

## Role of Culinary Herbs in Traditional Medicine and Cuisine

Herbs and spices have a long history in culinary applications, medicinal properties, and as natural preservatives (Tapsell et al., 2006). Herbs and spices are traditional culinary ingredients used for flavour enhancement, food preservation, aromatic qualities, and most importantly, for medical use, including digestive aid, nausea prevention, and boosting general health in ancient and modern times (Dahl et al., 2023). A papyrus from ancient Egypt, dating back to 1555 BCE, records the use of coriander, fennel, juniper, cumin, garlic, and thyme. The Sumerians utilised thyme for its health benefits starting in 5000 BCE, while Mesopotamian farmers cultivated garlic from 3000 BCE. An ancient trade in spices with Ethiopia lasted from 4500 to 1900 BCE. Egyptians highly regarded garlic, as garlic cloves were discovered in King Tutankhamun's tomb. Mint leaves were found in pyramids in Egypt dating back to approximately 1000 BCE (Block E, 1986; Chevallier A., 1996). Plants were used more often than spices in ancient Greece and Rome. Hippocrates (460 BCE) used over 300 substances, such as locally obtainable garlic and real cinnamon. It has been claimed that garlic can help with uterine cancer. Along with repairing the digestive system, mint was also good to combat all kinds of breath problems. At the same time, liquorice honey was suitable as a dessert to treat all respiratory disorders, even colds, coughs, asthma, and mouth sores. Although centuries before, garlic was also used to improve memory (Sharangi, 2018). Ayurveda, the ancient medical system believed to have originated in the Himalayas over 5000 years ago, was documented in Sanskrit poetry around the Vedas in 1500 BCE. It reached its peak in the seventh century. Ayurveda is a comprehensive medical theory revered as the ultimate health science. It prevents illness by promoting well-being and emphasising good eating habits. Ayurvedic medicine uses various herbs and spices to provide health-promoting benefits. Such herbs and spices include turmeric, used to treat jaundice; basil, which protects the cardiovascular system; mace, which helps with gastrointestinal infections; cinnamon, which enhances blood circulation; and ginger, which is multipurpose and significantly helps in the treatment of nausea. An anecdote elaborates on an individual taking up to 50 grams of garlic per week (Vladirmirescu, 2011).

## Composition and Properties of Gut microbiota

The gut microbiota is a rich ecosystem of numerous microorganisms, including bacteria, viruses, and eukaryotes. It is estimated to carry about ~3.8 × 10^13 microbes, most residing in the lower digestive tract, particularly in the large intestine or colon (Dahl et al., 2023). The state of the host may be linked to the composition of the gut microbiota, which is affected by direct and indirect factors, as shown by Sekirov et al. (2010). The indirect influence of certain factors evidences this fact. Various factors in the intestinal canal are affected by transit time and the nutrients present in the intestine. These factors can vary for individuals based on their health status, medication use, dietary habits, smoking status, and levels of physical activity (Figure 1). All these mentioned factors are strongly interconnected. Many components that account for the variability of gut microbiota have been discovered; however, 80% or more of these factors still lack explanation (Rothschild et al., 2018; Zhernakova et al., 2016).

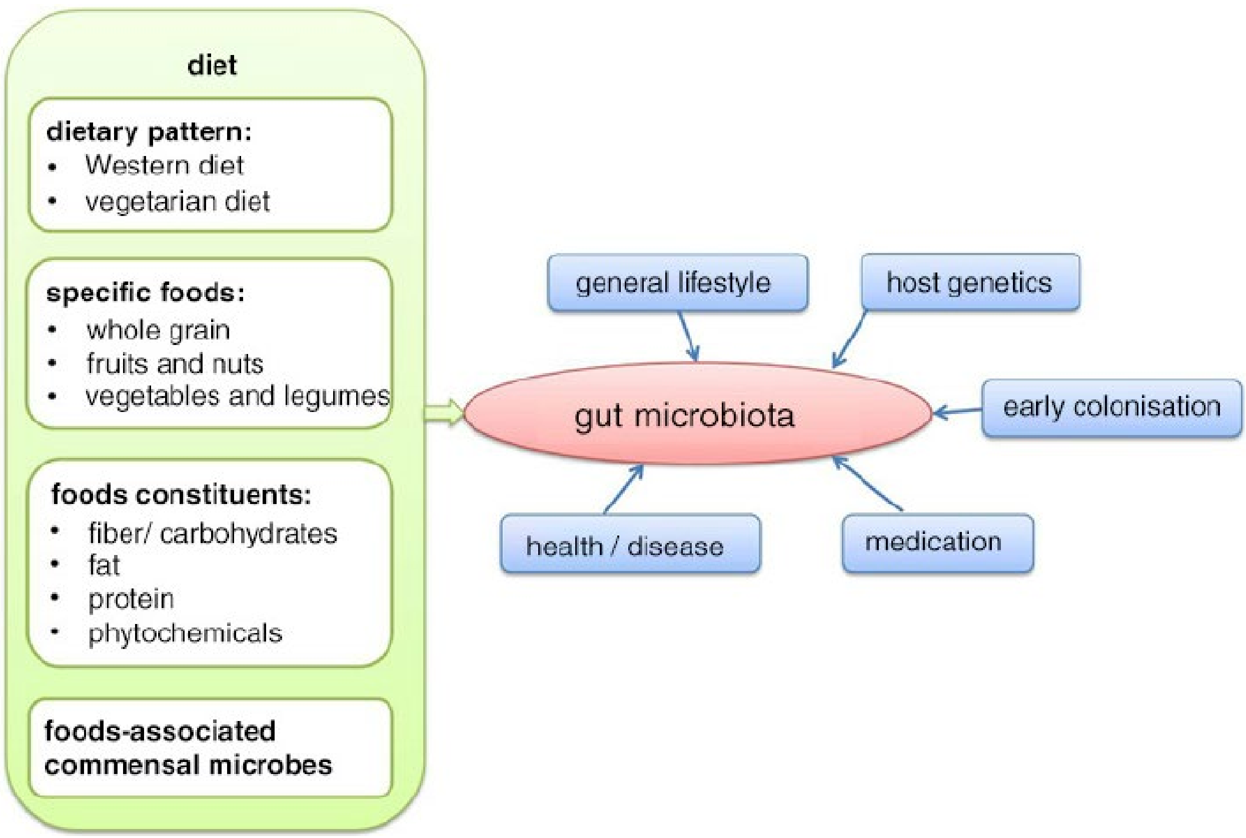


**Figure 1.** Factors affecting the structure of the human gut microbiota, especially emphasising the role of diet (Graf et al., 2015)

Understanding the prerequisites that cause changes in gut microbiota composition is essential for developing interventions to improve health. Individuals consume foods rich in various nutrients with different proportions of bioavailability, not relying solely on individual nutrients. Thus, the concentration of some of these nutrients depends on the consistency of the ingested food and the interaction of its components. Moreover, research has shown that some eating patterns are associated with similar groups; for instance, people who consume a lot of soda or sweets also tend to eat more snacks and fried potatoes (Huseinovic et al., 2019). On the other hand, to determine which dietary patterns are truly beneficial, future nutrition research should focus more on how individual foods are combined (known as dietary patterns) rather than on the consumption of specific nutrients to explore health outcomes (Cespedes & Hu, 2015). Researchers have investigated variations in gut microbiota composition among people depending on diet types, such as vegan/vegetarian and omnivore diets, and adherence levels to the Mediterranean diet. Nevertheless, the fact that the studies reflect only vegans or vegetarians who strictly observe their diet does not necessarily mean that their diet is intrinsically superior to that of non-vegetarians, especially if the studies show only a small gap (only 4.5%) in the Healthy Eating Index between vegans/vegetarians and non-vegetarians (Parker & Vadiveloo, 2019).

## Gut Microbiome and Health

The modulation of the gut microbiome can be achieved by gradually adding new, particular bacteria to a person's diet, for example, through prebiotics (Gibson et al., 2017). Regarding short-chain fatty acids (SCFAs), anaerobic gut microorganisms ferment indigestible carbohydrates—substances that can be potentially beneficial for health—and release gases (including SCFAs) and organic acids into the gut (Rastall & Gibson, 2015). These SCFAs, like butyrate, propionate, and acetate, positively influence gene expression, physiological functions, and a range of health outcomes, including relieving obesity indicators, managing the progression of type 2 diabetes, and potentially acting as anticancer agents. As the primary energy source for colonic epithelial cells, butyrate can be involved in apoptosis regulation, suggesting it can help prevent colon cancer (Canfora et al., 2015; Zeng et al., 2019). Acetate and propionate may contribute to fighting obesity and weight management by releasing satiety hormones and controlling satiety, as Canfora et al. (2019) suggested. Butyrate can reduce fat accumulation in obese individuals, potentially improving insulin sensitivity (Vrieze et al., 2012).

## Culinary Herbs and Spices and Their Effects on Gut Health

Culinary herbs are primarily fresh leaves and flowers. On the other hand, the rest of the parts, including roots, seeds, bark, stems, berries, and buds, are categorised as culinary spices and are typically dried (Tapsell et al., 2006). Culinary spices and herbs are rich in micronutrients and other bioactive components such as polyphenols, terpenes, alkaloids, and flavonoids (Chandrababu & Bastola, 2019; Mukherjee & Chakraborty, 2021; Opara & Chohan, 2014). Despite their influence on the gut microbiome among human groups, a detailed investigation of these dietary components is still lacking, making them an important element to consider in studies on diet and the microbiome. Many pre-clinical research works indicate the capability of cooking herbs and spices, or their vital components, to impact the microbiota of the intestinal system (Rosca et al., 2020; Yang et al., 2020).

For centuries, people have utilised herbs and spices to preserve food, enhance taste, enrich aroma, and provide medicinal benefits such as aiding digestion, treating nausea, and promoting overall health (Böck, 2012). Several herbs and spices used in the past are still important for culinary and medicinal purposes. For instance, liquorice root is commonly used as a natural sweetener to aid digestion. The Mediterranean diet uses garlic, mint, rosemary, thyme, and basil. Individuals with irritable bowel syndrome often use mint supplements to control their symptoms, while allicin, a compound in garlic, is known to reduce cholesterol and high blood pressure.

Despite this evidence, these plants are suggested to contribute to the health benefits of the Mediterranean diet, which reduces the likelihood of non-communicable diseases such as stroke, heart disease, and various cancers (Martinez-Lacoba et al., 2018; Tapsell et al., 2006).

## Specific Culinary Herbs and Their Effects on Gut Health

### *Cinnamon*

It has been increasingly proven that cinnamon's antimicrobial properties and ability to reduce inflammation are responsible for its protective impact against inflammatory bowel diseases (Li et al., 2020). Cinnamon essential oil (CEO), a natural plant-based extract, is considered safe as it is often used in food seasoning and traditional herbal remedies. Recently, the number of research papers describing the therapeutic properties of one of cinnamon's chemical components, cinnamaldehyde, has increased (Chao et al., 2008).

Hou (2015) conducted a study on pigs who were given 50 mg/kg of cinnamon oil in their diets, which reduced the incidence of diarrhoea in pigs post-weaning. Cinnamon oil, which contains antioxidant properties, also helps reduce intestinal damage and enhance intestinal absorption by improving the integrity of mucosal healing. Cinnamon oil can protect the gut against damage from inflammation, infections, and oxidative injuries. In another study carried out by Li et al. (2020), mice that were given cinnamon oil exhibited better variability and quantity of bacteria, with a reduction in Helicobacter and Bacteroides and a rise in Bacteroidales and bacteria generating short-chain fatty acids like Alloprevotella and Lachnospiraceae (Table 1).

***Ginger***

Ginger is from the Zingiberaceae plant family, and its scientific name is Zingiber officinale Roscoe. Although it originated in Asia, it is now grown in the West Indies, Africa, India, and other tropical areas. The underground rhizome is used to produce powdered ginger or spice. It comes in a range of colours, from white to brown. The rhizome can be processed into various products, including powder, syrup, and volatile oil. Ginger has been widely utilised in the culinary world since the 13th century (Singletary, 2010).

Ginger contains several bioactive substances responsible for its known biological processes. These substances include phenolic compounds, terpenes, lipids, and carbohydrates, which are believed to provide numerous health benefits (Jafarzadeh et al., 2021; Kiyama, 2020). The four main phenolic components obtained from ginger are gingerol, shogaols, paradols, and zingerone. These compounds are known for their potent anti-inflammatory and antioxidant properties in vitro (Black et al., 2010; Prasad & Tyagi, 2015). Ginger root is often used in cooking as a seasoning or supplement (Mohd Yusof, 2016). It can enhance the performance of gut bacteria and restore their diversity without causing any harmful effects on the stomach (Y. Lu et al., 2018; Ballester et al., 2022).

Research conducted by Wang et al. (2021) studied the effects of fresh ginger juice consumption on gut microorganisms in healthy individuals. The study involved 123 participants who consumed either ginger juice or a control solution daily. The results showed increased intestinal flora species diversity following ginger juice intervention, accompanied by alterations in specific bacterial taxa. Notably, there was a decrease in pro-inflammatory bacteria and a rise in species with anti-inflammatory properties.

Another study by Shen et al. (2024) analysed the changes in pain-related behaviour caused by the separate and combined use of gingerol-enriched ginger (GEG) in diabetic neuropathic pain (DNP) in rats. The study focused on alterations in physical constructs of inhibition and pain sensitivity and the definite role of the microbiome in neuropathic pain. Additionally, the researchers investigated mitochondrial function. The study involved 33 male rats divided into three groups: controls, DNP, and GEG. Rats treated with GEG during drug withdrawal showed elevated levels of certain gut microbiota and reduced levels of others. Furthermore, GEG induced changes not only in the development of mechanical hypersensitivity but also in anxiety and depressive behaviours.

**Table 1.** Effects of culinary herbs and spices on gut microbiota

| Herb or Spice | Study Type | Effects on Gut Microbiota | References |
|---|---|---|---|
| **Cinnamon** | Animal (mice) | Decrease *Helicobacter* and *Bacteroides*, increase *Alloprevotella* and *Lachnospiraceae* (SCFA producers) | Li et al., 2020 |
| **Ginger** | Human (clinical trial); Animal (rats) | Increase bacterial diversity, decrease pro-inflammatory bacteria | Wang et al., 2021; Shen et al., 2024 |
| **Turmeric** | Animal (broilers); Human (clinical trial) | Increase beneficial bacteria in the ileum, minimal changes in overall gut microbiota composition | Ji et al., 2024; Lopresti et al., 2021 |
| **Rosemary** | Animal (mice) | Increased Lactobacillus and Firmicutes decrease Bacteroidetes and Proteobacteria, which are associated with antidepressant effects and reduced inflammation in mice. | Guo et al., 2018 |

### *Turmeric*

Turmeric, also known as Curcuma longa, belongs to the ginger family. These plants are common in the southern and southwestern Asia regions. In many countries around the globe, turmeric is a common spice. This natural spice generally acts to suppress inflammation, kill microorganisms, scavenge for oxidative radicals, and block the entrance of cancerous cells. It is used as a spice and adds colour, taste, and character to food products. Turmeric has been well-established in India and China for ages and has been confirmed to be a medicine used to cure diseases such as infections, depression, and stress. Curcumin, a lipophilic polyphenol compound, is the primary focus of turmeric's health benefits because it is derived from the herb's roots (Kocaadam & Şanlier, 2017; Vaughn et al., 2016). Curcumin is extracted from the turmeric plant using a solvent and crystallised for purity (Zam, 2018).

An experiment by Ji et al. (2024) researched the impact of supplementing broiler diets with Lonicerae flos and turmeric extract (LTE) on intestinal health and growth performance. Three groups of broilers were studied: a control group (CON), a group containing LTE at a concentration of 300 g/t (LTE300), and another group containing LTE at a concentration of 500 g/t (LTE500). According to the outcomes, LTE supplementation dramatically enhanced gut health and growth performance, improved body and bone weight, and decreased serum endotoxin levels. Additionally, LTE improved the structure of the intestinal and immune systems. Analysis of the data related to microorganisms showed that the probiotic strain LTE300 was favourable for the human ileum.

Another study conducted by Lopresti et al. (2021) investigated the impact of curcumin extract (Curcuge) on gut symptoms and mood in adults diagnosed with self-reported digestive problems. The study was conducted for eight weeks with 79 randomly assigned to two groups: one receiving curcumin and the other a placebo. The findings showed that curcumin significantly reduced gastrointestinal symptoms and anxiety levels compared to the placebo. These findings indicated that the change in intestinal microbiota due to curcumin was minimal; the effect on small intestinal bacterial overgrowth was non-significant. The study suggests that curcumin could aid in relieving digestive symptoms and anxiety, although this mechanism of action might not be linked to changes in gut bacteria. More research is required to discover other mechanisms of curcumin's action on gastrointestinal health.

### *Rosemary*

Rosemary is a plant from the Lamiaceae family, renowned for its use as an herb and seasoning (Sánchez-Camargo & Herrero, 2017). A component of the well-known Mediterranean diet, it can add distinctive organoleptic characteristics (taste, aroma, and texture) to food. Rosemary has been an important part of traditional medicine for treating various minor issues, such as indigestion and common colds, as well as more serious or lethal conditions (González-Vallinas et al., 2015; Ulbricht et al., 2010). Polyphenols in rosemary extracts are noteworthy because their high phenolic content endows them with hepatoprotective, antibacterial, antifungal, and antioxidant qualities (Alizadeh et al., 2016). Despite its food value, rosemary is less commonly used due to its strong taste, odour, and colour. Small industries use chemical methods to remove these characteristics from antioxidants (Aziz et al., 2022).

A study conducted by Guo et al. (2018) found that extracts from rosemary (RE) have antidepressant properties in mice exposed to long-term constant stress, a model for depression in animals. The researchers examined how RE affected depressive-like symptoms, inflammation, and gut microbiota in chronic restraint stress (CRS) mice. The treatment with RE altered the gut microbiota's composition, increasing the proportion of beneficial microorganisms such as *Lactobacillu*s and *Firmicute*s while decreasing the percentage of potentially harmful bacteria such as *Bacteroidetes* and *Proteobacteria* (Table 1).

## Conclusion

Culinary spices and herbs are strong candidates for balancing the microbiota and restoring gut health. Bioactive substances, with their variety of physiological activities, may possess the potential to protect from inflammation, improve digestion, and lower the risk of chronic diseases. The value of herbs and spices in traditional medicine underscores their significance in human health across different populations and centuries. The gut microbiome resides in the gastrointestinal tract, and various factors such as diet, cooking methods, and existing microbes can influence it. Recent research has demonstrated that culinary herbs and spices can modify the microbiota in the intestinal tract. Adequate and properly conducted clinical trials are essential to validate that herbal remedies are sustainable methods of maintaining gut health and preventing gastrointestinal diseases. The widespread use of adding different herbs and spices to the diet can be an easy and effective strategy for bowel health and overall well-being. By utilising the natural properties of these compounds on a small scale, we can fine-tune our gut microbiome and help our immune system combat various health threats.

**Compliance with Ethical Standards**

**Conflict of interest:** The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** -

**Data availability:** -

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# Ultra işlenmiş besinlerin bazı hastalıklar ile ilişkisi

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## ÖZ

Ultra işlenmiş besinler şeker, tuz, sıvı ve katı yağların ana ürün olduğu kimyasal gıda katkı maddelerini de içeren çok bileşenli endüstriyel formülasyonlar olarak tanımlanmaktadır. Ultra işlenmiş besinlerin genel üretim amaçları; düşük maliyetli ve toplu üretim, uzun raf ömürlü ve markalı ürünler elde etmektir. Ultra işlenmiş besinleri ifade etmek için NOVA Grup 4 sınıflaması kullanılmaktadır. Paketli atıştırmalıklar (cips, kek, kraker, şeker vb.), yemeye ve ısıtılmaya hazır dondurulmuş ürünler, et ve tavuk ekstraktı ürünleri (bulyon, toz karışımlar), işlenmiş et ürünleri (sosisli sandiviç, nuggetstar), gazlı içecekler, meşrubatlar, paket süt ve kakaolu içecekler vb. ürünler ultra işlenmiş besinleri oluşturmaktadır. Ultra işlenmiş özellikle saf şeker içerikli besinlerin fazla tüketilmesi boş enerji alımına neden olduğundan elzem birtakım besin ögelerinin alımında yetersizliğe sebep olmaktadır. Ayrıca ultra işlenmiş besinler günlük diyetin enerji yoğunluğunu, şeker, doymuş yağ ve trans yağ asidi seviyelerini arttırmaktadır. Yüksek enerji yoğunluklu beslenme düzeni ise insanların vücut ağırlıklarında artışa sebep olmaktadır. Ayrıca yetersiz posa alımı ve obeziteye bağlı olarak diyabet, kardiyovasküler hastalıkları, hipertansiyon, böbrek hastalıkları, kolon, rektal ve meme kanseri gibi kronik hastalıklar da ortaya çıkabilmektedir. Bu nedenle küresel gıda sektörünün gelişmesine karşılık ülkeler kendi ulusal politikalarını geliştirmeli ve halk sağlığı için ultra işlenmiş besinlerin tüketimini azaltıcı çalışmalar yapmaları gerekmektedir.

**Anahtar Kelimeler:** NOVA grup 4, Obezite, Sağlık, Ultra işlenmiş besinler

## ABSTRACT

### The relationship of ultra-processed foods with some diseases

Ultra-processed foods are defined as multi-component industrial formulations that include chemical food additives in food production where sugar, salt, oils and fats are the main products. General production purposes of ultra-processed foods are to obtain low-cost and mass production, long shelf-life and branded products. NOVA Group 4 classification is used to express ultra-processed foods. Packaged snacks (chips, cake, crackers, candy, etc.), frozen products, meat and chicken extract products (bouillon, powder mixtures), processed meat products (hot dog, nugget star), fizzy drinks, beverages, packaged milk and cocoa drinks, etc. constitute ultra-processed foods. Excessive consumption of ultra-processed foods, especially those containing free sugar, causes the intake of empty calories and causes insufficient intake of some essential nutrients. Also, ultra-processed foods increase the energy density, sugar, saturated fat and trans fatty acid levels of the daily diet. A high-energy-density diet causes an increase in people's body weight. In addition to these results, chronic diseases such as diabetes, cardiovascular diseases, hypertension, kidney diseases, and colon, rectal and breast cancer may occur due to insufficient fibre intake and obesity. Therefore, in response to the development of the global food industry, countries should develop their own national policies and work to reduce the consumption of ultra-processed foods for public health.

**Keywords:** Health, NOVA group 4, Obesity, Ultra-processed foods

## Giriş

Son yıllarda küresel gıda sektörü besinin işlenmesinde ve teknolojideki ilerlemeler nedeniyle ultra işlenmiş besinlerin bulunabilirliğinin ve alım gücünün artması, pazarlama ağının genişlemesi ile sonuçlanan belirgin değişiklikler geçirmiştir. Gelişen besin işleme teknikleri ile besinin yapısında, içeriğinde ve lezzetinde önemli değişiklikler görülmüştür. Geleneksel olarak hazırlanan yemeklerin yerini zamanla endüstriyel olarak işlenmiş besinler almıştır (Poti ve ark., 2017). Böylece ultra işlenmiş besinler kısa sürede küresel gıda sektörünün en önemli unsuru haline gelmiştir. Artan dünya nüfusu, günlük çalışma sürelerinin uzaması, ucuz maliyetli üretim ve ultra işlenmiş besinlerin tüketime hazır olması tüketimlerinin bu denli yaygınlaşmasına sebep olmuştur (Cediel ve ark., 2018).

Ultra işlenmiş besinler şeker, tuz, sıvı ve katı yağların ana ürün olduğu, gıda üretiminde kullanılmayan bazı maddelerin (özellikle az işlenmiş besinler) duyusal özelliklerini taklit etmek için kullanılan, kimyasal gıda katkı maddelerini içeren çok bileşenli endüstriyel formülasyonlar olarak tanımlanmaktadır (Steele ve ark., 2016). Alkolsüz içecekler, tatlı veya tuzlu paketlenmiş atıştırmalıklar ve önceden hazırlanmış dondurulmuş yemekler gibi besinler ultra işlenmiş besinlere örnek olarak verilebilmektedir (Monteiro ve ark., 2018). Bu besinlerin genel üretim amaçları; düşük maliyetli ve toplu üretim, uzun raf ömürlü ve markalı ürünler elde etmektir. Ultra işlenmiş besinler, işlenmemiş veya az işlenmiş besinlere göre maksimum lezzet, markalaşma ve küresel pazar yükü ile önemli bir avantaja sahiptir (Monteiro ve ark., 2019).

Ultra işlenmiş besinler işlenmeleri sırasında bazı besin ögesi kayıplarına uğrayabilmekte, kullanılan bileşenler daha yoğun işlemlerden geçmekte ve genellikle enerji içeriği yoğun, besin ögesi bakımından dengesiz ürünler oluşmaktadır. Ultra işlenmiş besinlerin sağlık açısından olumsuz özelliği yağ, şeker ve tuz içeriğinin yüksek olmasıdır. Renklendiriciler, aromalar ve emülgatörler gibi katkı maddeleri, bu enerji içeriği yoğun besinleri daha çekici hale getirmek için ilave edilmektedir (Levine ve Ubbink, 2023). Pek çok gözlemsel çalışmada ultra işlenmiş besin tüketiminin çocuk ve yetişkinlerde vücut ağırlığında artış ve yetişkinlerde obeziteye bağlı pek çok kronik hastalık riskinin artmasıyla ilişkili olduğu gösterilmiştir (Elizabeth ve ark., 2020; Jardim ve ark., 2021; Zhang & Giovannucci, 2023). Bu derleme çalışmasında ultra işlenmiş besinler hakkında detaylı bilgi sunulup, bu besinlerin besin bileşimi kalitesi ve bazı hastalıklar ile ilişkisinin incelenmesi amaçlanmıştır.

## Besinlerin İşleme Düzeylerine Göre Sınıflandırılması

Ultra işlenmiş besinleri daha iyi anlayabilmek adına farklı işleme seviyeleri arasında ayrım yapan besinlerin sınıflandırılmasına ihtiyaç duyulmuştur (Poti ve ark., 2017). Besinlerin işleme düzeylerine göre yapılan birkaç sınıflama olmasına rağmen yaygın olarak NOVA kullanılmaktadır. NOVA sınıflaması obezite ve tip 2 diyabette görülen anormal artış sonrası Brezilyalı epidemiyologlar tarafından 2014 yılında geliştirilmiştir ve dört alt gruptan oluşmaktadır (Fardet, 2018).

### *NOVA Grup 1 (İşlenmemiş veya Az İşlenmiş Besinler)*

İşlenmemiş besinler, bitki ve hayvanların ham (çiğ) olanlarını ifade etmek için kullanılmaktadır. Az işlenmiş besinler ise yenilebilir bitki ve hayvan dokularına haşlama, kavurma, öğütme, alkolsüz fermantasyon gibi basit işleme yöntemlerinin uygulanmasıyla elde edilen besinlerdir (Elizabeth ve ark., 2020). Bu işlemler uygulanırken tuz, şeker, sıvı ve katı yağ gibi yeni maddeler eklenmemektedir. Bu işlemler doğal besinleri korumak, depolamaya uygun hale getirmek veya bu besinleri güvenle yenilebilir ve tüketilmesi daha keyifli hale getirebilmek için uygulanmaktadır (Monteiro ve ark., 2018). Meyveler, kök ve yaprak sebzeler, baklagiller, mantar, %100 meyve ve sebze suları, kırmızı et, tavuk, balık, deniz ürünleri, yumurta, süt, yoğurt, tahıllar, makarna, yağlı tohumlar, baharatlar, otlar, çaylar, kahveler, içme suları vb. örnekler verilebilmektedir (Cooper, 2018).

### *NOVA Grup 2 (İşlenmiş Yemeklik Ürünler)*

İşlenmiş yemeklik ürünler yemeği hazırlamak ve pişirmek için kullanılan maddelerdir. Bu maddelere tuz, şeker, pekmez, bal, un, bitkisel yağlar ve tereyağı gibi örnekler verilebilmektedir (Tristan-Asensi ve ark., 2023). Bu tür ürünleri tek başına yenilemeyen, ancak bir yemekte kullanıldığında yemeğin lezzetini arttıran ve yemeğin hazırlanmasına katkı sağlayan ürünler olarak düşünmek gerekmektedir (Monteiro ve ark., 2018).

NOVA Grup 1'de az işlenmiş besinlerden daha yüksek işleme seviyesini göstermek için bu grup 'orta derecede işlenmiş besinler' olarak da adlandırılabilmektedir. Örneğin, haşlanmış yumurta az işlenmiş bir besin olarak kabul edilirken, az miktarda yağ kullanılarak kızarmış yumurta (omlet) ise orta derecede işlenmiş bir besin olarak kabul edilmektedir (Cooper, 2018).

Unlar da işlenmiş bir ürün olarak kabul edilebilmektedir. Çünkü buğdaydan un elde edilirken çeşitli vitamin, mineral ve posa kaybı yaşanmakta ve sonuç olarak lezzet yönünden yeni bir ürün elde edilmektedir (Levine & Ubbink, 2023).

### *NOVA Grup 3 (İşlenmiş Besinler)*

Bu gruptaki besinler NOVA Grup 1'deki besinlere NOVA Grup 2'deki yemeklik ürünlerin eklenmesiyle oluşmaktadır. NOVA Grup 3'teki besinler aynı zamanda yüksek işlenmiş besinler olarak da ifade edilmektedir (Cooper, 2018). Burada işlemenin amacı NOVA Grup 1 besinlerin dayanıklılığını arttırmak veya duyusal niteliklerini değiştirmek ve geliştirmektir (Monteiro ve ark., 2018). Taze ekmek, taze peynir, bazı konserve ürünleri bu grup besinlere örnek olarak verilebilmektedir (Elizabeth ve ark., 2020).

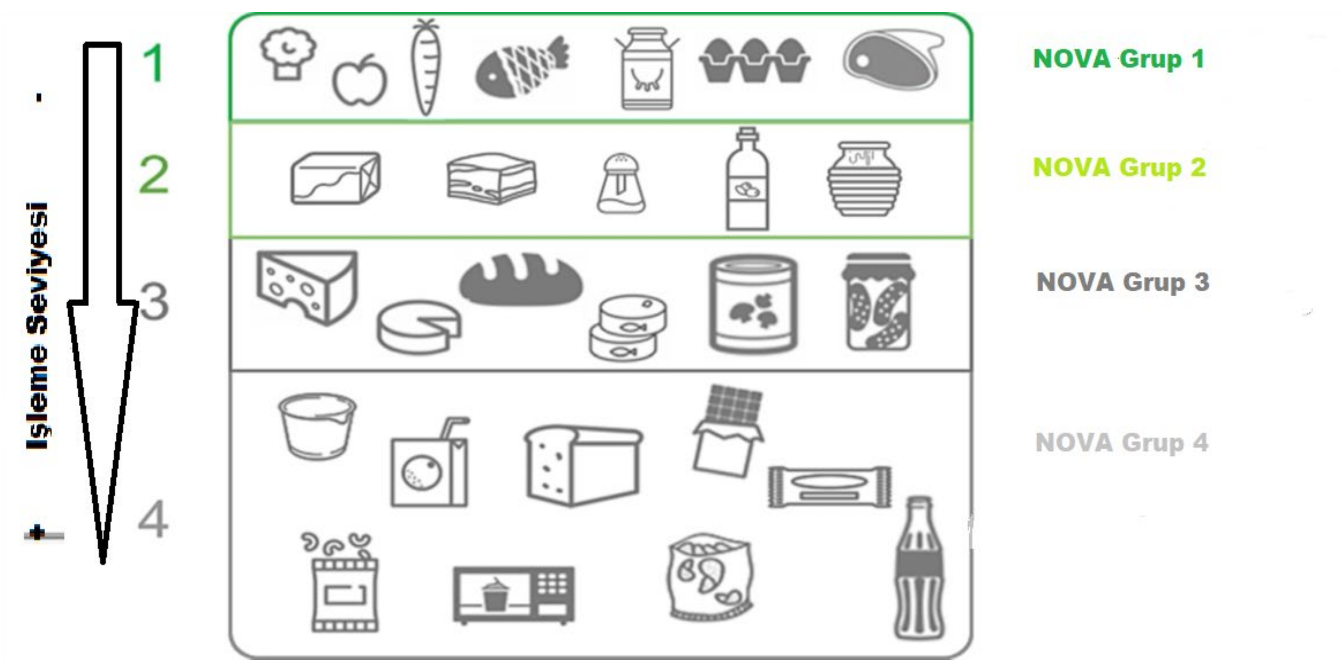
Konserve ürünlerin sınıflandırılması da kendi içinde;

- Kendi suyunda veya %100 suyunda paketlenmiş konserve meyveler, tuz eklenmemiş sebze ve baklagiller, su içinde paketlenmiş konserve balıklar az işlenmiş besinler (NOVA Grup 1),
- Şeker, tuz, yağ gibi diğer maddelerin eklendiği konserve ürünler ise yüksek işlenmiş besinler (NOVA Grup 3) olarak sınıflandırılmaktadır (Cooper, 2018).

### *NOVA Grup 4 (Ultra İşlenmiş Besinler ve İçecekler)*

Bu gruptaki besinleri tanımlamak tüketiciler, sağlık personelleri ve araştırmacılar için dahi zor olabilmektedir (Levine ve Ubbink, 2023). Kısaca ultra işlenmiş besinler bir dizi endüstriyel işlemden geçirilmiş, çoğunlukla özel endüstriyel kullanıma sahip çok bileşenli formülasyonlar olarak tanımlanabilmektedir (Steele ve ark., 2016). Ekmek yapımında sadece un, su, tuz ve maya kullanılarak oluşturulan ekmekler işlenmiş besinler grubuna; bu temel maddeler dışında ayrıca emülgatör, renklendirici ve bazı gıda katkı maddelerinin eklenmesiyle oluşan ekmekleri ise ultra işlenmiş besinler grubuna dahil edilebilmektedir. Rafine edilmiş buğday, yulaf, sade kornflakes az işlenmiş besinler grubunda iken; içerisine şeker, lezzetlendirici ve renklendirici gibi gıda katkı maddelerinin eklenip işlenmesiyle oluşmuş ürünler ise ultra işlenmiş besinler grubunda yer almaktadır (Monteiro ve ark., 2019).

Ayrıca paketli atıştırmalıklar (cips, kek, kraker, şeker vb.), yemeye ve ısıtılmaya hazır dondurulmuş ürünler, et ve tavuk ekstratı ürünleri (bulyon, toz karışımlar), işlenmiş et ürünleri (sosisli sandiviç, nuggetstar), gazlı içecekler, meşrubatlar, paket süt ve kakaolu içecekler vb. ürünler ultra işlenmiş besinleri oluşturmaktadır (Monteiro ve ark., 2018).




**Şekil 1.** Besinlerin işleme seviyelerine göre NOVA sınıflaması (Fardet, 2018)

**Figure 1.** NOVA classification of foods according to their processing levels (Fardet, 2018)

**Tablo 1**. PFDI'ya göre besinlerin sınıflandırılması

**Table 1.** Classification of foods according to PFDI

| PFDI Grup 0 (İşlenmemiş Besinler) | PFDI Grup 1 (Az İşlenmiş Besinler) | PFDI Grup 2 (Orta Derecede İşlenmiş Besinler) | PFDI Grup 3 (Yüksek Derecede İşlenmiş Besinler) | PFDI Grup 4 (Ultra İşlenmiş Besinler) |
|---|---|---|---|---|
| Taze sebze ve meyveler, mantarlar, yağlı tohumlar, taze otlar, su vb. | Dondurulmuş, kurutulmuş, vakumlanmış, paketlenmiş meyve, sebze ve mantar konserveleri; %100 meyve suları, şekersiz elma püresi, bitkisel yağlar, su içinde paketlenmiş konserve balıklar, pişmiş tahıllar, baklagiller, et ve kümes hayvanları, deniz ürünleri, haşlanmış yumurta, pastörize sade süt ve yoğurt, baharatlar, kuru otlar vb. | Tuz, şeker veya şurup eklenmiş sebze, meyve veya baklagil konserveleri; yağ eklenmiş balık konserveler, sebze turşuları, tavada kızartılmış sebze, et ve yumurtalar; şeker veya tuz eklenmiş fındık/tohum ezmeler; bira, elma şarabı, şarap vb. | Yapılan yemekleri kapsamaktadır. Doğal peynirler, kızartılmış besinler, salamura besinler, makarna, hazır ekmek, kekler, hamur işleri, şarküteri et ürünleri, viski, cin, rom, votka vb. | Bu sınıflama NOVA Grup 4 sınıflamasına benzerlik gösterir. Paketlenmiş kek, bisküvi, kraker vb; kahvaltılık gevrekler, enerji barları, paketli ekmek ve çörekler, et ve tavuk ekstratları (hot dog, tavuk nugget), zenginleştirilmiş ürünler, işlenmiş peynirler, margarinler, aromalı süt ve yoğurtlar vb. |

Besinlerin işleme düzeylerine göre yapılan bir başka sınıflama ise The Processed Food Dietary Index (PFDI) aşağıdaki tabloda verilmiştir (Cooper, 2018).

## Ultra İşlenmiş Besinlerin Üretim Aşamaları

Son yıllarda endüstriyel besin işleme teknikleri dünya çapında hızlı bir değişim göstermiştir. Isıtma, dondurma, kurutma, yıkama, fermantasyon, öğütme, pastörizasyon, paketleme ve diğer pek çok işlem besin işleme tekniklerindendir (Crimarco ve ark., 2022). Pastörizasyon gibi işlemler ham besinlerin güvenliğine katkı sağlarken, kurutma ve dondurma gibi işlemler ise besin ögesi kaybının önlenmesine yardım etmektedir. Bununla birlikte teknolojinin gelişmesiyle besin işlemenin doğası, kapsamı ve amacı büyük ölçüde değişmiş ve çoğu kez işlenmiş besin ürünlerinin besin kalitesini etkilemiştir (Seale ve ark., 2020). Besinler giderek daha fazla işlem dizisine tabi tutularak işlenir hale gelmiştir. Bu daha kapsamlı işleme teknikleri ise ürünleri taze besinlerden daha uzun süre güvenle koruyabilmeyi mümkün hale getirmiştir (Crimarco ve ark., 2022).

Ultra işlenmiş besinlerin üretimini sağlayan süreçler aşağıdaki endüstriyel adımları içermektedir (Monteiro ve ark., 2019; Capozzi, 2022);

1. Bütün besinlerin şeker, sıvı/katı yağlar, proteinler, nişastalar ve posa içeren maddelere ayrışmasıyla bu süreç başlamaktadır. Bu besinlerin ham maddeleri yüksek verimli bitkisel besinlerin (buğday, mısır, soya, pancar vb) veya hayvan karkaslarının püre edilmesinden, öğütülmesinden oluşmaktadır.
2. Bu besinlerin bazıları daha sonra hidrolize, hidrojenasyona veya bazı kimyasal değişikliklere maruz bırakılmaktadır.
3. Daha sonraki işlemler ise işlenmiş ve işlenmemiş besin maddelerinin ekstrüzyon, kalıplama ve ön kızartma gibi endüstriyel teknikler kullanılarak az miktarda besin ile birleşmesini içermektedir.
4. Nihai ürünleri daha fazla lezzetlendirebilmek için renklendiriciler, lezzetlendiriciler, emülsifiye ediciler ve diğer gıda katkı maddeleri sıklıkla eklenmektedir.
5. Süreç ise sentetik malzemelerden geliştirilmiş ambalajlama işlemi ile son bulmaktadır.

## Ultra İşlenmiş Besinlerin Üretiminde Kullanılan Gıda Katkı Maddeleri

Ultra işlenmiş besinleri tüketicinin arzu ettiği görünüm ve lezzete getirmek, besinlerin raf ömrünü uzatmak ve besin değerini koruyabilmek amacıyla besinlerin işleme aşamasının son basamaklarında bilinçli olarak ilave edilen kimyasal maddelere gıda katkı maddeleri adı verilmektedir (Karatepe & Ekerbiçer, 2017). Şu an dünya üzerinde 8000'in üzerinde gıda katkı maddesi vardır. Amerika Birleşik Devletleri'nde kullanımına onay verilen yaklaşık 2800 adet, Avrupa Birliği ülkelerinde ise 330'dan fazla gıda katkı maddesi bulunmaktadır (Chazelas ve ark., 2020). Ülkemizde ise 19 adet tatlandırıcı, 40 adet renklendirici ve 276 adet diğer katkı maddeleri olmak üzere toplam 335 adet gıda katkı maddesine onay verilmiştir (Eroğlu ve Ayaz, 2018). Sadece ultra işlenmiş besinlerin üretiminde kullanılan gıda katkı maddeleri koruyucular, antioksidanlar, aroma maddeleri, tatlandırıcılar, renklendirici ve ağartıcılar, emülgatörler, stabilizatörler, olgunlaştırıcılar, tampon maddeler, topaklaşmayı önleyici maddeler, kıvam vericiler, köpük yapıcı maddeler, tutucu maddeler, durultma maddeleri, yumuşatıcılar ve plastik yapı kazandırıcı maddelerdir. Bu gıda katkı maddeleri ultra işlenmiş besinlerdeki istenmeyen duyusal özellikleri gizlemekte, görüntü, tat, koku ve dokunma gibi duyuları tüketicilere daha cazip hale getirmektedir (Monteiro ve ark., 2019).

Besin etiketlerinde 'E' kodunu taşıyan gıda katkı maddeleri toksikolojik açıdan güvenilir gıda katkı maddeleri olarak tanımlanmaktadır. 8000'in üzerindeki gıda katkı maddelerinin şu an sadece 350-400 adedi 'E' kodunu taşımaktadır (Atman, 2004).

## Ultra İşlenmiş Besinlerin İçeriği ve Kalitesi

Genellikle bağırsak parazitlerinin neden olduğu düşünülen ancak temelinde diyetle yetersiz alımın sebep olduğu mikro besin ögesi eksiklikleri, gelişmekte olan ülkelerde yaşayan 5 yaş altı çocukların en az yarısında görülüp dünya genelinde 2 milyar kişiyi etkileyen ve çeşitli hastalıklar için risk faktörü olarak belirtilen bir durumdur (Louzada ve ark., 2015a). Ultra işlenmiş özellikle saf şeker içerikli besinlerin fazla tüketilmesi boş enerji alımına neden olduğundan elzem birtakım besin ögelerinin alımında yetersizliğe sebep olmaktadır (Steele ve ark., 2016; Levine & Ubbink, 2023).

İki yaş ve üzeri 33694 katılımcı üzerinde yapılan bir çalışmada ultra işlenmiş besin tüketimi ile diyetle enerji, karbonhidrat, saf şeker ve doymuş yağ alımları arasında pozitif korelasyon; protein, posa, A, C, D, B6 ve B12 vitamini, niasin, tiamin, riboflavin, çinko, demir, magnezyum, kalsiyum, fosfor ve potasyum alımları arasında ise negatif korelasyon olduğu görülmüştür (Moubarac ve ark., 2017). Yapılan bir başka çalışmada ise ultra işlenmiş besin tüketimi yüksek olan katılımcıların diyetle daha fazla enerji, karbonhidrat, saf şeker, toplam ve doymuş yağ alımı görülürken; daha düşük protein ve posa alımlarının olduğu görülmüştür (Vergeer ve ark., 2019). Ultra işlenmiş besinlerin mikro besin öğeleriyle ilişkisini inceleyen bir başka çalışmada ultra işlenmiş besinlerin yüksek tüketimi ile günlük diyetle alınan D, E, B12 vitamini, niasin, pridoksin, bakır, demir, fosfor, magnezyum, selenyum ve çinko arasında negatif korelasyon ($p<0.05$); kalsiyum, tiamin ve riboflavin arasında ise pozitif yönlü bir korelasyon gözlenmiştir (Louzada ve ark., 2015b). Kolombiya'da 5-12 yaş arası çocuklar arasında yapılan bir başka çalışmada ise ultra işlenmiş besin tüketimi arttıkça günlük diyetle alınan omaga-3 yağ asidi, çoklu doymamış yağ asidi, A, B2, C, E vitamini, kalsiyum ve magnezyum düzeylerinde azalma; sodyum, şeker ve trans yağ asidi düzeylerinde ise artış gözlenmiştir (Cornwell ve ark., 2017). Bielemann ve ark. (2015)' nın yapmış oldukları çalışmada da bireylerin günlük enerji alımlarının ultra işlenmiş besinlerden sağlama oranı arttıkça günlük diyetle alınan yağ, kolesterol, sodyum, demir, kalsiyum ve enerji miktarında artma; karbonhidrat, protein ve diyet posasında ise azalma tespit etmiştir ($p<0.001$). Ayrıca Martini ve ark. (2021)' nın yapmış oldukları bir meta analiz çalışma sonucuna göre ultra işlenmiş besin tüketimi arttıkça günlük diyetle alınan saf şeker, toplam ve doymuş yağ miktarında artma; protein, posa, potasyum, çinko, magnezyum, A, C, D, E, niasin ve B12 vitamin miktarlarında ise azalma olduğunu saptamıştır. Bu noktada ultra işlenmiş besinlerin diyeti sağlıksız bir noktaya sürüklediği ifade edilebilir.

**Tablo 2.**'E' Koduna Göre Gıda Katkı Maddelerinin Temel İşlevlerine Göre Sınıflandırılması (Karatepe & Ekerbiçer, 2017)

**Table 2.** Classification of Food Additives According to Their Basic Functions According to 'E' Code (Karatepe & Ekerbiçer, 2017)

| Gıda Katkı Maddeleri | 'E' Kod Numarası |
|---|---|
| Renklendiriciler | 100-180 |
| Koruyucular | 200-297 |
| Antioksidanlar | 300-321 |
| Emülsifiyerler ve Stabilizatörler | 322-500 |
| Asit-Baz Sağlayıcıları | 500-578 |
| Tatlandırıcılar ve Koku vericiler | 620-637 |
| Diğer Gıda Katkı Maddeleri | 900-927 |

## Bazı Hastalıklar ile İlişkisi

Ultra işlenmiş besinler ile kronik hastalıklar arasında ilişkiyi gösteren pek çok çalışma bulunmaktadır. Bunların başında obezite, diyabet, kanser gibi günümüz toplumunun büyük bir kesimini etkileyen hastalıklar vardır. Bu bölümde ultra işlenmiş besin tüketimi ile bahsi geçen hastalıklar arasındaki ilişkiyi ortaya koyan literatür verileri incelenmiştir.

### *Obezite*

Günümüzde hızla artan sayıda ultra işlenmiş besinler üreten ve satan çok büyük uluslararası şirketler tarafından yönetilen küresel gıda sektörü dünya çapında obez sayısındaki artıştan sorumludur (Moubarac ve ark., 2014). Çünkü ultra işlenmiş besinler günlük diyetin enerji yoğunluğunu, şeker, doymuş yağ ve trans yağ asidi seviyelerini arttırmaktadır. Yüksek enerji yoğunluklu beslenme düzeni ise insan vücudunun enerji dengesini düzenlemesini zorlaştırmakta ve bu durum da insanların aşırı ağırlık kazanımlarına sebep olmaktadır (Louzada ve ark., 2015a). Yaş aralığı 20-64 olan 15977 birey üzerinde yapılan bir çalışmada özellikle kadınlarda ultra işlenmiş besin tüketimi ile beden kütle indeksi ($p=0.002$) ve bel çevresi değerleri ($p=0.008$) arasında pozitif yönlü bir ilişkinin olduğu görülmüştür (Juul ve ark., 2018). İsveç'te yapılan uzun süreli bir çalışmada ise (1960-2010) 1980 ile 2010 yılları arasında ultra işlenmiş besinlerden soda tüketiminde %315; cips ve şekerlemeler gibi aperitif besinlerde ise %367'lik bir artış görülmüştür. Ultra işlenmiş besin tüketim oranlarındaki bu değişimlere paralel olarak yetişkin obezite oranı 1980'de %5 iken; 2010'da ise %11'in üzerine çıkmıştır (Juul & Hemmingsson, 2015). Costa ve ark. (2019)' nın 307 çocuk üzerinde yaptıkları çalışmada da bireylerin günlük aldıkları enerjinin ultra işlenmiş besinlerden gelen yüzdesi arttıkça bel çevresinin anlamlı derecede arttığını saptamıştır ($p<0.05$). Bu durumda ultra işlenmiş besin tüketiminin doğrudan obezite için bir risk faktörü olduğu söylenebilir.

### *Diyabet ve Metabolik Sendrom*

Yetersiz posa alımı ve obeziteye bağlı olarak diyabet, koroner kalp hastalıkları, hipertansiyon, kolon, rektal ve meme kanseri gibi hastalıklar da ortaya çıkabilmektedir (Louzada ve ark., 2015a). Bu tip bulaşıcı olmayan hastalıklardan dünya geneli mortalitenin %70'inden sorumlu olduğu bilinmektedir. Ultra işlenmiş besin tüketimindeki artış, sağlıksız beslenme alışkanlıklarının görülmesi ile birlikte bulaşıcı olmayan kronik hastalıklarda da artış görülmektedir (Chen ve ark., 2020). Srour ve ark. (2019a) Fransa'da yetişkinler üzerinde yaptıkları bir çalışmada ultra işlenmiş besin tüketimi ile tip 2 diyabet gelişmesi riski arasında pozitif yönlü bir korelasyon gözlemiştir ($r=1.15$; $p=0.0009$). Bir başka çalışmada ise ultra işlenmiş besin ve içeceklerin aşırı tüketimi ile yüksek tip 2 diyabet riski arasında anlamlı derecede ilişki olduğu tespit edilmiştir (Llavero-Valero ve ark., 2021). Tavares ve arkadaşları (2011) yapmış oldukları çalışmada metabolik sendromlu adölesanlarda günlük ortalama enerji, karbonhidrat ve ultra işlenmiş besin alımlarının daha yüksek olduğunu gözlemiştir ($p<0.05$). Yapılan bir başka çalışmada ise 20 yaş üstü katılımcıların günlük enerji alımlarının ultra işlenmiş besinlerden sağlama yüzdesindeki her %10' luk artış metabolik sendrom prevalansındaki %4'lük artışla ilişkilendirilmiştir (Steele ve ark., 2019).

### *Hipertansiyon ve Kardiyovasküler Hastalıklar*

Kardiyovasküler hastalıklar kalp ve damarlarda önemli morbidite ve mortaliteye sahip, dünya çapında önde gelen mortalite sebebidir (Gaidai ve ark., 2023). Mendonça ve arkadaşları (2017) İspanyol yetişkinler üzerinde yaptıkları çalışmada ultra işlenmiş besinlerin fazla tüketimi ile hipertansiyon gelişme riskinin yüksek olduğu sonucuna ulaşmıştır ($r=1.21$; $p=0.004$). Yapılan başka çalışmada ultra işlenmiş besin tüketimi yüksek olan bireylerin düşük olanlara göre hipertansiyon görülme riskinin %23 daha fazla olduğu tespit edilmiştir (Silva-Scaranni ve ark., 2021). Bir başka çalışmada da ultra işlenmiş besinlerin fazla tüketilmesi daha yüksek kardiyovasküler hastalık riski ile ilişkili bulunmuştur (Srour ve ark., 2019b). Bonaccio ve ark. (2022)' nın yapmış oldukları çalışmada ise ultra işlenmiş besinleri fazla tüketen katılımcıların az tüketenlere göre tüm nedenlere bağlı mortalite riskleri (OR:1.38; %95 GA; Cl: 1.00-1,91) ve kardiyovasküler hastalıklar kaynaklı mortalite risklerinin (OR:1.65; %95 GA; Cl: 1.07-2.55) daha yüksek olduğunu saptamıştır ($p<0.05$).

### *Kanser*

Kanser önemli mortalite nedenlerinden biridir. Dünya çapında 2020 verilerine göre yaklaşık 10 milyon ölüme veya altı ölümden birine neden olduğu bildirilmiştir. En sık görülen kanser türleri meme, akciğer, kolon, rektum ve prostat kanserleridir (WHO, 2022). Besin işleme derecesi ile artmış kanser riski arasındaki ilişki son yıllarda araştırma konusu olmuştur (Lian ve ark., 2023). Yapılan bir çalışmada ultra işlenmiş besin tüketim oranının %10 artmasıyla tüm kanser riskini 1.12 kat, meme kanseri riskini ise 1.11 kat arttırdığı görülmüştür (Fiolet ve ark., 2018). Kolonoskopi yapılarak çalışmaya dahil edilen 652 katılımcı üzerinde yapılan bir çalışmada ise yüksek ultra işlenmiş besin tüketimi ile tespit edilen kolorektal adenomlarla arasında pozitif bir ilişki olduğu görülmüştür (OR:1.75; %95 GA; Cl: 1.14-2.68) (Fliss-Isakov ve ark., 2020). Yapılan bir meta analiz sonucuna göre ultra işlenmiş besin tüketimi ile prostat hariç kolorektal, meme, pankreas, kronik lenfositik lösemi, merkezi sinir sistemi tümörleri ve genel kanser riski arasında anlamlı pozitif bir ilişkinin olduğu bildirilmiştir (Isaksen & Dankel, 2023).

### *Böbrek ve Bağırsak Hastalıkları*

Dünya geneli kronik böbrek hastalıklarına bağlı ölümlerin sayısı son 20 yılda artmış ve kronik böbrek hastalıklarından etkilen insan sayısının da artması beklenmektedir (Kityo & Lee, 2022). Cai ve ark. (2021) yapmış oldukları çalışmada günlük beslenmede ultra işlenmiş besin alımındaki %10'luk artışta kronik böbrek hastalıkları riskini 1.07 kat arttırdığını saptamıştır ($p<0.05$). Liu ve arkadaşları (2023) yapmış oldukları çalışmada da 153985 katılımcının 12.1 yıllık takibi sonrası 4058'inin yeni başlangıçlı kronik böbrek hastalığı teşhisi konduğunu tespit etmiştir. Aynı çalışmada diyabeti olan katılımcıların günlük beslenmede ultra işlenmiş besin alımındaki %10'luk artışta kronik böbrek hastalıkları riskini 1.11 kat, diyabeti olmayan katılımcılarda ise 1.03 kat arttırdığını gözlemiştir. Yapılan bir meta analiz sonucuna göre ultra işlenmiş besin alımındaki her %10'luk artış %7 daha yüksek kronik böbrek hastalıkları riski ile ilişkili bulunmuştur (OR:1.07; %95 GA; Cl: 1.04-1.10; $p<0.001$) (He ve ark., 2024).

Ultra işlenmiş besinlerin fazla tüketilmesi düşük posa ve sebze tüketimine neden olacağından dolayı bağırsak sağlığını olumsuz etkilemektedir (Leo & Campos, 2020). Schnabel ve ark. (2018) yapmış oldukları çalışmada ultra işlenmiş besin tüketimi arttıkça irritabl bağırsak sendromu vakalarında artış olduğunu saptamıştır. Narula ve arkadaşlarının (2021) yapmış oldukları çalışmada 9.7 yıllık takip sonrası 116087 yetişkin katılımcının 467'sinde inflamatuvar bağırsak hastalığı gelişmiştir. Aynı çalışmada ultra işlenmiş besinlerin fazla tüketilmesi inflamatuvar bağırsak hastalığı riskini 1.82 kat arttırdığı tespit edilmiştir (OR:1.82; %95 GA; Cl: 1.22-2,72; p: 0.006). Ayrıca yapılan bir kohort araştırmasında 7.7 yıllık takip sonrası 440 ölüm olduğu gözlenmiş ve sonuç olarak ultra işlenmiş besin tüketimi ile mortalite arasında pozitif bir ilişki olduğu görülmüştür (Rojo ve ark., 2019).

## SONUÇ

Ultra işlenmiş besinlerin tüketimi ile günlük beslenmede saf şeker, tuz ve doymuş yağ alımı artmakta; protein, posa, vitamin ve mineral alımı ise azalmaktadır. Bu durum da enerjisi yoğun ve boş enerji içerikli beslenme sonucunda başta obezite olmak üzere beslenmeyle ilişkili bulaşıcı olmayan kronik hastalıkların artışına neden olmaktadır. Bu yüzden küresel gıda sektörünün gelişmesine karşılık ülkeler kendi ulusal politikalarını geliştirmeli, sağlıklı besinlere erişilebilirlik kolaylaştırılmalı ve halk sağlığı için ultra işlenmiş besinlerin tüketimini azaltıcı çalışmalar yapılması gerekmektedir. Özellikle endüstriyelleşerek kentlerde yoğun bir şekilde yaşamaya başlayan toplumun çeşitli destekler ile tekrar kırsal yaşama döndürülmesi ve buna bağlı olarak işlenmemiş tarım ve hayvancılık üretiminin arttırılması sağlanmalıdır. Bunu takiben kırsalda artan üretimin hak ettiği değeri bulması, kent yaşamındaki halka yüksek oranda fiyat artışı yaşanmadan aktarılması için de gerekli önlemler alınmalıdır. Sağlıklı bir toplum hedefine hastalıkları tedavi etmekle değil hastalıkları önleyerek ulaşmak gerekliliğinden yola çıkarak tüketilen besinlerin doğal ortamda yetişmesi ve toplumun tamamına dağıtılması ülkelerin başlıca sağlık politikası konusu olmalıdır.

#### Etik Standartlar ile Uyumluluk

**Çıkar çatışması:** Yazarlar, bu yazı için gerçek, potansiyel veya algılanan çıkar çatışması olmadığını beyan etmişlerdir.

**Etik izin:** Araştırma niteliği bakımından etik izne tabii değildir.

**Veri erişilebilirliği:** -

**Finansal destek:** Bu çalışma herhangi bir fon tarafından desteklenmemiştir.

**Teşekkür:** -

**Açıklama:** -

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# Impact and interventions of waterborne and foodborne illnesses caused by bacterial pathogens in Nigeria: A review

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## ABSTRACT

Waterborne and foodborne illnesses caused by bacterial pathogens are major public health concerns, especially in developing countries like Nigeria—waterborne pathogens such as *Escherichia coli, Salmonella* spp. and *Klebsiella* spp. Contribute to the spread of health challenges, primarily due to poor sanitation, contaminated drinking water, and inadequate hygiene. Similarly, foodborne pathogens, including *Escherichia coli, Listeria monocytogenes* and *Salmonella* spp., are major causes of human illness, with animal-based foods often acting as transmission vectors. This review examines the current state of diagnosis, highlighting that most household water sources in Nigeria are vulnerable to contamination, with significant microbial loads exceeding WHO standards. It raises the need for effective interventions such as improved hygiene practices, water supply, sanitation and food safety management systems. Furthermore, this review discusses the impact of these pathogens on public health, noting that waterborne and foodborne diseases result in substantial mortality and economic burdens. Also, implementing good hygienic practices, Hazard Analysis Critical Control Point (HACCP) systems, and public health education are essential strategies for reducing the incidence of these diseases. This review concludes by calling for a collaborative effort among governments, policymakers, stakeholders, and researchers to develop and implement multifaceted interventions to combat these pervasive health threats.

**Keywords:** Waterborne illness, Foodborne pathogen, Public health, Contamination, Interventions

## Introduction

Waterborne illnesses are health problems caused by consuming water contaminated with disease-causing microbes or pathogens. These pathogens are transmitted directly to humans when contaminated water is used for drinking, bathing, washing, and cooking (Meki et al., 2022). *Salmonella* spp., *Escherichia coli, Klebsiella* spp., *Proteus mirabilis, and Enterobacter* spp. are some bacteria associated with waterborne diseases (Iwuala et al., 2018). The problems encountered with drinking water in some parts of Nigeria have raised public health concerns. According to the World Health Organization, over 2.6 billion people lack access to safe drinking water, which causes approximately 2.2 million deaths each year, 1.4 million of which are children (WHO, 2023; Nwabor, 2016). In another report, the United Nations Department of Economic and Social Affairs -UNDESA (2019) estimated that nearly 900 million people worldwide cannot access safe drinking water. Despite numerous efforts by various levels of government and other organisations interested in water and its safety, waterborne diseases remain a major public health and environmental concern.

Foodborne microorganisms are major pathogens that affect food safety and cause human illness worldwide. Bacteria cause two-thirds of human foodborne diseases worldwide, with a disproportionate burden in developing countries like Nigeria (Gugsa & Meselu, 2020; Etinosa et al., 2021). Food from animals is the primary reservoir of many foodborne bacterial pathogens, and animal-derived foods are the main transmission vehicles. *Staphylococcus aureus, Salmonella* spp., *Campylobacter* spp., *Listeria monocytogenes, and Escherichia coli* are the most common bacterial pathogens that cause foodborne illness and death worldwide when contaminated animal products are consumed (Bintsis, 2017; Oduori et al., 2022; WHO, 2022). Human infections caused by these major bacteria are characterised by gastrointestinal symptoms such as nausea, vomiting, diarrhoea, abdominal cramps, and other agent-specific symptoms (Odeyemi, 2016). Some strains can lead to serious complications or even death (WHO, 2022).

## Current State of Diagnosis

### *State of Diagnosis for Waterborne Illnesses*

At all economic levels, drinking water has a well-documented history of spreading microbial infections to large populations and inflicting disease. For instance, Cholera is a waterborne illness influenced by rainfall, drought, and global climate events, with a high ability to be transferred from one person to another. Its epidemiology begins in endemic areas and expands to congested slums and refugee camps, with human displacement being a significant factor in its spread from one location to another (Rebaudet, 2013). Unimproved water supply, poor sanitation, faecal contamination, limited level of education for caregivers, improper hygiene, and climate change are major factors responsible for such poor water quality in developing countries and the spread of illness (Cissé, 2019; Adamu et al., 2020). Also, the microbiological quality of household drinking water in Enugu City and Delta State, Nigeria, showed unsafe standards for drinking (Ocheli et al., 2020; Okpasuo et al., 2020). For instance, *Escherichia coli* (38.0%), *Giardia lamblia* (35.2%), *Entamoeba histolytica* (33.0%), *Salmonella typhi* (19.9%), *Proteus* spp. (13.2%), *Shigella dysentery* (9.4%), *Klebsiella spp*. (7.4%), *Enterobacter spp*. (5.5%), and *Cryptosporidium spp*. (5.2%) were found in 344 (85.4%) of the 403 samples collected from stool, using a cross-sectional multi-stage sampling design across Enugu State, Nigeria (Okpasuo et al., 2020). Table 1 presents major waterborne and foodborne pathogens that cause illness. Transmission ways for waterborne pathogens include consumption of contaminated water, recreational activities such as swimming in contaminated pools, lakes, rivers, or oceans, inadequate sewage disposal and lack of proper sanitation facilities, runoff from agricultural fields carrying pathogens, improper storage and handling of water, climate and environmental factors like heavy rains, floods, and natural disasters (Shanmugam et al., 2024). Radiopharmaceutical and medical waste also pose risks to soil and water contamination, affecting plants and food products (Cetinkaya, 2024). Seasonal factors affecting biological contamination include microbial contamination of groundwater, which was higher in the dry season than in the wet season (Ocheli et al., 2020).

According to the findings, most household water sources are vulnerable to contamination at multiple points along their journey from source to mouth (Okpasuo et al., 2020). Except for a few locations in Okigwe (sachet water 1%) and Orlu zone (borehole 2%), most drinking water sources in Imo state, Nigeria, had bacterial loads exceeding WHO standards of zero total coliform colonies/100 mL (Okpasuo et al., 2020). The study area had a significant relationship between water quality and hospital records of waterborne illness (Iwuala et al., 2018). Similar findings were observed in Sokoto, Shuni, and Tambuwal (Nwabor et al., 2016). Water samples from 96% of the wells in Ibadan Municipal City were found to be contaminated with both total and faecal coliform counts ranging from 0 to $160 x 10^3$/100 ml and 0 to $22 x 10^3$/100 ml, respectively (Odeleye & Idowu, 2015).

**Table 1.** Major waterborne and Foodborne Pathogens that cause Illness in Nigeria

| Bacterial Pathogens | Illnesses | Sources | References |
|---|---|---|---|
| **Waterborne** | | | |
| *Escherichia coli* | Diarrhoea, urinary tract infections, respiratory illness, and pneumonia | Contaminated water, food, and direct contact with infected animals or people | Okpasuo et al., 2020; WHO, 2022 |
| *Salmonella* spp. | Typhoid fever, paratyphoid fever, and salmonellosis | Contaminated water, food (especially poultry, eggs, and dairy products) | Heredia and Garcia, (2018). WHO, 2022 |
| *Vibrio cholerae* | Cholera | Contaminated water, seafood, and other foods. | Rebaudet, 2013; WHO, 2022 |
| *Giardia lamblia* | Giardiasis | Contaminated water, food, and surfaces | Okpasuo et al., 2020 |
| *Cryptosporidium* spp. | Cryptosporidium spp. | Contaminated water, food, and surfaces | Okpasuo et al., 2020; WHO, 2022 |
| *Shigella* spp. | Shigellosis (bacillary dysentery) | Contaminated water, food, and person-to-person contact | Nwabor et al., 2016 |
| **Foodborne** | | | |
| *Salmonella* spp. | Salmonellosis, typhoid fever | Contaminated food, especially poultry, eggs, and dairy products | Heredia and Garcia, (2018). WHO, 2022 |
| *Escherichia coli* | Diarrhoea, urinary tract infections, respiratory illness, and pneumonia | Contaminated food, water, and direct contact with infected animals or people | Odeyemi, 2016; WHO, 2022 |
| *Campylobacter* spp. | Campylobacteriosis | Contaminated food, particularly raw or undercooked poultry, unpasteurised milk, and untreated water | WHO, 2022 |
| *Listeria monocytogenes* | Listeriosis | Contaminated food, especially dairy products, deli meats, and smoked fish | Bintsis, 2017; Oduori et al., 2022 |
| *Norovirus* | Gastroenteritis | Contaminated food, water, and surfaces | WHO, 2022 |
| *Staphylococcus aureus* | Staphylococcal food poisoning | Contaminated food, particularly those that are improperly stored or handled | Bintsis, 2017 |
| *Bacillus anthracis* | Enteritis | Contaminated food, particularly rice and other starchy foods that are left at room temperature for too long | Ghareeb and Ali, 2023 |

Waterborne pathogens originate from several sources, including animal excretions, human and livestock faecal wastes, and contaminated food products. Animal excretions serve as a significant reservoir for zoonotic pathogens like *Bacillus anthracis, Campylobacter jejuni, Escherichia coli, Salmonella enterica,* and *Vibrio cholera*, which can lead to severe infections when transmitted through water (Ghareeb & Ali, 2023). Human, industrial, agricultural and livestock faecal wastes, often due to failing septic systems or improper manure management, can contaminate groundwater with microbial pathogens, necessitating the testing of water samples for microbial indicators as a warning sign of potentially pathogenic microorganisms (Danilova, 2020). Additionally, contaminated food products can harbour pathogens such as *Escherichia coli, Listeria monocytogenes, Salmonella, Shigella, Adenovirus, and Cryptosporidium*, emphasising the need for innovative pathogen detection techniques and stringent food safety management in the industry (Dimitrakopoulou et al., 2024). Environmental reservoirs like water, river, lake, and water-related devices can also harbour antimicrobial-resistant bacteria, including *Pseudomonas aeruginosa, Mycobacterium* spp, and *Legionella* spp, highlighting the importance of surveillance strategies to prevent healthcare-associated infections (Hayward et al., 2020).

### *State of Diagnosis for Foodborne Illnesses*

Several pathogens have been identified as causing foodborne illnesses, with the most common pathogenic bacteria being *Escherichia coli, Salmonella* spp., *Campylobacter* spp., *Listeria* spp., and *Enterobacteria* spp. *Listeria monocytogenes* are found in unpasteurised dairy products and various ready-to-eat foods (Laslo & Gyorgy, 2019; Oduori et al., 2022). For instance, *Salmonellosis* outbreaks are caused by raw milk, raw or undercooked poultry, and contaminated drinks (Heredia & Garcia, 2018). The occurrences of *Vibrio Cholera* are linked to rice, vegetables, millet gruel, and various types of seafood (Bintsis, 2017; WHO, 2022). Transmission ways for foodborne pathogens can occur through contaminated raw ingredients, improper cooking, cross-contamination, poor food storage, unhygienic food handling, use of contaminated water, improper preservation, and infected food handlers (Shanmugam et al., 2024). Furthermore, the World Health Organization estimates that foodborne pathogens kill more than 200,000 people in Nigeria each year due to improper processing, preservation, and service (Ibginosa, 2021). Therefore, contaminated drinking water and poor food handling practices cause microbial infections, health issues, and high mortality rates due to inadequate sanitation, poor hygiene, and climate change.

## Impact on Public Health

### *Impact of Waterborne Illnesses on Public Health*

According to WHO (2022), 5.8 billion people will use safely managed drinking water services in 2020 because many water sources have been improved and are contamination-free. Bacterial pathogens cause the spread of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid, and polio; these health risks are preventable. Each year, it is estimated that 505,000 people die from diarrhoea caused by unsafe drinking water, poor sanitation, and poor hygiene (WHO, 2022). However, diarrhoea is largely preventable, and 297,000 children under five could be saved each year if these risk factors were addressed (WHO, 2022). Two thousand twenty-one more than 251.4 million people needed schistosomiasis prevention treatment, an acute and chronic disease caused by parasitic worms contracted through contact with infected water (WHO, 2022). For instance, residents of Yenagoa, Nigeria, have limited access to clean water, which predisposes them to diarrhoea and typhoid diseases, of which more cases were reported during the dry season (Ohwo & Omidiji, 2021). Other waterborne illnesses include skin and infectious eye illnesses like trachoma. Trachoma can cause vision loss or blindness, and rural populations, children, elders and health-challenged individuals are at a higher risk.

### *Impact of Foodborne Illnesses on Public Health*

The rising mortality rate associated with preventable foodborne illnesses is a major concern, as it disproportionately affects infants, young children, adults and sick people. According to a World Health Organization (WHO) report, 550 million people become ill and die each year as a result of diarrheal diseases caused by eating foods contaminated with microbial pathogens (WHO, 2022). The overall productivity loss caused by foodborne diseases in developing countries is estimated to cost $95.2 billion annually, with approximately $15 billion spent on treating foodborne illnesses (WHO, 2023). Nigeria has the highest burden of foodborne illness in the AFR D subregion, with 1276 (459-2263) Disability Adjusted Life Years (DALYs) per 100,000 populations (Oduori et al., 2022). In Nigeria, stunting and malnutrition are prevalent in children under the age of five, with prevalence rates of 36.8% and 8.9%, respectively (National Population Commission (NPC), 2019). In developing countries, bacterial and parasitic diseases are associated risk factors with malnutrition.

### *Intervention*

*Interventions of waterborne illness*

In accordance with SDG 6 - Clean Water and Sanitation, statistically, according to the World Health Organization (2010), these intervention practices can prevent 94% of waterborne diarrheal cases. Water supply, sanitation, hand washing, household water treatment, and safe storage reduce diarrhoea by 25%, 32%, 45%, and 39%, respectively (Manetu & Karanja, 2021). Other intervention methods include organising waterborne disease sensitisation campaigns, collaborating with health organisations to support the Nigerian government directly, and reducing unsafe drinking water and waterborne illnesses in Nigeria (Adeyinka et al., 2014). Regular monitoring of drinking water using quality indicators is essential for reducing public health hazards.

Meki et al. (2022) discovered that using 2 doses of cholera vaccines, an adequate potable water supply and safe storage, household disinfection, point-of-use chlorination, and hygiene improvement are effective methods for controlling cholera outbreaks. Therefore, interventions should be specific. Furthermore, in Ile-Ife, Nigeria, it was discovered that most cases were caused by poor sanitation, with most residents using open-pit toilets and living near market centres where large amounts of waste were generated and improperly disposed of in nearby streams. Therefore, separating human waste from drinking water is paramount (Manetu & Karanja, 2021).

WHO collaborates closely with UNICEF on various water and health issues, including water, sanitation, and hygiene in healthcare facilities. WASH FIT (Water and Sanitation for Health Facility Improvement Tool) aims to help small, primary healthcare facilities in low- and middle-income areas through a continuous cycle of improvement that includes risk assessments, risk prioritisation, and the creation of specific, targeted actions (WHO, 2022).

Good hygienic practices and Hazard Analysis Critical Control Point (HACCP) systems are essential tools in mitigating waterborne illness by identifying possible risks and implementing proper disposal of waste and sewage to prevent contamination of water sources and food, ensuring access to clean and safe drinking water by treating water sources with filtration, chlorination, or boiling; regular monitoring of water quality to detect and address contamination promptly (Onu et al., 2024). Alternative methods and technologies for interventions can also be implemented, such as boiling, household slow sand filters, filtration and preventive strategies for water management (Ocheli et al., 2020).

*Intervention of foodborne illnesses*

The control and prevention of foodborne illness can be achieved through good hygienic practices (GHPs), sanitation in operating procedures, and the implementation of standardised Hazard Analysis Critical Control Points (HACCP) and pasteurisation procedures in food processes (Bintsis, 2017; Etinosa et al., 2021). The emergence of multidrug-resistant bacteria associated with consuming contaminated animal products is currently a major public health concern, and there should be a coordinated surveillance and monitoring system for foodborne bacterial pathogens, particularly in developing countries such as Nigeria (Gugsa & Meselu, 2020). Food safety management systems are currently being developed to estimate the risks to human health posed by food consumption and to identify, select, and implement mitigation strategies for controlling and reducing these risks (Odeyami, 2016). Furthermore, applying appropriate food safety education programs for everyone involved in food production and consumption is critical to actualizing SDGs target 2 – Zero hunger.

Good hygienic practices and HACCP models are significant means of fostering foodborne pathogens through regular handwashing with soap and clean water, especially before handling food and after using the toilet, ensuring food handlers are free from infectious diseases and have access to clean clothing and protective gear; regular cleaning and disinfecting of food preparation and storage areas; keeping raw and cooked foods separate to prevent cross-contamination; cooking food to appropriate temperatures to kill harmful pathogens; storing food at safe temperatures to prevent the growth of bacteria (Dimitrakopoulou et al., 2024; WHO, 2023).

Comprehensive management plans should also aim to assess and identify vulnerable populations at risk of waterborne and foodborne illnesses. It involves conducting baseline surveys, mapping high-risk areas, improving water quality through infrastructure development, and implementing water treatment programs. Regular testing and testing ensure compliance with WHO standards. Enhancement of food safety involves safe food handling practices, training programs, and regular inspections. Education and awareness campaigns are launched to promote hygiene, safe water, and food practices (Onu et al., 2024). Healthcare interventions include improved access to medical care, vaccination programs, and antimicrobial stewardship. Emergency response and contingency planning involve developing contingency plans for rapid response to disease outbreaks, establishing early warning systems, and training community health workers. Collaboration and partnerships with government agencies, Non-Governmental Organizations (NGOs), and international bodies are encouraged. Community involvement is encouraged to foster a sense of ownership and responsibility. Sustainable practices include environmental management, waste management, and long-term monitoring (Hayward et al., 2020). By implementing this comprehensive management plan, vulnerable populations can be better protected from waterborne and foodborne illnesses, improving overall health and well-being.

## Conclusion

In conclusion, waterborne and foodborne illnesses caused by bacterial pathogens pose significant public health challenges, especially in developing countries like Nigeria. Contaminated water and food sources cause cholera, typhoid, and foodborne infections. Infrastructure development, regular testing, and community-based programs are essential to manage these illnesses. Food safety can be enhanced through proper handling, regulations, and inspections. Education, awareness campaigns, and healthcare interventions are crucial. Collaboration between government agencies, NGOs, policymakers, stakeholders, researchers, the general public and international organisations is essential. Rapid methods like biosensors for detecting pathogens are also needed, alongside human capacity development in cutting-edge technologies and detection methods.

**Compliance with Ethical Standards**

**Conflict of interest:** The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** -

**Data availability:** -

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**Disclosure:** -

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The journal "**FOOD and HEALTH**" establishes the highest standards of publishing ethics and benefits from the contents of the **International Committee of Medical Journal Editors (ICMJE)**, **World Association of Medical Editors** (WAME), **Council of Science Editors (CSE)**, **Committee on Publication Ethics** (COPE), **European Association of Science Editors (EASE)**, **Open Access Scholarly and Publishers Association (OASPA)**, and **Directory of Open Access Journals (DOAJ).**

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**Title (should be clear, descriptive, and not too long)**

**Full Name(s) and Surname (s) of author(s)**

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**Material and Methods**

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**Conclusion**

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| Type of manuscript | Page | Abstract word limit | Reference limit |
|---|---|---|---|
| Original Article | ≤30 | 200 | 40 |
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....(Erkan, 2011).

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