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Effect of magnetized water and magnetic field treatments on the physicochemical properties, total phenolic and antioxidant capacity of sprouted oats flour

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ABSTRACT

One proposed method to optimizing water use in agriculture involves to pass irrigation water through a magnetic field. This study examined the impacts of magnetized water and magnetic field treatments on the moisture content, ash content, pH, acidity, color indices, total phenolic content, and antioxidant capacity of sprouted oats flour. To produce sprouted oats, the grains were soaked for 24 h under the specified conditions, dehulled, and incubated at 25°C for 48 h for sprouting. Sprouting did not significantly alter the ash content of the oat flours ($p>0.05$). The ash content of commercial flour was significantly higher than that of other flours ($p<0.05$). The sprouting with magnetic field increased the acidity of the oat flours from 0.47 to 1.12 %; this also significantly reduced the pH of the sprouted oat powders from 6.3 to 6.1 ($p<0.05$). The sprouts that developed in a magnetic field exhibited higher acidity due to enhanced growth and increased enzyme activity. The pH and lightness of the commercial flour were significantly lower than those of other flours ($p<0.05$). Sprouting oats under a magnetic field significantly decreased the lightness and redness of the flours ($p<0.05$). The yellowness index of the sprouted oat flour treated with a magnetic field was significantly higher than that of other flours ($p<0.05$). The total phenolic content of oat seeds and the sprouted oats flours treated with untreated water, magnetized water, and a magnetic field were 379.55, 513.37, 598.31, and 694.97 µg gallic acid/g, respectively. Overall, treatment with a magnetic field was identified as the most effective method for sprouting oats, as it enhanced both the total phenolic content and the antioxidant capacity of the flour.

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1. Introduction

Cereal grains are a main source of dietary nutrients for people, especially those in the developing countries [1]. Compared to other cereals, oat (*Avena sativa* L.) seeds contain a high amount of oil (about 6-18%). Due to this high oil content, oats are also rich in vitamin E and other antioxidants, which help protect the oil and prevent oxidative reactions [2]. Recent studies show that sprouting is cost-effective and efficient method to improve the bioactive composition of oats [3-5].

Sprouted whole grains contain higher levels of essential amino acids required by the body for protein synthesis. Additionally, these sprouted grains are more easily digestible and can enhance nutritional efficiency [6,7]. Consumption of sprouted cereals and legumes is becoming popular in different parts of the world [8-10]. Sprouting cereals for a limited period increases the activity of hydrolytic enzymes, enhances the levels of certain essential amino acids, total sugars, and B-group vitamins, while reducing starch content and antinutrients [11]. Sprouting breaks down portions of starch and protein, reduces anti-nutritional factors, and enhances the levels of essential minerals and vitamins in food. Additionally, it contributes to improved flavor and taste [6]. El-Mouhamady et al. [3] found that 25°C is the best temperature for the activity of enzymes related for sprouting, showing how important it is to control the temperature during this process. Figueroa-Pérez et al. examined the effects of temperature (20, 25, and 30 °C) and relative humidity (50, 55, and 60 %) as abiotic stressors on oat sprouts phytochemical fingerprint [4]. Their findings showed that the temperature and relative humidity affect the phytochemical profile and growth rate of oat sprouts during the sprouting process. The researchers recommend that functional food and beverage manufacturers select sprouts produced under conditions that promote high phenolic compound content for developing products aimed at providing antioxidant benefits.

Magnetic water technology, as an innovative, environmentally friendly, and cost-effective technique, is increasingly being utilized in agriculture. Magnetic water is produced by treating the normal water with a magnetic field, which alters its molecular structure, leading to the formation of new hexagonal arrangements [12]. Magnetization can alter the hydrogen bonding between water molecules, resulting in changes to its physicochemical properties, while ionization can utilize specific frequencies to break down polymers and enhance solubility. As a result, irrigation with magnetized and ionized water affects crop growth, enhance yield, and improve water use efficiency [13]. The use of magnetized water and magnetic fields enhances the sprouting rate of cereal grains and increases their phenolic compound and vitamin content [12,14,15]. To investigate the physiological mechanisms underlying the enhanced growth observed in plants irrigated with magnetized water compared to those treated with non-magnetized water, Ma et al. [16] evaluated its effects on leaf chlorophyll content and photosynthetic rate. Their findings revealed that treatment with magnetized water led to a significant increase in chlorophyll concentration. Moreover, under saline-alkaline stress conditions, irrigation with magnetized water significantly improved nitrogen accumulation in plant roots, suggesting enhanced nutrient uptake efficiency and greater stress resilience.

Sronsri et al. [17] studied the impact of the magnetic generator device on the growth quality and quantity of lettuce cultivated in a circulating hydroponic system. The findings indicated that seeds treated with magnetized water sprouted more quickly and exhibited a higher sprouting rate. The nutrient solution circulated through the device enhanced plant height and increased both the fresh and dry weights of the plants. Additionally, the magnetized nutrient solution improved the levels of essential elements, chlorophylls, carotenoids, and vitamin C. Irungu et al. [18] examined the effects of various factors, including magnetic field intensity and exposure duration, on the physical and chemical properties of stored potatoes. The results showed that the alternating current magnetic fields led to noticeably higher specific gravity, dry matter, starch, and the number of sprouts per tuber. However, they also caused lower weight loss, total sugars, reducing sugars, and non-reducing sugars compared to direct current magnetic fields.

The magnetic field influences living organisms by promoting seed sprouting, enhancing plant growth, and increasing overall yield [19]. In the study by Wang et al. [20], sprouting increased the levels of free and bound total phenolics and flavonoids, with magnetic field-assisted sprouting resulting in even higher concentrations of these compounds compared to conventional sprouting. Living organisms interact with electromagnetic energy in four primary ways: (1) they can absorb this energy, (2) it can alter their physiological functions, (3) it can affect the electrical signals in their cell membranes, and (4) it can influence the movement of charged particles and molecules within their bodies when exposed to electromagnetic fields [21]. This study will examine the effects of magnetized water and magnetic fields on the moisture content, ash content, pH, acidity, color indices, total phenolic content, and antioxidant capacity of sprouted oats flours.

2. Materials and methods

2.1. Preparing sprouted oats

Oat seeds were purchased from Pakan Bazr Isfahan Company (Isfahan, Iran). After cleaning and separating the waste, the oats were washed and soaked in untreated water, magnetized water, and magnetized water in a magnetic field for 24 h at 25°C (Fig. 1). A magnetic-alkaline ionized water production device (bipolar model with timer, Meghnatis Sazan Hayat Co., Iran) was used to magnetize the water and produce the magnetized water solution. To prepare the magnetized water, 2 liters of tap water was poured into a polyethylene container, and the water container, which was then placed inside the device for two h. The intensity of the magnetized water and magnetic field generated by the device were measured using a Gauss meter (Model TES-3196, Taiwan). The magnetic field intensity generated by the device was 2.8 Gauss, while the magnetic field intensity of the magnetized water inside the device measured 1.4 Gauss, and that of the magnetized water outside the device was 0.6 Gauss. In the next step, the excess water was drained from the peeled seeds, which were then placed in a flat container and covered with a thin towel. During the sprouting stage, untreated water was used for the first group (control sample), while magnetized water was used for the second group. For the third group, the seeds, along with the container and towel, were placed entirely within the magnetic field during the sprouting stage. The container with seeds was then kept at 25°C for 48 h to allow germination.

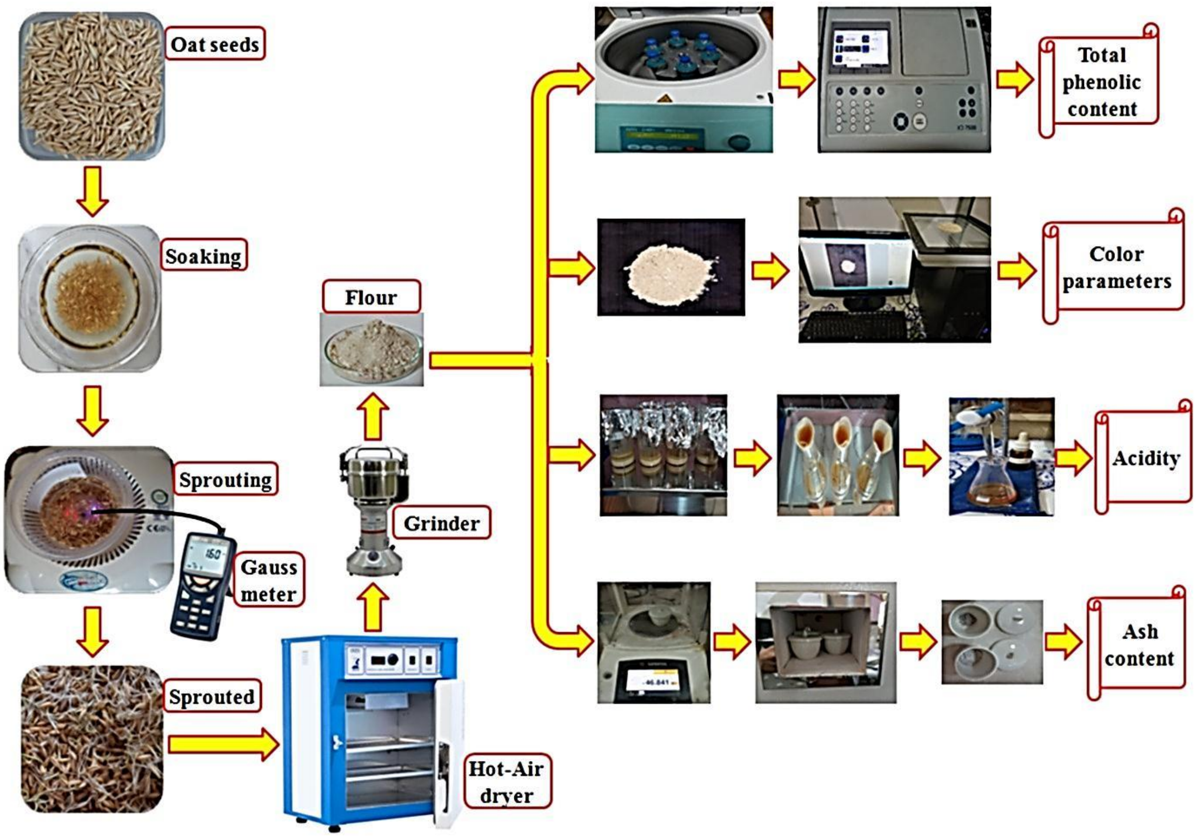


Fig. 1. Procedures for preparation and analysis of magnetic field-treated sprouted oat flour

2.2. Hot-air drying

The sprouted oat seeds were dried at 70°C in a convection oven (Shimaz, Iran), with their weight measured at 5-min intervals using a digital balance (GM-300p, Lutron, Taiwan) with a precision of 0.01 g, until a constant weight was achieved.

2.3. Powdering the dried sprouts

The dried oat sprouts were ground using an industrial grinder (Best, China). The resulting powder was packed in polyethylene bags to prevent moisture absorption during storage. The samples were then stored in a refrigerator at 6°C until further analysis. For comparison, commercially produced sprouted oat flour, consisting of processed oat bran and oat flour, was obtained from Food Industries Group 111 (Mazandaran, Iran).

2.4. Moisture and ash contents

To determine the moisture content of flours produced from sprouted oats treated with untreated water, magnetized water, and magnetic field, a clean, dry steel container was first prepared and weighed. Subsequently, 5 g of each flour sample was placed into the container, which was then transferred to a drying oven (Shimaz, Iran) and heated at 105°C for approximately 4 h, or until a constant weight was achieved [22]. The weight of each sample before and after drying was measured using a digital balance (GM-300p, Lutron, Taiwan) with a precision of 0.01 g. The moisture content was then calculated on a wet basis, based on the amount of water lost relative to the initial sample weight.

To determine the ash content of flours produced from sprouted oats using different treatments, empty crucibles were first cleaned, dried, and weighed. Then, 3 g of each flour sample was weighed and initially incinerated over a gas flame, followed by placement in an electric muffle furnace (Pars-Azma-Co., Iran) at 500°C for 8 h. The weights of the crucibles and samples were measured using a laboratory balance with a precision of 1 mg (Sartorius, Switzerland). The ash content of the sprouted oat flours was calculated using the method and equation described by Amin Ekhlas et al. [1].

2.5. pH of flours

According to Iranian National Standard No. 37 (2018), the pH of sprouted oat flour was determined by thoroughly mixing 10 g of flour with 100 mL of distilled water and allowing the mixture to stand for 20 min. The pH meter (Metrohm 827 pH Lab, Switzerland) was calibrated using buffer solutions at pH 4.0 and 7.0 prior to measurement. The pH of the aqueous phase was then recorded using the calibrated instrument.

2.6. Acidity of flours

According to Iranian National Standard No. 103 (2018), to measure the acidity of the sprouted oat flour, ten g of the flour was poured into a 125 ml Erlenmeyer flask, then 50 ml of 67% ethanol was added. After stirring with a stirrer for 5 min and after settling, the upper layer of the solution was passed through filter paper. In the next step, 25 ml of the filtered solution was poured into an Erlenmeyer flask. After adding three drops of 3% phenolphthalein reagent, titration was carried out with 0.1 N NaOH (sodium hydroxide) solution. The titration was completed when a pink color appeared. In the final step, the amount of NaOH used was recorded and the acidity was calculated using method and equation described by Amin Ekhlas et al. [1].

2.7. Color parameters of flours

Image processing techniques were employed to determine the color parameters of sprouted oat flour. Surface images of the flour samples were acquired using an HP Scanjet 300 scanner. The color space of the images was converted from RGB to the CIELAB components, L^* (lightness), a^* (green to red), and b^* (blue to yellow), using ImageJ software (version 1.42e, USA) along with the appropriate plugin [23].

2.8. Total phenolic content

The total phenolic content of sprouted oat flour was determined following the method described by Amin Ekhlas et al. [1]. To prepare the oat flour extract, 2 g of flour was mixed with 20 mL of 80% methanol and stirred using a magnetic stirrer (Shimaz, Iran) for 30 min. The resulting mixture was transferred to a Falcon tube and centrifuged (Universal 320R, Hettich, Germany) at 4000 rpm for 5 min. The supernatant was collected and used as the oat flour extract for subsequent analysis.

The total phenolic content was quantified as gallic acid equivalents (GAE) using the Folin-Ciocalteu method. A 0.5 mL aliquot of the oat flour extract was transferred to a test tube, followed by the addition of 0.5 mL of Folin–Ciocalteu reagent (Sigma-Aldrich, USA). After 5 min of incubation, 2 mL of sodium carbonate solution (20% w/v; Merck, Germany) was added to the tube, and the mixture was shaken for 30 seconds. The solution was then allowed to stand at approximately 25°C for 15 min, after which 10 mL of distilled water was added. The mixture was centrifuged (Universal 320R, Hettich, Germany) at 4000 rpm for 5 min to remove any precipitated solids. The absorbance of the resulting supernatant was measured at 725 nm using a spectrophotometer (XD-7500, Lovibond, Germany) and compared against a standard curve prepared with gallic acid. The results are expressed as micrograms of gallic acid equivalent (μg GAE) per gram of dry sample.

To construct the standard calibration curve, gallic acid (GA) solutions (Merck, Germany) were prepared at concentrations of 0, 0.005, 0.01, 0.02, and 0.04 g per 100 mL of distilled water. Instead of the oat flour extract, 0.5 mL of each GA standard solution was subjected to the same procedure as described above. The resulting absorbance values were then used to generate the standard curve. Total phenolic content in the oat flour samples was then calculated using Equation 1 and expressed as micrograms of gallic acid equivalent per gram of dry material (μg GAE/g):

$$\text{Total phenol} = 0.5 \times (0.0185\text{ABS} - 0.0007)/100 \times 20 \times 10^{6} [\mu\text{gGA/g dry}] \quad (1)$$

In this equation, ABS represents the absorbance of the sample measured at 725 nm, and GA refers to gallic acid, used as the standard compound for quantification.

2.9. Antioxidant capacity

To evaluate the antioxidant capacity of sprouted oat flour, a 0.1 mM solution of 2,2-diphenyl-1-picrylhydrazyl (DPPH) was prepared (Sigma-Aldrich, USA). The antioxidant capacity was then determined following the method described by Vejdanivahid and Salehi [24]. To prepare the oat flour extract, 2 g of flour was mixed with 20 mL of 80% methanol and stirred for 30 min using a magnetic stirrer (Shimaz, Iran). The mixture was then transferred to a Falcon tube and centrifuged at 4000 rpm for 5 min using a centrifuge (Universal 320R, Hettich, Germany). The resulting supernatant was collected and used as the extract. For the determination of free radical scavenging activity, 2 mL of the extract was mixed with 2 mL of DPPH solution in a test tube. The mixture was incubated at 25°C for 30 min in the dark. Absorbance was then measured at 517 nm using a spectrophotometer (XD-7500, Lovibond, Germany).

2.10. Statistical analysis

All determinations were performed in triplicate. Microsoft Excel 2013 was used to calculate means and standard deviations (SD) and to generate graphical plots. Statistical analysis was conducted using Duncan's multiple range test in SPSS software (version 21.0; SPSS Inc., Chicago, IL, USA), with a significance level at 5% ($p<0.05$).

3. Results and discussion

3.1. Moisture and ash contents

The moisture content of the oat seeds used in this study was 3.7%. The flour produced from these seeds exhibited a higher moisture content of 5.29%, attributed to tissue degradation and subsequent release of water. Fig. 2a shows the impact of using untreated water, magnetized water, and magnetic field on the moisture content of the flour obtained from oat sprouts. According to the figure, treating oat seeds with magnetized water and magnetic field during sprouting resulted in a significant decrease in the moisture content of the sprouted oat flour compared to the unsprouted sample ($p<0.05$). Germination is characterized by the degradation of macromolecules such as starch, involving complex metabolic changes primarily driven by the activation of enzymes like α- and β-amylases, which initiate starch breakdown in the early stages of the process [25]. This process also impacts the internal and cellular structure of the seed, resulting in sprouted oat flour retaining less moisture after drying and milling.

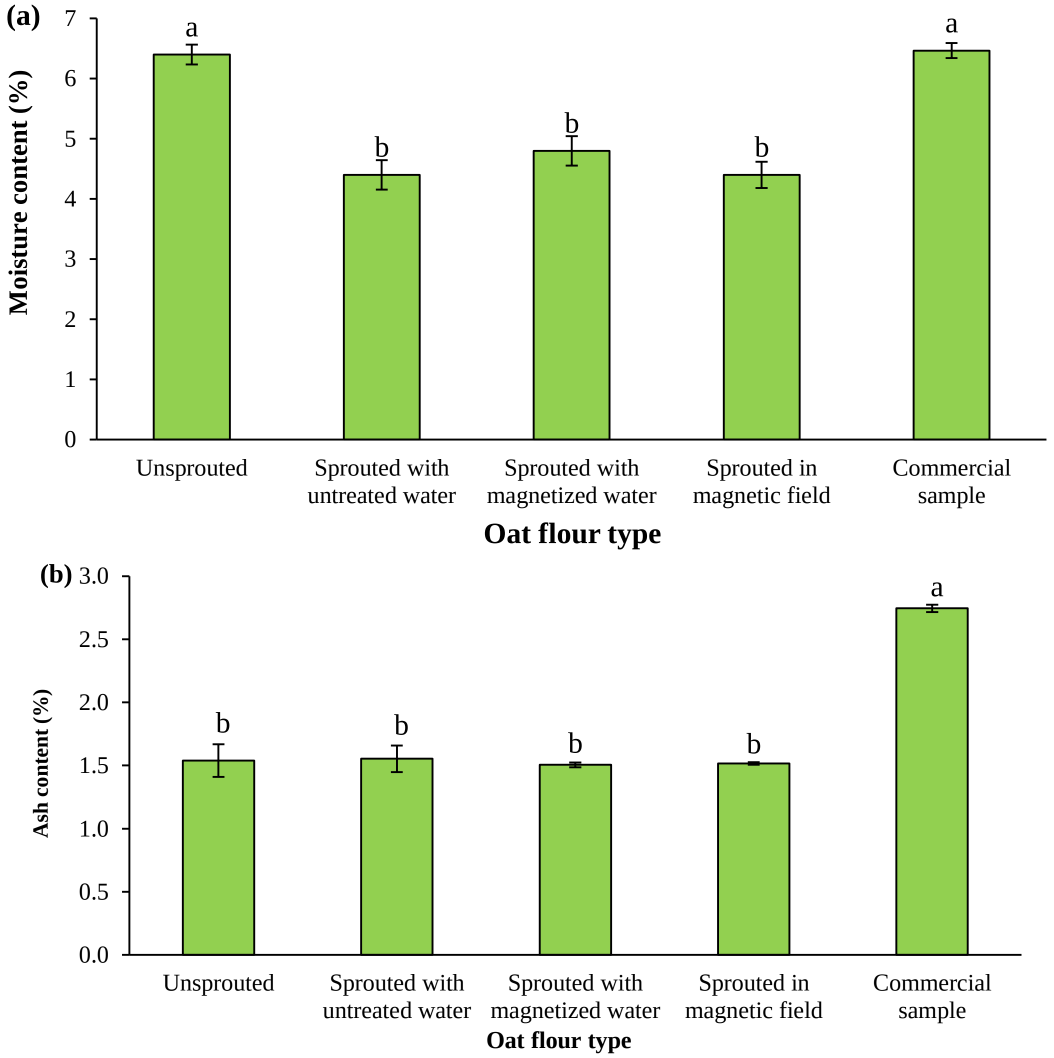


Fig. 2. Moisture (a) and ash (b) contents of unsprouted and sprouted oat flours compared to commercial sprouted oat flour
Error bar represents the standard deviation of replicates (n=3). Different letters represent the statistically significant differences at $p<0.05$ (Duncan test) between different treatments.

The enhanced nitrogen uptake observed in plants irrigated with magnetized water may be attributed to the upregulation of genes involved in nitrogen transport and assimilation. Studies have shown that magnetized water can significantly increase the expression levels of certain genes in plant shoots, indicating that magnetic treatment may influence gene expression pathways associated with nutrient absorption and metabolic activity [16]. The results of Ercan et al.'s [19] study showed that the magnetic field harmed the cell membranes of root cells. This damage changed the membrane potential, affecting ion transfer and nutrient uptake in barley seedlings grown in a magnetic field. The amount of oat seed ash used in this study was 1.54%. Furthermore, the average ash content of flours made from sprouts grown with untreated water, magnetized water, in a magnetic field, and the commercial sample was 1.55%, 1.51%, 1.52%, and 2.74%, respectively (Fig. 2b). The results show no significant difference in the ash content of the sprouted oat flours treated with untreated water, magnetized water, and a magnetic field ($p>0.05$). Only the ash content of the commercial flour was considerably different from the other flours ($p<0.05$), possibly because the oat seeds were milled with bran or there was too much bran. Shamshirsaz et al. [26] reported the ash content of oat flour as 2.25 %.

3.2. pH and acidity of flours

The pH of flours prepared from sprouted oats using untreated water, magnetized water, magnetic field, and the commercial sample is shown in Fig. 3a.

Sprouting enhances enzymatic and microbial activity, which in turn reduces the pH of the product [27]. Exposure of the samples to the magnetic field improved the sprouting rate of oats; consequently, the enhanced enzyme activity increased acidity, leading to a decrease in the pH of the flour [20]. The figure demonstrates a significant difference in the flour produced from sprouted oats exposed to a magnetic field compared to those treated with magnetized water and untreated water ($p < 0.05$). The commercial flour exhibited the lowest pH value, showing a significant difference compared to the other flours ($p < 0.05$). Consistent with our findings, Sobowale et al. [28] reported that sprouted pigeon peas exhibit a lower pH (5.20) compared to the control sample (5.65). This decrease is attributed to enzyme secretion during sprouting, which breaks down complex molecules into simpler acidic compounds.

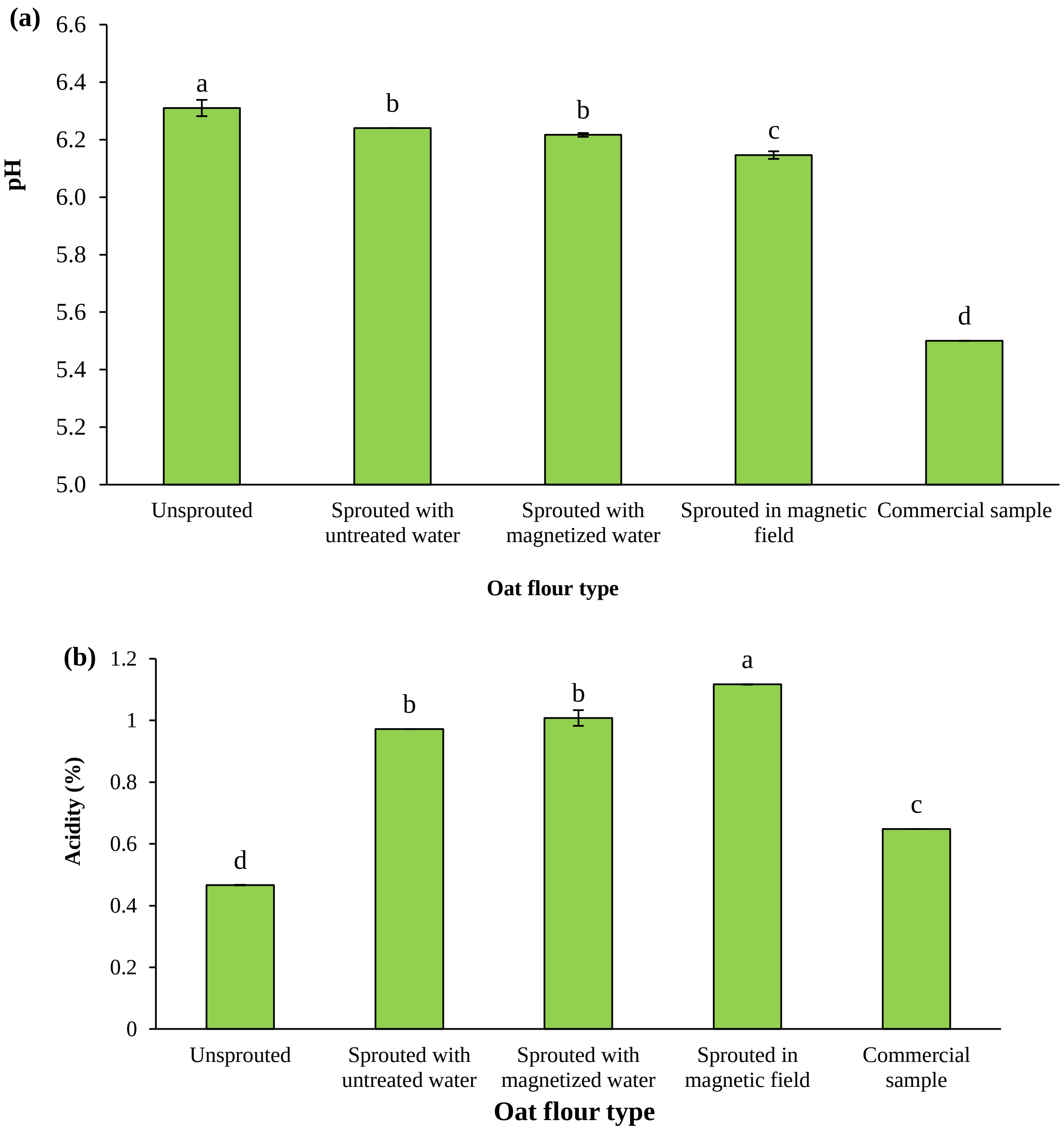


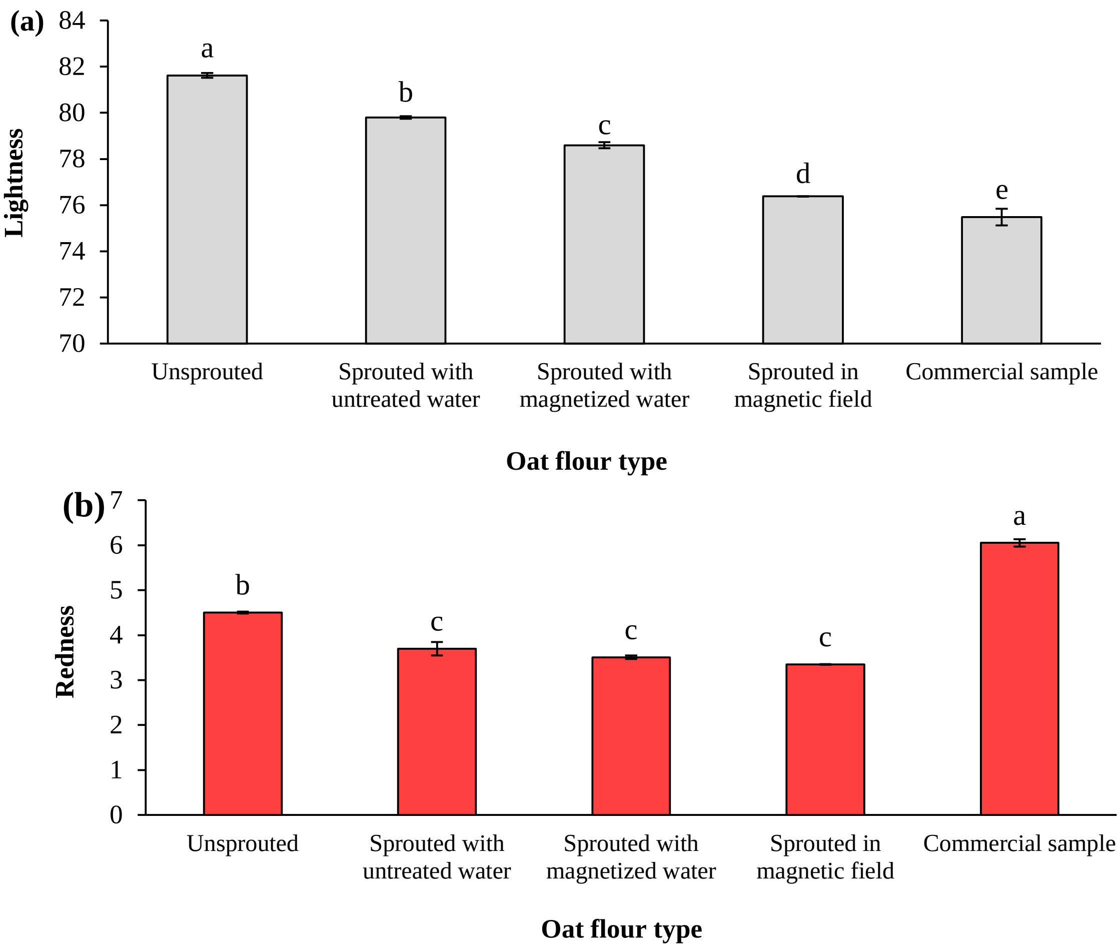
Fig. 3. pH (a) and acidity (b) of unsprouted and sprouted oat flours compared to commercial sprouted oat flour

Error bar represents the standard deviation of replicates (n=3). Different letters represent the statistically significant differences at $p<0.05$ (Duncan test) between different treatments.

In this study, the acidity of the unsprouted oat flour was 0.47%. The acidity values of sprouted oat flours treated with untreated water, magnetized water, and a magnetic field were 0.97%, 1.01%, and 1.12%, respectively (Fig. 3b). During sprouting, the acid content of the oats also increases due to increased enzymatic and microbial activity [28]. The use of magnetized water and exposure to a magnetic field improved the sprouting rate of oats compared to untreated water. Hence the acidity values of the oat flours treated with magnetized water and exposed to a magnetic field were higher than that of the untreated water. There are also significant differences between the samples sprouted in the presence of a magnetic field and magnetized water ($p<0.05$).

3.3. Color parameters of flours

In this study, the lightness (L^*), redness (a^*), and yellowness (b^*) values of the unsprouted oat flour were 81.6, 4.5, and 10.4, respectively. The surface color indices of flours prepared from oat seeds sprouted with untreated water, magnetized water, a magnetic field, and commercial samples are presented in Fig. 4. The results showed that as oat seeds sprouted, the lightness parameter of the flours reduced and the yellowness index increased. The lightness values of sprouted oat flours treated with untreated water, magnetized water, and a magnetic field were 79.8, 78.6, and 76.4, respectively. The commercial flour exhibited the lowest lightness value, showing a significant difference compared to the other flours ($p<0.05$).



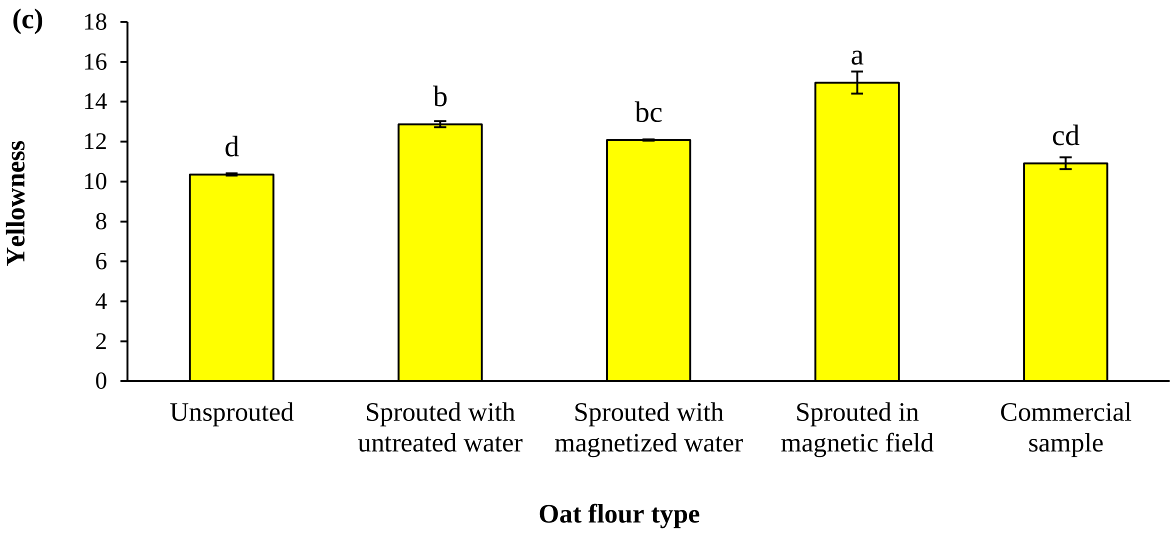


Fig. 4. Color indices (lightness (a), redness (b), and yellowness (c)) of unsprouted and sprouted oat flours compared to commercial sprouted oat flour

Error bar represents the standard deviation of replicates (n=3). Different letters represent the statistically significant differences at $p<0.05$ (Duncan test) between different treatments.

The sprouting rate of oats treated with magnetized water and exposed to a magnetic field was higher than that of the oats treated with untreated water, resulting in a lower lightness index for these samples compared to sprouted oats treated with untreated water. According to Ozturk et al. [29], flour becomes darker than wheat seed flour upon sprouting, with lightness decreasing and both yellowness and redness increasing during the sprouting process.

Sprouting oats under a magnetic field significantly decreased the redness parameters of the flours from 4.50 to 3.35 ($p<0.05$). In line with the findings of the present study, Perveen et al. [30] reported a significant decrease ($p<0.05$) in the redness value of wheat flour color from 3.1 to 2.9 as the sprouting time increased from 48 h to 72 h.

3.4. Total phenolic content

Sprouting is a common method used to enhance the nutritional value and digestibility of food. Sprouted grains contain higher levels of essential amino acids and phenolic compounds [6]. Magnetic fields influence the soil-water-plant system based on the type of plants and the water used for irrigation, which result in the improved plant yield and water productivity [17]. The total phenolic content of the oat flour used was 379.55 µg gallic acid/g, which is comparable to values reported by other researchers. For instance, Dastan et al. [31] reported a total phenolic content of 370.95 µg gallic acid/g in oats. Ercan et al. [19] found that magnetic field treatment can enhance the nutritional status of plants. They suggested that the observed increase in growth performance may be related to changes in nutrient uptake, potentially caused by damage to cell membranes. Fig. 5 shows the impact of treatment with magnetized water and a magnetic field on the total phenolic content of oat flours. The total phenolic content of the sprouted oats flours treated with untreated water, magnetized water, and a magnetic field was 513.37, 598.31, and 694.97 µg gallic acid/g, respectively. Treatments with magnetized water and exposure to a magnetic field enhanced the sprouting rate, resulting in increased phenolic compound levels in the sprouts and a higher total phenolic content in the flour. Bakhtiari and Okhovat [32] reported that the application of magnetized water significantly enhanced the concentration of soluble sugars compared to the control. Additionally, the use of magnetized water led to increased accumulation of anthocyanins and carotenoids in corn leaves. These findings suggest that magnetized water may improve crop productivity by promoting the synthesis of photosynthetic pigment and facilitating sugar transport and accumulation, ultimately contributing to higher overall yield. In line with the findings of the present work, Gan et al. [33] reported that a significant increase in phenolic compounds in oats during sprouting. Tian et al. [5] also examined the impact of oat sprouting on the physicochemical properties of oats and reported that sprouting increases the amount of phenolic compounds in oats. Wang et al. [20] investigated the impact of employing a magnetic field pretreatment on sprouting characteristics, phenolic biosynthesis, and antioxidant capacity of quinoa. The findings indicated that the parameters of magnetic field pretreatment had different influences on the sprouting properties of five quinoa varieties. The total phenolic content and phenolic acid levels in seeds sprouted for 24 h increased by 20.48% and 26.54%, respectively. This enhancement was associated with the activation of the phenylpropanoid pathway through increased enzyme activity and gene expression.

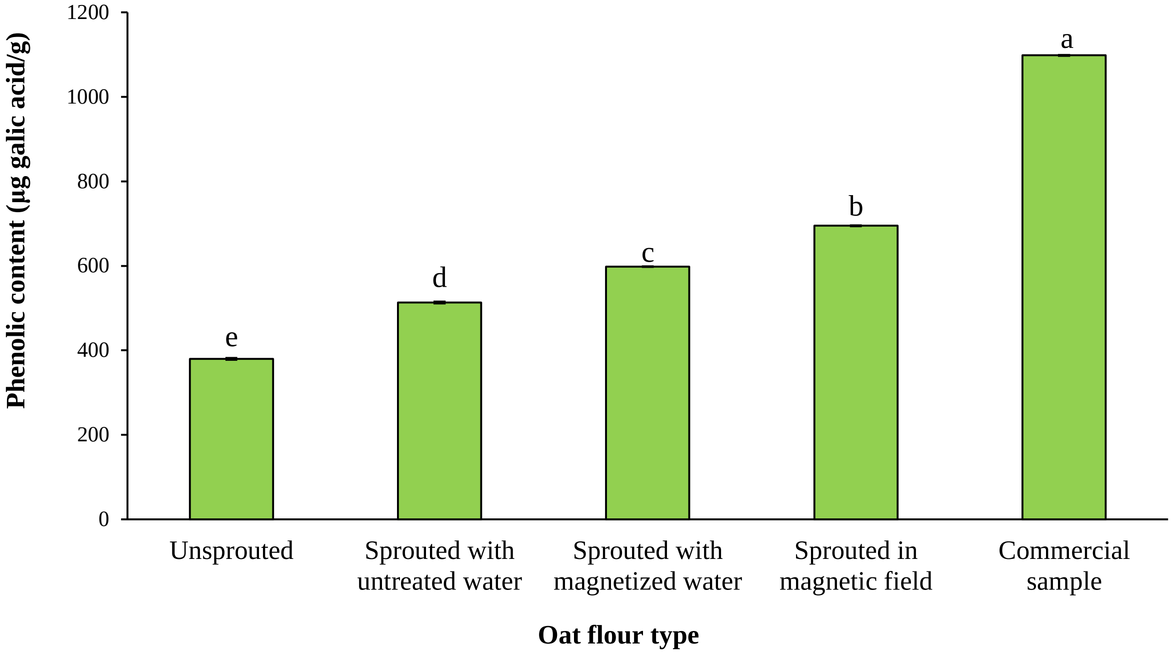


Fig. 5. Total phenolic content of unsprouted and sprouted oat flours compared to commercial sprouted oat flour
Error bar represents the standard deviation of replicates (n=3). Different letters represent the statistically significant differences at $p<0.05$ (Duncan test) between different treatments.

3.5. Antioxidant capacity

Enzymes are activated throughout the germination process, which helps to improve the digestibility of compounds contained in the grains. The germination process increases vitamins, phenolic compounds, and dietary fibers, and enhances antioxidant activity by increasing the availability of reducing sugars and free amino acids, particularly lysine [34]. The antioxidant capacity of the oat flour used in this study was 80.66. Dastan et al. [31] reported that an antioxidant activity of 67.25% in oat flour. Fig. 6 shows the effect of sprouting and magnetic treatments on the antioxidant capacity of oat flours. This figure shows that the commercial flour had the lowest antioxidant capacity, which was statistically significant compared to the other flours ($p<0.05$). The antioxidant capacities of the sprouted oats flours treated with untreated water, magnetized water, and magnetic field, and the commercial flour sample were 86.18, 91.73, 96.11, and 53.07%, respectively. Since the sprouting rate of oats treated with magnetized water and magnetic field was higher, the antioxidant capacity was consequently improved. The highest antioxidant capacity value was shown by the magnetic field-treated oat sprouts, which represents a significant difference from the other flours ($p<0.05$). Gan et al. [33] also found that the sprouting process increases the antioxidant capacity of extracts from sprouted edible seeds. Wang et al. [20] revealed that exposure to a magnetic field enhanced gene expression of phenylalanine ammonia lyase, 4-coumarate-CoA ligase, chalcone synthase, and chalcone isomerase, as well as improved antioxidant enzyme activity and phenolics compounds. These changes contribute to the antioxidant levels in quinoa.

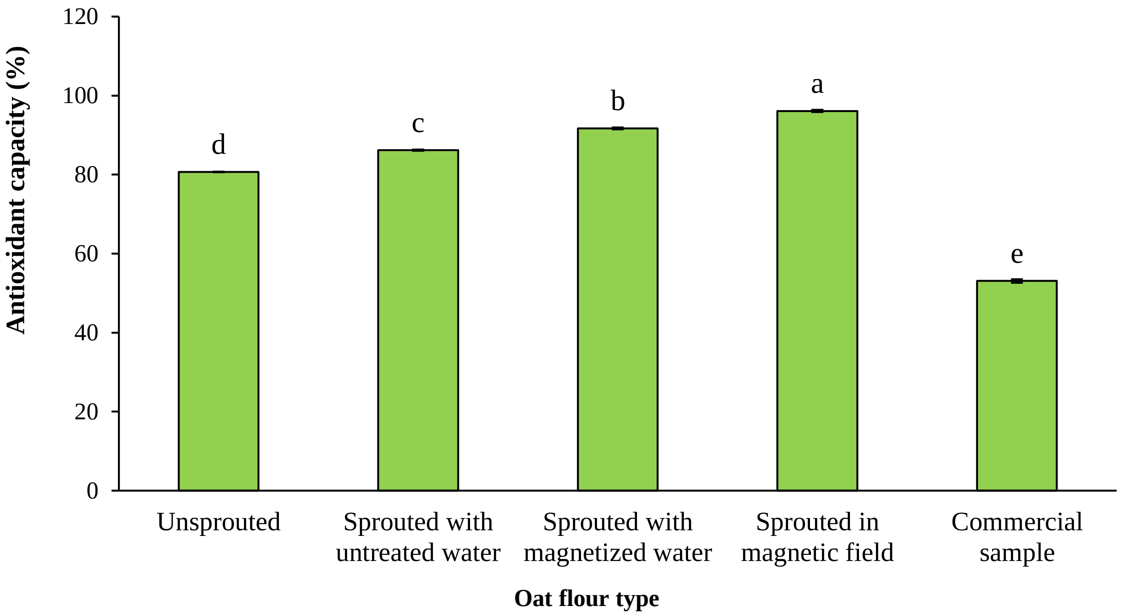


Fig. 6. Antioxidant capacity of unsprouted and sprouted oat flours compared to commercial sprouted oat flour
Error bar represents the standard deviation of replicates (n=3). Different letters represent the statistically significant differences at $p<0.05$ (Duncan test) between different treatments.

4. Conclusion

Application of magnetized water and magnetic field treatments enhances seed germination rates and overall crop yield. Sprouted oats, a gluten-free product suitable for individuals with celiac disease, are rich in vitamins, phenolic compounds, and antioxidants. Sprouted oat flour can be incorporated into various food products to improve their quality attributes. In this study, flours derived from sprouted oats exhibited significantly lower moisture content compared to flours from unsprouted oats and commercial samples. Additionally, the acidity, yellowness, and antioxidant capacity of sprouted oat flour treated with magnetic fields were significantly higher than those of other flours ($p<0.05$). The results also demonstrated a reduction in surface color lightness of the flour as sprouting progressed. Treatments involving magnetized water and magnetic fields increased the sprouting rate, which correlated with elevated levels of phenolic compounds and a higher total phenolic content in the flour. The concurrent application of magnetic fields during sprouting improved both the quality and nutritional profile of the resulting sprouted oat flour. Overall, magnetic field and magnetized water treatments show promise as effective methods to enhancing seed germination rates and improving the nutritional quality of food products containing sprouted oat flour. Future studies should explore the biochemical mechanisms underlying the effects of magnetic treatments on germination and bioactive compound formation. Research on other crops and the effects on sensory properties of sprouted flour products is recommended.

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Conflict of interest: The authors declared no conflict of interest.

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فصلنامه فناوری‌های جدید در صنعت غذا

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مقاله پژوهشی

تأثیر تیمارهای آب مغناطیسی‌شده و میدان مغناطیسی بر ویژگی‌های فیزیکوشیمیایی، فنل کل و ظرفیت آنتی‌اکسیدانی آرد جودوسر جوانه‌زده

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چکیده

روش پیشنهادی برای بهینه‌سازی مصرف آب در کشاورزی، عبور دادن آب آبیاری از یک میدان مغناطیسی است. در این مطالعه تأثیرات تیماردهی با آب مغناطیسی و میدان مغناطیسی بر مقدار رطوبت و خاکستر، pH، اسیدیته، شاخص‌های رنگ، مقدار فنل کل و ظرفیت آنتی‌اکسیدانی آرد جودوسر جوانه‌زده بررسی شده است. برای تهیه جودوسر جوانه‌زده، ابتدا دانه‌ها به مدت ۲۴ ساعت در شرایط مذکور خیسانده شدند و سپس پوسته آن‌ها جدا شد. پس از آن، دانه‌ها به مدت ۴۸ ساعت در دمای ۲۵ درجه سلسیوس برای جوانه‌زنی نگهداری شدند. جوانه‌زنی جودوسر تأثیر معنی‌داری بر مقدار خاکستر آردهای تهیه‌شده نداشت (p>۰/۰۵). مقدار خاکستر آرد تجاری به‌طور معنی‌داری بیشتر از سایر آردها بود (p<۰/۰۵). جوانه‌زنی با میدان مغناطیسی، اسیدیته آرد جودوسر را از ۰/۴۷ به ۱/۱۲درصد افزایش داد؛ همچنین، به‌طور معنی‌داری pH پودر جودوسر جوانه‌زده را از ۶/۳ به ۶/۱ کاهش داد (p<۰/۰۵). جوانه‌هایی که در میدان مغناطیسی رشد کردند، به‌دلیل رشد بیشتر و فعالیت آنزیمی افزایش‌یافته، اسیدیته بیشتری داشتند. pH و روشنایی آرد تجاری به‌طور معنی‌داری کمتر از سایر آردها بود (p<۰/۰۵). جوانه‌زنی جودوسر با میدان مغناطیسی، به‌طور معنی‌داری روشنایی و قرمزی آردها را کاهش داد (p<۰/۰۵). شاخص زردی آرد جودوسر جوانه‌زده تیمار شده با میدان مغناطیسی، به‌طور معنی‌داری بیشتر از سایر آردها بود (p<۰/۰۵). مقدار فنل کل دانه‌های جودوسر و آردهای جودوسر جوانه‌زده با آب تیمارنشده، آب مغناطیسی‌شده و در معرض میدان مغناطیسی به‌ترتیب ۳۷۹/۵۵، ۵۱۳/۳۷، ۵۹۸/۳۱ و ۶۹۴/۹۷ میکروگرم اسید گالیک در هر گرم بود. به‌طورکلی، استفاده از میدان مغناطیسی به دلیل افزایش مقدار فنل کل و ظرفیت آنتی‌اکسیدانی آرد، به‌عنوان بهترین روش برای جوانه‌زنی جودوسر انتخاب شد.

واژه‌های کلیدی: اسیدیته، جوانه‌زنی، روشنایی، شاخص‌های رنگ

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