

THE INFLUENCE OF THE DURATION OF THE GERMINATION PROCESS ON THE FOOD QUALITY INDICATORS OF SPROUTED LENTILS

Dalė Šumskienė, Rokas Drevinskas

Kauno kolegija Higher Education Institution

Abstract. Germination is one of the simplest and most effective biological processes capable of improving the nutritional value and functional properties of legumes. Lentils are characterized by a high content of proteins, minerals, and bioactive compounds; therefore, their germination has become increasingly important for developing products with enhanced nutritional value. The aim of this study was to determine the effect of different germination durations on the food quality indicators of sprouted lentils. The research was carried out in 2025 at the laboratories of the Department of Food and Agrotechnologies at Kauno kolegija Higher Education Institution. Seeds of three lentil varieties - red, green, and black lentils - were investigated. The seeds were germinated for 48 and 96 hours at a temperature of 21 °C. The contents of dry matter, ash, soluble solids, chlorophyll a, chlorophyll b, and carotenoids were determined during the study. The obtained data were statistically evaluated using analysis of variance (ANOVA).

The results showed that increasing germination duration reduced the dry matter content in all lentil samples, while the content of soluble solids increased. The highest dry matter content was determined in red lentils after 48 h of germination (39.98%), whereas the highest soluble solids content was observed after 96 h of germination (25.7%). The study also demonstrated that chlorophyll and carotenoid accumulation depended on lentil variety and germination duration. The greatest increase in chlorophyll a and chlorophyll b content was found in red lentils, while carotenoid content increased most significantly in green lentils. In black lentils, pigment concentrations decreased or remained relatively stable during prolonged germination.

The study confirmed that germination positively affects the nutritional and functional quality of lentils; however, the intensity of these changes depends on lentil variety and germination duration. The obtained results may be applied to the development of functional food products and in the optimization of germination technologies for the food industry.

Keywords: germination, lentils, food quality, carotenoids

Introduction

Germination is an effective bioprocessing strategy for enhancing the nutritional quality and functional potential of legumes (Subramani et al., 2026). Germination is a simple and inexpensive process that can be carried out without modern or costly equipment and does not require special knowledge (Delian et al., 2015). Germinated seeds can be used to develop innovative products. Extensive breakdown of seed-storage compounds and the synthesis of structural proteins and other cell components occur during germination (Danilčenko et al., 2017). Among plant protein sources, legume crops are the main dietary sources for >1 billion people, providing high protein yields (18–32%) and generous economic and environmental benefits (Bautista-Expósito et al., 2024). Some pulse crops (peas, fava beans, and lentils) are excellent sources of high-quality proteins for human nutrition. Legume proteins contain all the essential amino acids (EAA) and are rich in lysine (K), leucine (L), aspartic acid (D), glutamic acid (E), and arginine (R); whereas cysteine (C), methionine (M), tryptophan (W), and threonine (T) are considered to be limited (Boye et al., 2010; Joshi et al., 2017).

The most popular seeds for germination are wheat, alfalfa, and lentils (Danilčenko, Jarienė, 2005; Chelladurai, Erkinbaev, 2020). Lentils (*Lens culinaris* L.), similar to other food legumes or pulses, are nutrient-dense with reported positive health implications. Several recent studies have demonstrated that legumes, particularly lentils, may offer additional health advantages to fulfill a person's basic nutritional needs (Dewan et al., 2024). The composition and nutritional value of lentils vary widely among lentil varieties. Lentils are available in a variety of colors, including brown, black, red, yellow, and green, depending on the cultivar and the seed coat and cotyledon composition (Mustafa et al., 2022). Grusak (2009) reported the following compositional ranges, compiled from different studies: carbohydrates (43.4% to 74.9%), protein (15.9% to 31.4%), fat (0.3% to 3.5%), total fiber (5.1% to 26.6%), and ash (2.2–6.4%).

Optimal seed germination requires water, darkness, optimal temperature, and oxygen (Finch-Savage, Leubner-Metzger, 2006; Finch-Savage, Footitt, 2017; Šumskienė, 2023). Also, the important factor is germination time (Ranal, Santana, 2006). Longer sprouting periods (3–5 days) and/or higher temperatures (25–35 °C) are required to enhance the synthesis and/or release of bioactive compounds in plants. The nutritional changes that occur during sprouting are often linked to beneficial effects on health (Lemmens et al., 2019).

The aim of the study is to determine the effect of different germination durations on selected quality parameters of sprouted lentils intended for food, including dry matter, ash, soluble solids, chlorophyll a, chlorophyll b, and carotenoid content.

The object of the study is sprouted lentil (*Lens culinares* L.) seeds for food.

Research objectives:

1. to determine the chemical composition of sprouted lentil seeds for food;
2. to investigate the effect of the duration of the germination process on the chemical composition of different sprouted (red, green, black) lentils for food.

Research methods and conditions

The research was conducted in 2025 at the laboratories of the Department of Food and Agrotechnologies at Kauno kolegija Higher Education Institution. For lentil germination, sprouters manufactured by the French company „Vilmorin“ were used. These sprouters had a diameter of 20 cm, a capacity of 1 liter, and were disinfected with an ethanol solution.

They were also equipped with excess water collectors and siphon drainage systems. For additional protection against water stagnation, the trays' bottoms were ribbed.

The seeds were germinated for 48 and 96 hours in a dark, well-ventilated room at a temperature of 21 °C. At the beginning of the study, the seeds were carefully selected; damaged seeds, those with unusual coloration, or containing impurities were removed. The seeds were then soaked for 12 hours in a volume of water four times greater than the seed volume (ratio 1:4). After 12 hours, the water was drained, and the seeds were allowed to dry until they remained moist but not wet. The seeds were moistened with potable water every 12 hours.

After 2 days (48 hours) of germination, the sprouted seeds were harvested, weighed, and samples were prepared for analysis. The contents of dry matter, crude ash, soluble solids, chlorophyll, and carotenoids were determined immediately.

After 4 days (96 hours), the remaining sprouted seeds were harvested, weighed, and samples were prepared for analysis. The same analyses as after 2 days were performed on the freshly germinated seeds intended for food use.

In germinated seeds, the following was determined using standard methods:

- Dry matter content (%) – determined according to LST ISO 751:2000;
- Crude ash content (%) – determined by the gravimetric method (Januškevičius, Mikulionienė, 2006);
- Soluble solids content (g/100 g) – measured using a refractometer (LST ISO 751:2000);
- Chlorophyll a, chlorophyll b, and carotenoids – determined by the spectrophotometric method based on optical density measured in 1 cm glass cuvettes at the following wavelengths: 440.5 nm for carotenoids, 662 nm for chlorophyll a, and 644 nm for chlorophyll b (Bluzmanas et al., 1990).

The research data were statistically analyzed using analysis of variance (ANOVA) with the computer software STATISTICA 10 (Sakalauskas, 2003). The statistical significance of differences between means was evaluated using Fisher's LSD test at $p < 0.05$.

Results

Dry matter losses are inevitable in germinating seeds because of imbibition and other physiological processes that take place during the germination. One of the basic tasks in seed germination technology is minimizing dry matter losses, since the higher dry matter amount in the product – the higher its nutritional value (Tarasevičienė et al., 2009). Table 1 presents the results of our study (amount of dry matter, ash, and soluble dry matter).

Table 1. Quality parameters of sprouted lentils for food

Sprouted lentils for food	Duration of germination, h	Amount of dry matter, %	Amount of ash, %	Soluble dry matter, %
Red	48	39,98 a	1,54 a	24,00 a
Green	48	36,16 b	1,68 a	20,80 b
Black	48	38,48 a	2,15 a	16,30 c
Red	96	38,41 a	1,53 a	25,70 a
Green	96	32,88 c	2,07 a	20,63 b
Black	96	35,08 b	1,60 a	24,20 a

Note: Significant differences ($p < 0.05$) between means are indicated by different lowercase letters

The highest dry matter content (39.98%) was determined in red lentil seeds after 48 h of germination. The dry matter content decreased consistently in all investigated lentil seeds depending on the duration of germination. The decrease in dry matter content may be associated with intensive respiration of germinating seeds, seed type, germination duration, and temperature (Televičiūtė et al., 2020; Aktaş et al., 2022; Romano et al., 2023).

Mineral substances are characterized by ash content. Minerals play an important role in maintaining human health by participating in metabolic processes, immune response, nerve transmission, and skeletal development (Razzaque, 2025; Espinosa-Salas et al., 2023). Adequate intake of mineral substances is important for maintaining normal growth, development, and overall physiological functions in the human body (Razzaque, 2025).

During the experiment, it was determined that ash content in sprouted lentil seeds ranged from 1.53 to 2.15%. The highest ash content was determined in black lentils germinated for 48 h (2.15%), whereas the lowest value was observed in red lentils germinated for 96 h (1.53%). Germination duration had no significant effect on ash content in the investigated lentil samples, since no significant differences ($p > 0.05$) were observed between the means. However, green lentils showed a tendency toward increased ash content after 96 h of germination.

One of the most important indicators for evaluating raw material quality and technological properties is soluble solids content. (Gong et al., 2025).

The highest soluble dry matter content was identified in the red lentil seeds (25.7%) after 96 h of germination (Table 1). The lowest soluble dry matter content was determined in black lentil seeds after 48 h of germination. In red lentil seeds, the content of soluble dry matter increased by 7.08% after 96 hours of germination. Germination duration significantly increased soluble dry matter content in black lentil seeds, resulting in a 37.11% increase, consistent with previous studies reporting biochemical changes during lentil germination (Rico et al., 2021; Dragomir et al., 2025; Das et al., 2026).

Chlorophylls are commonly found in two major forms: chlorophyll a and chlorophyll b, which differ at the 7-carbon position. Chlorophyll a contains a methyl ($-\text{CH}_3$) group, while chlorophyll b contains an aldehyde ($-\text{CHO}$) group. These structural differences result in different colors: chlorophyll a appears greenish-blue, while chlorophyll b appears greenish-yellow (Yilmaz, Gökmen, 2016; Carillo et al., 2022). Chlorophyll is one of the most important ingredients in many products, and is used in the production of pharmaceutical products, in addition to being a natural food pigment (Nethravathy et al., 2019; Masyita et al., 2025). Chlorophyll and its derivatives have health-promoting properties, in addition to being used as colorants in food and pharmaceuticals. Sun et al. (2024) concluded that chlorophylls have a promising role in preventing nerve damage, atherosclerosis, cardiovascular diseases, metabolic syndrome, diabetes, ophthalmic diseases, viral diseases, chronic inflammatory diseases, and tumors.

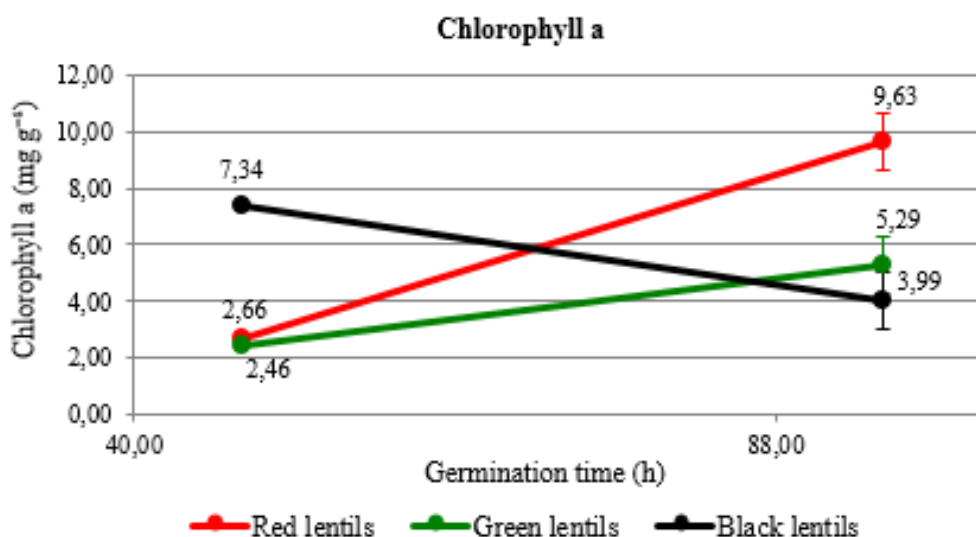


Fig. 1. Chlorophyll a content in sprouted lentil seeds for food

Figure 1 shows that chlorophyll a content in lentil seedlings depended on both germination duration and genotype. After 48 h of germination, black lentils had the highest chlorophyll a concentration (7.34 mg g⁻¹), while red and green lentils showed lower values (2.66 and 2.46 mg g⁻¹). After 96 h, red lentils demonstrated the greatest increase, reaching 9.63 mg g⁻¹, whereas green lentils increased moderately to 5.29 mg g⁻¹. In contrast, chlorophyll a in black lentils decreased to 3.99 mg g⁻¹.

These results suggest that germination stimulates chlorophyll accumulation differently across lentil genotypes. The strong increase observed in red lentils may be associated with enhanced synthesis of photosynthetic pigments during seedling growth. Similar genotype-dependent effects and increased pigment accumulation during germination have been reported in previous studies (Priti et al., 2021). Overall, the findings confirm that germination can improve the nutritional quality of lentil sprouts, particularly in red lentil varieties.

After 48 h (Fig. 2), black lentils showed the highest chlorophyll b concentration (14.02 mg g^{-1}), while red and green lentils had lower values of 5.39 and 4.69 mg g^{-1} , respectively. After 88 h of germination, red lentils exhibited the greatest increase in chlorophyll b, reaching 19.85 mg g^{-1} , whereas green lentils increased to 11.15 mg g^{-1} . In contrast, chlorophyll b content in black lentils declined to 8.06 mg g^{-1} .

The results indicate that chlorophyll accumulation during germination is strongly genotype-dependent. Increased chlorophyll b levels in red and green lentils suggest active development of the photosynthetic apparatus during seedling growth. Similar effects of germination on chlorophyll synthesis and bioactive compound accumulation in legumes have been reported by Günal-Köroğlu et al. (2025) and Umar et al. (2025).

Meanwhile, the decrease in chlorophyll b observed in black lentils may be associated with intensified chlorophyll degradation or increased phenolic compound synthesis during prolonged germination, as discussed by Holanda et al. (2026).

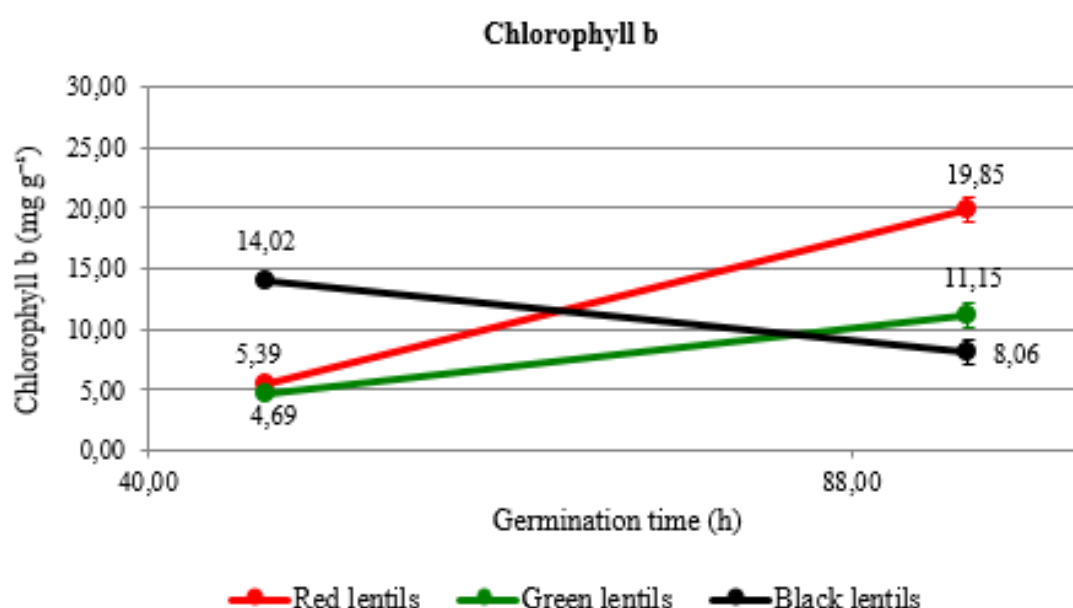


Fig. 2. Chlorophyll b content in sprouted lentil seeds for food

A similar genotype-related pigment reduction in dark-seeded legumes was also described by Pencheva et al. (2026). Overall, the findings confirm that optimization of germination conditions is important for maximizing pigment accumulation and improving the functional quality of lentil sprouts.

Carotenoids are an evolutionarily ancient group of molecules that play various roles in plant growth and development. Carotenoids are very abundant in flowers and fruits, conferring yellow, orange, and red colors to attract insects and animals for pollination or seed dispersal (Kolašinac et al., 2021). Carotenoid-rich sources, mainly fruits and vegetables, have received a lot of attention recently due to the health benefits observed with regular consumption. Carotenoids are associated with enhanced immune system function and a lower risk of developing degenerative chronic diseases, such as age-related macular degeneration, type 2 diabetes, obesity, neurological and cognitive disorders, and osteoporosis (Madrid et al., 2020).

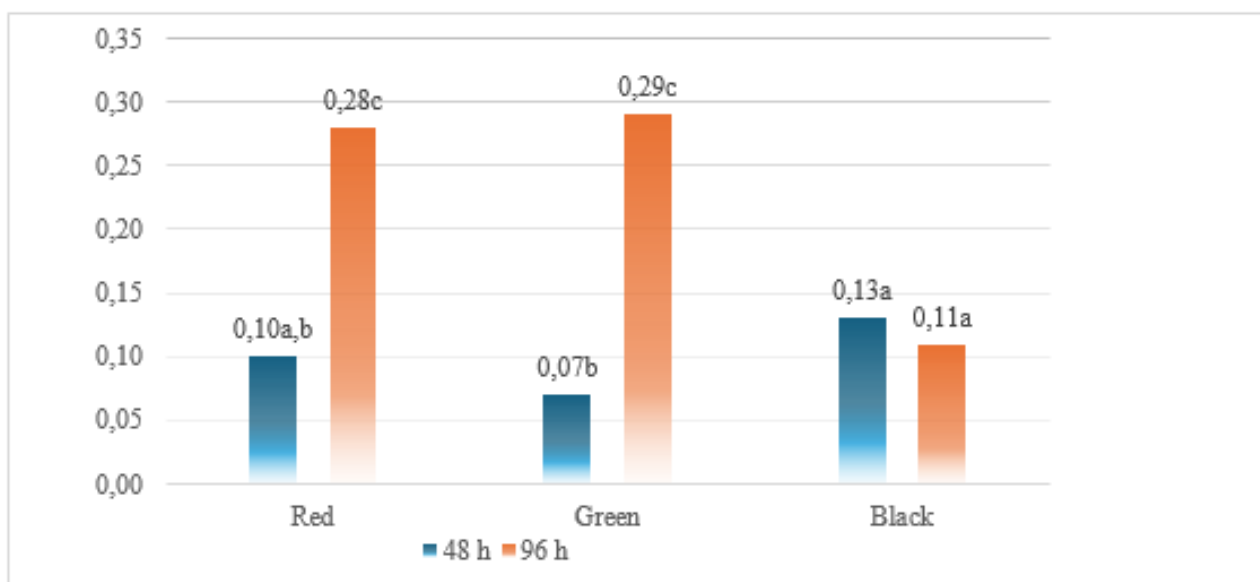


Fig. 3. Carotenoid content in sprouted lentil seeds for foods (mg g⁻¹)

Figure 3 shows that carotenoid accumulation in lentil seedlings was strongly influenced by both genotype and germination duration. After 48 h, black lentils contained the highest carotenoid concentration (0.13 mg g⁻¹), whereas red and green lentils showed lower values of 0.10 and 0.07 mg g⁻¹, respectively. After 96 h of germination, green lentils exhibited the greatest increase in carotenoid content, reaching 0.29 mg g⁻¹, while red lentils increased similarly to 0.28 mg g⁻¹. In contrast, black lentils showed only a slight decrease to 0.11 mg g⁻¹.

The increase in carotenoid concentration in red and green lentils suggests enhanced synthesis of antioxidant pigments during seedling development. Carotenoids are important for protecting photosynthetic structures against oxidative stress and for promoting chloroplast development during germination. Similar increases in carotenoid biosynthesis and antioxidant activity in germinated legumes were reported by Świeca et al. (2012) and Umar et al. (2025).

Meanwhile, the relatively stable carotenoid content in black lentils may indicate genotype-specific regulation of pigment metabolism or increased synthesis of other protective compounds during prolonged germination. Similar genotype-dependent responses in germinated legumes were also described by Sun et al. (2022) and Świeca et al. (2012). Overall, the results confirm that germination positively affects carotenoid accumulation, particularly in red and green lentil varieties.

Conclusions

The highest dry matter content was determined in red lentils after 48 hours of germination, indicating that shorter germination periods are more favorable for preserving this quality parameter. Ash content varied only slightly among the investigated samples. Longer germination promoted the accumulation of soluble solids, particularly in red and black lentils, reflecting more intensive biochemical processes during seed sprouting. The greatest increase in chlorophyll a and chlorophyll b content was observed in red lentils, highlighting their stronger potential for pigment accumulation during germination. Carotenoid content increased most markedly in green lentils after 96 hours of germination, whereas black lentils showed stable or reduced pigment concentrations during prolonged germination.

Overall, the findings confirmed that germination improves the nutritional and functional quality of lentils; however, the extent of these changes depends on lentil variety and germination duration. The obtained results may be applied to optimize lentil sprouting technologies and develop functional food products with improved nutritional and sensory quality.

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DAIGINIMO TRUKMĖS ĮTAKA DAIGINTŲ LĘŠIŲ MAISTO KOKYBĖS RODIKLIAMS

Santrauka

Daiginimas yra vienas iš paprasčiausių ir efektyviausių biologinių procesų, galinčių pagerinti pupinių augalų maistinę vertę ir funkcines savybes. Lęšiai pasižymi didele baltymų, mineralinių medžiagų ir biologiškai aktyvių junginių koncentracija, todėl jų daiginimas tampa aktualus kuriant didesnės maistinės vertės produktus. Tyrimo tikslas – nustatyti skirtingos daiginimo trukmės poveikį daigintų lęšių maisto kokybės rodikliams. Tyrimai atlikti 2025 m. Kauno kolegijos Maisto ir agrotechnologijų katedros laboratorijose. Tirtos trijų veislių lęšių sėklos: raudonieji, žalieji ir juodieji lęšiai. Sėklos buvo daiginamos 48 ir 96 val. 21 °C temperatūroje. Tyrimo metu nustatytas sausųjų medžiagų, pelenų, tirpių sausųjų medžiagų, chlorofilo a, chlorofilo b ir karotenoidų kiekis. Gauti duomenys statistiškai įvertinti taikant dispersinę analizę (ANOVA).

Nustatyta, kad ilgėjant daiginimo trukmei sausųjų medžiagų kiekis visuose lęšiuose mažėjo, o tirpių sausųjų medžiagų kiekis didėjo. Didžiausias sausųjų medžiagų kiekis nustatytas raudonuosiuose lęšiuose po 48 val. daiginimo (39,98 %), o didžiausias tirpių sausųjų medžiagų kiekis – po 96 val. daiginimo (25,7 %). Tyrimo rezultatai parodė, kad chlorofilų ir karotenoidų kaupimasis priklausė nuo lęšių rūšies bei daiginimo trukmės. Didžiausias chlorofilo a ir chlorofilo b padidėjimas nustatytas raudonuosiuose lęšiuose, o karotenoidų kiekis labiausiai padidėjo žaliuosiuose lęšiuose. Juoduosiuose lęšiuose pigmentų kiekis ilgėjant daiginimui mažėjo arba išliko stabilus.

Tyrimas parodė, kad daiginimas teigiamai veikia lęšių maistinę ir funkcinę vertę, tačiau šių pokyčių intensyvumas priklauso nuo lęšių veislės ir daiginimo trukmės. Gauti rezultatai gali būti pritaikomi kuriant funkcinius maisto produktus bei optimizuojant daiginimo technologijas maisto pramonėje.

Reikšminiai žodžiai: daiginimas, lęšiai, maisto kokybė, karotenoidai

Information about the authors

Dr. Dalė Šumskienė. Kauno kolegija Higher Education Institution, Faculty of Informatics, Engineering and Technologies, assistant. Research field – agronomy.

Email address: dale.sumskiene@go.kauko.lt.

ORCID: 0009-0007-1519-6922

Rokas Drevinskas. Kauno kolegija Higher Education Institution, Faculty of Informatics, Engineering and Technologies, student. Research field – agronomy.

Email address: rokas.dre551@go.kauko.lt