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# The Effect of Water and Ultrasound-Assisted Bath Extractions on the Bioactive Properties, Phenolic Compounds and Minerals of Germinated and Barley and Wheat Seeds

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## ABSTRACT

**Germination is an economical, simple, rapid, and highly efficient method for enhancing the nutritional and bioactive properties of cereal grains. This study evaluated the chemical composition and bioactive compounds of barley and wheat seeds subjected to germination and sonication treatments using analytical, spectrophotometric, and chromatographic methods. The total phenolic amouns of the barley and wheat seed samples were defined to be between 97.37 (control) and 177.28 (germinated barley) to 46.49 (control) and 164.69 mgGAE/100g (germinated wheat, respectively. While total flavonoid contents of the barley are assayed between 30.20 (germinated barley) and 32.75 mg/100g (control), total flavonoid amounts of the wheat were described to be between 2.93 (control) and 18.74 mg/100g (germinated). Germination and sonication of barley and wheat seeds resulted in an increase moisture content, total phenolic compoundst, and antioxidant activity compared to the control samples. The highest concentrations of catechin was detected in barley samples, while rutin was detected in wheat samples. Because sonication (ultrasonic extraction) allows for greater extraction (removal) of phenolic compounds in plants, an increase in phenolic compound levels can be observed after sonication. In addition, antioxidant activities of germinated barley and wheat seeds were stated to be between 4.11 (control) and 8.18 mmol/kg (germinated barley) to 3.72 (control for wheat) and 7.97 mmol/kg (germinated wheat), respectively. P was macroelement detected in the highest amounts in barley samples. As a microelement, Zn and Mn contents of barley samples were assayed to be between 18.37 and 31.10 mg/kg to 14.32 and 15.66 mg/kg, respectively.**

**The chemical properties of germinated and sonicated barley and wheat seeds showed significant differences compared to the control, demonstrating the potential of these treatments to enhance the bioactive and nutritional quality of cereal grains.**

**Keywords:** cereal, water- and ultrasonic bath, germination, bioactive componds.

## INTRODUCTION

Wheat (*Triticum aestivum* L.) is among the most widely produced grains in the world. Because wheat production is affected by climate change, it undergoes a natural germination or sprouting process under conditions of high humidity and temperature (Nonogaki et al., 2019; El-Berawey and Eldebawy, 2025). Phenolic constituents and antioxidant activities of cereals have been the focus of research in recent years (Shamanin et al., 2022; Baranzelli et al., 2023; Menga et al., 2023). In addition, barley (Hordeum vulgare L.) is considered one of the world's most important economic and food crops. Barley has been traditionally used in the animal feed and malt industries and is increasingly being used as an ingredient in food products due to its biologically active components (Martinez et al., 2018; Madakemohekar et al., 2018). Barley, which has the potential to be used as a partial or complete substitute in a wide variety of grain-based foods, is used in breakfast cereals, casseroles, soups, porridges, flour mixes and baby foods, while in Middle Eastern and African countries it is used in bread, biscuits, pita bread, porridge, cakes and yufka breads after being ground (Domon et al., 1993; Lukinac and Juki'c, 2022). Phenolic compounds, which cannot be synthesized in the human body and are important products of secondary metabolism in plants, are mostly

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consumed through food. Phenolic acids, flavonoids, and lignans are distributed throughout the structural domains of grains and constitute important sources of dietary polyphenols (Azmir et al., 2013; Tian et al., 2019). The addition of various additives to foods to extend shelf life and improve sensory qualities such as flavor, odor, and appearance leads to numerous health problems, leading conscious consumers to seek natural foods rich in vitamins, minerals, bioactive compounds, and antioxidants (Yetim et al., 2009; Şenlik and Alkan, 2021). Germination, on the other hand, is an economical, simple, rapid, and highly efficient method. It is defined as the biochemical and physiological changes that occur in the seed during growth (such as protein breakdown, lipid oxidation, conversion of complex carbohydrates to simple sugars, water absorption, and cell differentiation) to provide energy and essential components for plant survival. Germination, as a process, begins with the uptake of water from the dormant, dry seed and ends with the elongation of the radicle, which extends along the embryo axis, often penetrating the surrounding structures. As the seedling grows, primary storage reserves begin to be mobilized. Since the germination conditions of each plant and seed vary according to family and species, it is quite difficult to standardize the germination process, where conditions such as temperature, nutrients, light and humidity play a very important role (Yetim et al., 2009; Kılınçer and Demir, 2019). When germinated and normal grains are compared in terms of vitamins, minerals, antioxidant properties and various bioactive compounds (phenolic acids, isoflavones, etc.), it has been shown in many studies that germinated plants and seeds have a higher value (Yetim et al., 2009; Tarzi et al., 2012; Lopez-Martinez et al., 2017; Kılınçer and Demir, 2019). Germination not only changes in the chemical properties of the food but also in its physical properties (flavor, odor, texture, color) (Kılınçer and Demir, 2019). The release or increase in the amount of these bioactive components, which are generally found in plants as esterified or bound to glycosides, have an aromatic ring and at least one hydroxyl (-OH) group in their structures, and are defined as secondary metabolites with various functions in the growth and development of the plant, gives the food the feature of being a 'functional food' (Uyar and Sürücüoğlu, 2010). The germination process, which improves the nutritional values and functional compounds of grains and increases their bioavailability, is considered a biotechnological process (Cáceres et al., 2014). The germination process breaks down grain storage materials for respiration and enables the synthesis of new cell components for embryo development. At the same time, the protein content of germinated seeds increases, while their carbohydrate and mineral content decreases (Sharma et al., 2016). Phenolic compounds synthesized during seed germination not only increase the antioxidant activity of seeds but also increase the nutraceutical properties of seeds (Cevallos-Casals and Cisneros-Zevallos, 2010). Phenolic constituents increase the antioxidant concentration in the product upon germination (Zieliński and Kozlowska, 2000; Peng et al., 2015). As the germination process activates the endogenous enzymes of the grains, some important substances such as starch, fat and protein are broken down into small molecules (Wu et al., 2013). Ultrasound application, which has become widely used in the extraction process, acts by mechanically breaking down cell walls and ensuring substance transfer and is considered a faster alternative method compared to other extraction methods (Lavilla and Bendicho, 2017; Özcan et al., 2020). Ultrasound-assisted extraction, a simple, cheap, fast and effective extraction method, is known as a green extraction process that allows higher bioactive compounds to be extracted from plant materials compared to conventional extraction methods. In addition, the application of ultrasound contributes economically and environmentally to industrial applications since it reduces the use of organic solvent and extraction time (Azmir et al., 2013; Coelho et al., 2021). Recently, the use of cereal sprouts has been increasing due to their high nutritional value and health-promoting factors such as amino acids, fiber, minerals,

vitamins, flavonoids and phenolic acids (Niroula et al., 2019; Chon, 2013; Singhal et al., 2012). The findings may offer an economical, environmentally friendly, and efficient method for the production of polyphenol-fortified functional foods and improve the utilization of barley and wheat seeds.

The bioactive compounds, phenolic compounds, and mineral profiles of raw and germinated barley and wheat seeds shaken in water and ultrasonic baths are determined, and usage standards are planned to be determined based on their compositional properties. The objective of this study is to investigate the effects of water baths and ultrasonic baths on the bioactive compounds, antioxidant activity and minerals of raw, germinated and sonicated barley and wheat seeds.

## MATERIAL AND METHODS

### Material

Barley (Ramata cv) and wheat (Taner cv) seeds were provided from a farmer in Konya district in Turkey in 2025. The seeds were cleaned of foreign substances.

### Methods

*Moisture content*

The moisture contents of wheat and barley samples were assayed by the KERN & SOHN GmbH infrared moisture analyser until a constant weight.

*Sonication and germination process*

Barley (Ramata) and wheat (Taner) samples were soaked in water at a ratio of 1:2 (w/v) for 24 hours. After soaking, the samples were divided into 2 groups and sonication was applied to one of the groups for 1 hour in ultrasonic water-bath (35 kHz). Sonicated and unsonicated samples were subjected to germination for 3 days.

*Extraction procedure*

Extraction procedure were extracted according to the method recommended by Vaher et al. (2010).

*Total phenolic content*

Total phenolic amounts of seed extracts were fullfilled using the Folin-Ciocalteu reagent according to the reğort by described by Yoo et al. (2004).

*Total flavonoid content*

Total flavonoid amounts of wheat and barley samples were carried out by using 0.3 ml of $NaNO_2$, 0.3 ml of $AlCl_3$ and 2 ml of NaOH solutions according to the method described by Yoo et al. (2004).

*DPPH free radical scavenging activity*

The antioxidant activities of seed extracts were determined using 1,1-diphenyl-2-picrylhydrazyl (DPPH) according to the study recommended by Lee et al. (1998).

*Determination of phenolic compounds*

HPLC (Shimadzu) equipped with a PDA detector and an Inertsil ODS-3 column was used for analysis and chromatographic separation of phenolic compounds of wheat and barley samples.

*Mineral results of melon seeds*

After 0.5 g ground cereal seeds were dried in an oven at 70ºC till constant weight. Then, it was burned by using 5ml of 65% $HNO_3$ and 2 ml of 35% $H_2O_2$ in a microwave. After making up the resulting solution volume (20 mL) with distilled water, elements were established by the ICP-OES (Tošic et al., 2015).

*Statistical analysis*

JMP version 9.0 was used for analysis of variance (ANOVA). The results are mean±standard deviation (MSTAT C) of independent suproiting and shaking systems. Genotype×treatment results were obtained according to the 2x3x1 trial design.

## RESULTS AND DISCUSSION

### Chemical and bioactive properties of germinated-sonicated barley and wheat seeds

Chemical and bioactive properties of raw, germinated, and sonicated barley and wheat

seeds are shown in Table 1. Sonication was applied to germinated barley seeds. The chemical properties of germinated and sonicated barley and wheat seeds showed significant differences compared to the control. The moisture contents of barley and wheats were determined between 6.85 (raw (control) and 53.29% (germinated barley) to 8.58 (control) and 52.30% (germinated wheat), respectively. Total phenolic amouns of the barley and wheat seed samples were defined to be between 97.37 (control) and 177.28 (germinated barley) to 46.49 (control) and 164.69 mgGAE/100g (germinated wheat, respectively. While total flavonoid contents of the barley are assayed between 30.20 (germinated barley) and 32.75 mg/100g (control), total flavonoid amounts of the wheat seeds were described to be between 2.93 (control) and 18.74 mg/100g (germinated). In addition, antioxidant activities of germinated barley and wheat seeds were determined to be between 4.11 (control) and 8.18 mmol/kg (germinated barley) to 3.72 (control for wheat) and 7.97 mmol/kg (germinated wheat), respectively.

*Table 1.* Bioactive properties of raw, germinated and sonicated barley and wheat samples

| Sample | Process | Moisture content (%) | Total phenolic content (mg/100 g) | Total flavonoid content (mg/100 g) | Antioxidant activity (mmol/kg) |
|---|---|---|---|---|---|
| Barley | Control | 6.85±0.45c* | 97.37±3.06c | 32.75±0.83a | 4.11±0.00c |
| | Germinated-sonicated | 47.00±0.18b | 156.31±1.97b | 31.65±0.25b | 7.23±0.00b |
| | Germinated | 53.29±0.18a | 177.28±2.59a | 30.20±0.45c | 8.18±0.00a |
| Wheat | Control | 8.58±0.23c | 46.49±1.54c | 2.93±0.43c | 3.72±0.01c |
| | Germinated-sonicated | 46.41±0.33b | 134.53±2.45b | 18.28±0.30b | 7.04±0.01b |
| | Germinated | 52.30±0.44a | 164.69±0.50a | 18.74±0.11a | 7.97±0.00a |

*standard deviation and values within each column followed by different letters are significantly different at $P < 0.05$.

**Phenolic constituents of germinated-sonicated barley and wheat seeds**

The phenolic compound contents of raw, germinated, and sonicated barley and wheat grains are shown in Table 2. The predominant phenolic compounds in barley samples were catechin, 3,4-dihydroxybenzoic acid, syringic acid, gallic acid, and caffeic acid, while rutin, catechin, gallic acid, 3,4-dihydroxybenzoic acid, syringic acid, and caffeic acid were detected in wheat seed samples. In general, the phenolic compound amounts of wheat samples were higher than those of barley samples. 3,4-Dihydroxybenzoic acid and catechin contents of barley samples were identified to be between 4.77 (germinated-sonicated barley) and 5.25 mg/100g (germinated barley) to 9.44 (control) and 13.55 mg/100g (germinated-sonicated barley), respectively. In addition, while gallic acid amounts of the barley samples vary between 0.32 (control) and 5.28 mg/100g (germinated-sonicated barley), caffeic acid amounts of barley seeds were detected to be between 1.81 (control) and 3.15 mg/100g (germinated barley). Also, syringic acid amounts of the barley seeds were characterized to be between 1.47 (control) and 2.36 mg/100g (germinated-sonicated barley). In wheat samples, gallic acid and 3,4-dihydroxybenzoic acid amounts of the wheat seeds were identified to be between 13.43 (control) and 26.55 mg/100g (germinated wheat) to 5.11 (control) and 27.01 mg/100g (germinated-sonicated wheat seed), respectively. In addition, while catechin amounts of wheat seeds vary between 0.84 (control) and 75.76 mg/100g (germinated-sonicated wheat seed), caffeic acid contents of wheat samples were described to be between 1.37 (control) and 4.10 mg/100g (germinated-sonicated wheat seed). In addition, syringic acid and rutin quantities of wheat seeds were detected to be between 0.58 (control) and 31.01 mg/100g (germinated-sonicated wheat seeds) to 1.70 (control) and 129.39 mg/100g (germinated-sonicated wheat seeds), respectively. While quercetin contents of the wheat seeds vary between 1.00 (control) and 1.96 mg/100g (germinated), kaempferol amounts of the wheat samples were detected to be between 0.84 (control) and 2.48 mg/100g (germinated wheat seeds), respectively.

*Table 2.* Phenolic compounds of raw, germinated and sonicated barley and wheat samples

| Phenolic compounds (mg/100 g) | Control | Germinated-Sonicated-Barley | Germinated-Barley |
|---|---|---|---|
| Gallic acid | 0.32±0.02c* | 5.28±1.49a | 4.32±0.22b |
| 3,4-Dihydroxybenzoic acid | 5.05±1.57b | 4.77±0.80c | 5.25±0.27a |
| Catechin | 9.44±3.46c | 13.55±1.64a | 13.03±0.45b |
| Caffeic acid | 1.81±1.54b | 1.89±0.33b | 3.15±0.52a |
| Syringic acid | 1.47±0.68c | 2.36±1.00a | 1.72±0.41b |
| Rutin | 0.66±0.28b | 0.57±0.03c | 2.40±0.34a |
| p-Coumaric acid | 0.18±0.10b | 1.25±0.57a | 0.14±0.05c |
| Ferulic acid | 0.12±0.03c | 1.00±0.43a | 0.64±0.15b |
| Resveratrol | 0.21±0.09c | 0.33±0.09b | 0.35±0.05a |
| Quercetin | 1.40±0.72a | 0.65±0.14c | 1.17±0.17b |
| Cinnamic acid | 0.29±0.25c | 0.39±0.08b | 0.66±0.11a |
| Kaempferol | 0.49±0.36b | 1.09±0.12a | 0.49±0.07b |
| Phenolic compounds (mg/100 g) | Control | Germinated-sonicated-Wheat | Germinated-Wheat |
| Gallic acid | 13.43±3.03c | 22.44±1.92b | 26.55±0.04a |
| 3,4-Dihydroxybenzoic acid | 5.11±3.10c | 27.01±2.08a | 15.80±2.51b |
| Catechin | 0.84±0.36c | 75.76±1.67a | 15.02±1.02b |
| Caffeic acid | 1.37±0.73c | 4.10±0.34a | 3.88±1.10b |
| Syringic acid | 0.58±0.12c | 31.02±0.78a | 6.51±0.64b |
| Rutin | 1.70±0.56c | 129.39±0.04a | 124.22±1.04b |
| p-Coumaric acid | 0.20±0.04c | 1.03±0.09a | 0.81±0.09b |
| Ferulic acid | 0.13±0.06c | 0.59±0.07a | 0.54±0.23b |
| Resveratrol | 0.19±0.04c | 0.59±0.15a | 0.27±0.04b |
| Quercetin | 1.00±0.77c | 1.37±0.19b | 1.96±0.26a |
| Cinnamic acid | 0.29±0.10c | 1.16±0.24a | 0.82±0.24b |
| Kaempferol | 0.84±0.41c | 1.80±0.66b | 2.48±0.47a |

*standard deviation and values within each row followed by different letters are significantly different at $P < 0.05$.

**Mineral contents of germinated-sonicated barley and wheat seeds**

Mineral contents of raw, germinated and sonicated barley and wheat seeds were analyzed by ICP-OES and the results are shown in Table 3. P was the macroelement detected in the highest amounts in barley samples, followed by K, Mg and Ca in decreasing order. P and K amounts of the barley seeds were determined to be between 3004.25 (control) and 3209.56 mg/kg (germinated barley) to 2983.18 (germinated-sonicated barley seeds) and 3649.71 mg/kg (control), respectively. Also, while Ca contents of barley samples vary between 483.68 (control) and 634.03 ng/kg (germinated barley). As a microelement, the element found in the highest amounts in barley samples was Zn, and Zn and Mn contents of barley samples were characterized to be between 18.37 (control) and 31.10 mg/kg (germinated-sonicated barley seed) to 14.32 (germinated-sonicated barley) and 15.66 mg/kg (germinated barley), respectively. Fe amounts of barley seeds varied between 7.80 (germinated) and 10.53 mg/kg (control). P and K contents of the wheat samples were stated to be between 1661 (germinated-sonicated wheat seeds) and 5268 mg/kg (control) to 4256 (control) and 13522 mg/kg (germinated wheat), respectively. Also, Ca and Mg amounts of the wheat seeds were establshed to be between 744 (germinated) and 4272 mg/kg (control) to 1263 (germinated) and 2207 mg/kg (control), respectively. The Mn and Fe contents of germinated and sonicated wheat samples were found to range from 36.69 (control) and 148.54 mg/kg (germinated-sonicated wheat) to 21.49 (control) and 177.99 mg/kg (germinated), respectively. Zn amounts of the wheat samples were stated to be between 1.95 (germinated-sonicated wheat) and 12.84 mg/kg (control).

*Table 3.* Mineral contents of raw, germinated and sonicated barley and wheat samples

| Barley samples | P | K | Ca | Mg |
|---|---|---|---|---|
| Control | 3004.25±17.35c* | 3649.71±34.12a | 483.68±8.54c | 1017.67±15.87b |
| Germinated-sonicated | 3111.91±21.56b | 2983.18±28.75c | 573.02±11.67b | 1040.72±21.38b |
| Germinated | 3209.56±18.93a | 3012.64±15.42b | 634.03±28.56a | 1130.55±41.54a |
| | Fe | Zn | Cu | Mn |
| Control | 10.53±1.17a | 18.37±3.45c | 5.65±1.15a | 15.61±3.51a |
| Germinated-sonicated | 9.68±1.26b | 31.10±5.67a | 5.60±0.96b | 14.32±1.67b |
| Germinated | 7.80±0.98c | 27.87±3.28b | 5.64±1.57a | 15.66±1.98a |
| Wheat samples | P | K | Ca | Mg |
| Control | 5268±58.97a | 4256±68.28c | 4272±32.54a | 2207±30.05a |
| Germinated-sonicated | 1661±11.02c | 10399±123.94b | 753±12.47b | 1399±7.78b |
| Germinated | 2013±54.56b | 13522±159.95a | 744±10.74c | 1263±13.60c |
| | Fe | Zn | Cu | Mn |
| Control | 21.49±1.26c | 12.84±0.10a | 7.93±0.04a | 36.69±0.20c |
| Germinated-sonicated | 126.86±0.27b | 1.95±0.02c | 0.97±0.01b | 148.54±0.31a |
| Germinated | 172.99±0.85a | 5.65±0.16b | 0.65±0.005c | 114.27±1.08b |

*standard deviation and values within each row followed by different letters are significantly different at $P < 0.05$.

Germination and sonication of barley and wheat seeds resulted in an increase in moisture, bioactive properties compared to the control. The increase in bioactive compounds and antioxidant activity values of seeds following sonication and germination is likely due to the breakdown of cell walls containing bioactive compounds during sonication, resulting in increased phenolic compound release (Muller et al., 2013; Xu et al., 2017). Additionally, the release of bioactive compounds resulting from biochemical reactions in the seeds during germination may have increased the bioactive compound content of the seeds. The decrease in total flavonoid content during barley seed germination compared to control seeds is likely due to the fact that during germination, the seed acts as an energy source by degrading phenolic compounds such as flavonoids, which are the building blocks and energy required for embryo development. Furthermore, the activity of enzymes such as polyphenol oxidase and peroxidase increases during germination, which can lead to the oxidative degradation of flavonoids (Caceres et al., 2014). The highest moisture content and bioactive properties of seeds were observed in germinated seeds. In general, the total phenolic and flavonoid contents and antioxidant activities of barley were found to be higher than those of wheat. The total phenol and flavonoid quantities of the barley, soaked barley and dried barley samples were recorded to be between 58.49 (dried barley) and 69.10 mgGAE/100g (soaked barley) to 145.22 (dried barley) and 157.75 mgQE/100g (soaked barley), respectively (Younis et al., 2024). The total phenol content of green malt and dried-roasted malt were recorded to be between 115.85 ($3^{rd}$ day) and 237.80 mgGAE/100g ($7^{th}$ day) to 111.83 ($3^{rd}$ day) and 346.04 mg GAE/100g ($7^{th}$ day), respectively (Younis et al., 2024). While the total phenolic contents of barley varieties are found between 0.881 to 1.457 mgGAE/g, the total flavonoids amounts of barley seeds were identified to be between 0.325 to 0.527 mg/g (Holtekjolen et al., 2006; Ragaee et al., 2006). In other study, total phenolic contentsof whole barley flour were assigned to be between 3.07 to 4.48 mg GAE/g (Sharma and Gujral, 2010). Also, Zhao et al. (2008) reported that total phenolic contents of 14 different malting barley varieties were described to be between 2.17 to 2.56 mg GAE/g (dw). The germination significantly increased the total phenolic content and antioxidant activity of barley at 12 h and 12 h after the germination process (Sharma and Gujral, 2010). The release of bound phenolic constituents from germinated barley as a result of enzymatic activity increased both the antioxidant properties and the total phenolic content of barley during malting (Dvorakova et al., 2008; Alvarez-Jubete et al., 2010). In other study, total phenolic and flavonoid contents of barley were determined

as (688.84 mg/100 g) and (59.23 mg/100 g), and it was observed that they increased by 28.55% and 10.15%, respectively, compared to untreated samples (Zhang et al., 2023). Total polyphenol amounts and radical scavenging activity (DPPH assay) values of control and malted barley samples changed between 0.86 and 1.45 μg/ml to 19.23 and 27.37%, respectively (Vingrys et al., 2022). Our results differed from the literature results due to the sonication processes applied.

Following germination and sonication, the phenolic compound content of barley and wheat samples increased compared to the control. The highest concentrations of catechin were detected in barley samples, while rutin was detected in wheat samples. The amounts of other phenolic compounds in barley and wheat samples were generally quite low. The increase in phenolic compound content in germinated and sonicated barley and wheat samples compared to the control may be due to biochemical and ultrasonic waves disrupting the polysaccharide cell walls, allowing more phenolic compounds to be released. Because sonication (ultrasonic extraction) allows for greater extraction (removal) of phenolic compounds in plants, an increase in phenolic compound levels can be observed after sonication. This increase is likely due to the cavitation created during sonication (ultrasound waves creating and imploding microscopic bubbles in a liquid), which disrupts the structure of plant cells, causing cell walls to break down and intracellular components (such as phenolics) to more easily pass into the solvent. At the same time, sonication allows the solvent to reach deeper into the plant tissue, dissolving the phenolic compounds there, making components that are normally difficult to reach soluble. Sonication physically disrupts plant cells, facilitating the transfer of phenolic compounds into the solvent. This results in an increase in the total phenolic amount measured. In reality, phenolic production within the plant itself does not increase; more is simply released. While different barley varieties contain 20.8-70.4 (+)-catechin, 0.9-3.9 caffeic acid, 9.4-2.1 *p*-coumaric acid, 0.1-4.3 mg/kg ferulic acid, malt grains of the same varley varieties contained 64-604 (+)-Catechin, 1.0-18.8 caffeic acid, 5.1-11.7 (−)-Epicatechin, 1.5-2.5 ferulic acid, 0.6-2.0 mg/kg sinapic acid (Carvalho et al., 2015). While catechin amounts of barley samples are registrated between 5.83 (dried barley) and 10.29 mg/100g (soaked barley), catechin amounts of green and dried-roasted malt samples were identified between 5.20 (malt for 3$^{rd}$ day) and 56.42 mg/100g (malt for 7$^{th}$ day) (Younis et al., 2024). The amounts of catechin and kaempferol in raw and germinated barley pieces were found to be between 5.85 (germinated barley grain) and 19.71 mg/100 g (radicle) to 3.91 (germinated barley grain) and 4.62 mg/100 g (foil) (Ahmed et al., 2024). The major predominant phenolic compounds of raw and germinated barley were catechin and pyrogallol (El-Refai et al., 2012). Untreated (control) and germinated barley seeds contained 0.36 and 0.47 mg/100g kaempferol, 0.51 and 0.48 rutin, 132.59 and 239.58 mg/100g catechin, 20.46 and 12.56 mg/100g ferulic acid, 2.87 and 13.61 hydroxybenzoic acid, 5.76 and 66.16 p-coumaric acid (Zhang et al., 2023). The phenolic compound contents of raw and germinated, sonicated barley differed from the results of previous studies. These changes may be due to the growing conditions, maturity, and analytical procedures applied. No statistically significant difference was found between the Mg contents of raw (control) and germinated-sonicated barley samples. Furthermore, Cu and Mn contents of control and germinated barley samples were found to be statistically insignificant. In addition, the Fe, Mn, and B contents of the wheat samples were higher than the barley samples, while the Zn and Mn contents were detected at low levels. With germination, the P, Ca, and Mg contents of the barley samples increased compared to the control, while the K contents decreased. While the Fe content of the barley samples decreased, an increase in the Zn content was observed. An increase in the Fe, Mn, and B contents of the wheat samples was detected. However, the Cu

contents of the germinated and sonicated wheat sample decreased significantly compared to the control. The element contents of the sonicated barley and wheat samples were generally higher, but lower than those of the germinated seeds. The increase in macronutrient contents (phosphorus, potassium, calcium, magnesium) in grains during germination is not an absolute increase, but rather an increase in bioavailability or specific forms. This increase likely mobilizes stored nutrients (e.g., proteins, carbohydrates, fats, and minerals) during seed germination to support embryo growth. During this process, stored minerals become soluble and more readily utilized by cells. Mineral salts dissolve and convert to ionic form (e.g., $K^+$, $Ca^+$), causing them to appear higher in analyses. During germination, various enzymes such as phytase, amylase, and protease become active. These enzymes break down phytic acid, releasing phosphorus, and break down proteins, releasing nitrogenous compounds. Thus, measurable macronutrients appear to increase. Since carbon is lost through respiration ($CO_2$ output) during germination, this reduces the seed's total dry matter, causing macronutrients to appear increased relative to total dry matter. While normal barley seeds contain 2.69 Ca, 29.25 Mg, 208.05 K, 0.75 Cr and 0.64 Mn mg/100 g, germinated barley seeds contained 4.72 Ca, 30.78 Mn, 268.15 K, 0.91 Cr and 0.78 Mn mg/100g) (Lotfy et al., 2021). Barley grains contain important amounts of minerals necessary for biological processes and metabolic functions during germination. Changes observed in the chemical composition of the grain during germination are likely due to climatic conditions, duration of wetting and germination, and other factors (Ahmed et al., 2024).

## CONCLUSIONS

The chemical properties of germinated and sonicated barley and wheat seeds showed significant differences compared to the control. Germination and sonication treatments increased moisture content, total phenolic compounds, and antioxidant activity in both barley and wheat. The highest concentrations of catechin were detected in barley samples, while rutin was detected in wheat samples. Because sonication (ultrasonic extraction) allows for greater extraction (removal) of phenolic compounds in plants, an increase in phenolic compound levels can be observed after sonication.

In general, wheat samples exhibited higher macroelement contents than barley samples. Furthermore, germination increased the levels of phosphorus (P), calcium (Ca), and magnesium (Mg) in barley samples compared with the control, while potassium (K) levels decreased.

Overall, the results demonstrate that germination and sonication are effective techniques for improving the bioactive compound content and antioxidant properties of cereal grains.

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