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NUTRITIONAL COMPOSITION, BIOLOGICAL ACTIVITIES, AND POTENTIAL APPLICATIONS OF PEANUT SPROUTS (*ARACHIS HYPOGAEA* L.): A REVIEW

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Abstract

Peanut sprouts (*Arachis hypogaea* L.) are the germinated product of peanut seeds – a legume rich in protein, unsaturated fatty acids, and bioactive compounds. The germination process not only changes the chemical structure but also activates the endogenous enzyme system, thereby significantly improving the nutritional value and antioxidant capacity of the seeds. Many studies have recorded a significant increase in phenolic compounds, flavonoids, resveratrol, and free radical scavenging activity (DPPH) during the germination stage. In addition, the content of essential amino acids, minerals (K, Mg, Zn, and Fe), and lipids beneficial to health were also improved, reflecting the high potential application of peanut sprouts in functional foods. Germination methods and post-harvest treatments, such as freeze-drying, convection drying, or ultrasonic extraction, have been shown to strongly affect the final biological activity. Therefore, this review focuses on systematizing studies on mineral composition, fatty acids, amino acids, germination conditions, and potential applications of peanut sprouts, aiming to provide a comprehensive view to serve the orientation of exploitation and development of functional food products from this raw material source.

Keyword: antioxidant activity, amino acids, bioactive compounds, peanut sprouts, resveratrol

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is one of the most important crops of the legume family (Fabaceae), widely cultivated in tropical and subtropical regions of the world (Akram *et al.*, 2018). With its rich nutritional properties, peanuts have long played an important role in the human diet, providing a high source of energy, good quality protein, and many essential micronutrients (Arya *et al.*, 2016). On average, peanuts contain about 45–55% oil, 20–30% protein, along with vitamins (E, B1, and B3), minerals (K, Mg, Fe, and Zn), and bioactive compounds such as polyphenols and resveratrol (Akhtar *et al.*, 2014). Through that, peanuts are not only a popular food source but also considered a potential raw material for the functional food and pharmaceutical industries.

In recent years, the trend of using functional foods and "sprouted" foods has attracted great attention from researchers and consumers, because the germination process can significantly increase the biological value of seeds (Waliat *et al.*, 2023). Under the influence of suitable conditions such as temperature, humidity, and light, endogenous enzymes in seeds are strongly activated, leading to changes in chemical composition, cell structure and content of secondary metabolites (Ozden *et al.*, 2021). Several studies have demonstrated that germination increases the content of free amino acids, unsaturated fatty acids, vitamins, phenolic compounds, and antioxidant activity, while reducing some anti-nutritional factors inherent in seeds (Kuo *et al.*, 2004).

Peanut sprouts are a prime example of this positive transformation. During the sprouting process, the resveratrol content – a polyphenol compound with strong antioxidant and anti-inflammatory properties – increases dozens of times compared to the original seed (Meng *et al.*, 2021). In addition, changes in the mineral, fatty acid, and amino acid composition improve the product's nutritional value and applicability. Thanks to that, peanuts are not only interesting as a nutritious food source but also as a potential natural ingredient for health protection and disease prevention.

Based on that importance, this review aims to systematize the existing information on peanut sprouts, including mineral composition (minerals), fatty acids (fatty acids), amino acids (amino acids), environmental, and processing conditions, as well as potential applications in the food and biomedical fields. Synthesizing and analyzing these contents not only helps to better understand the nutritional value and biological activity of peanut sprouts but also contributes to the orientation of applied research and product development in the future.

TERMS DESCRIPTION AND METHODOLOGY

Terms Description

To establish a common conceptual foundation for this review, the following key terms are defined:

Peanut sprout (*Arachis hypogaea* L.): The germinated product obtained from peanut seeds after controlled soaking and sprouting conditions. It is characterized by increased levels of bioactive compounds, especially phenolics, flavonoids, and resveratrol (Zhou *et al.*, 2021).

Bioactive compounds: Secondary metabolites synthesized during germination, including phenolic acids, flavonoids, resveratrol, and other antioxidant substances that contribute to functional and nutraceutical properties (Hung and Chen, 2022).

Nutritional value: The composition of macro- and micronutrients in peanut sprouts, encompassing proteins, amino acids, lipids (particularly unsaturated fatty acids), minerals (K, Mg, Fe, Zn), and vitamins (Ortiz and Martirosyan, 2024).

Processing and germination conditions: Technological parameters influencing seed sprouting and product quality, including soaking time, germination temperature, duration, light exposure, and post-harvest treatments such as drying or extraction (Hung and Chen, 2022).

Functional food applications: The utilization of peanut sprouts or their extracts as natural ingredients or supplements to enhance the nutritional and antioxidant properties of food products (Park *et al.*, 2022).

Review Framework

This study follows the scoping review principles outlined by Arksey and O'Malley (2005). This integrative approach was selected because the research on peanut sprouts encompasses multiple disciplines—food chemistry, nutrition, and processing technologies. To enhance methodological transparency, the review process was conducted following a predefined protocol including database selection, search strategy, eligibility criteria, and data extraction procedures.

Search Strategy and Databases

A systematic search was performed across the databases Web of Science, Scopus, PubMed, ScienceDirect, and Google Scholar, covering publications from 2001 to 2025.

Boolean search strings included the following keywords and their combinations: "peanut sprout", "germinated peanut", *"Arachis hypogaea germination", "phenolic compounds", "flavonoids", "resveratrol", "antioxidant activity", "amino acid profile", "mineral composition", "bioactive compounds", and "functional food."*

A total of 102 records were initially identified. After removing 21 duplicate records, 81 studies remained for screening. To ensure relevance, only the most pertinent results from Google Scholar were considered.

Eligibility Criteria and Screening

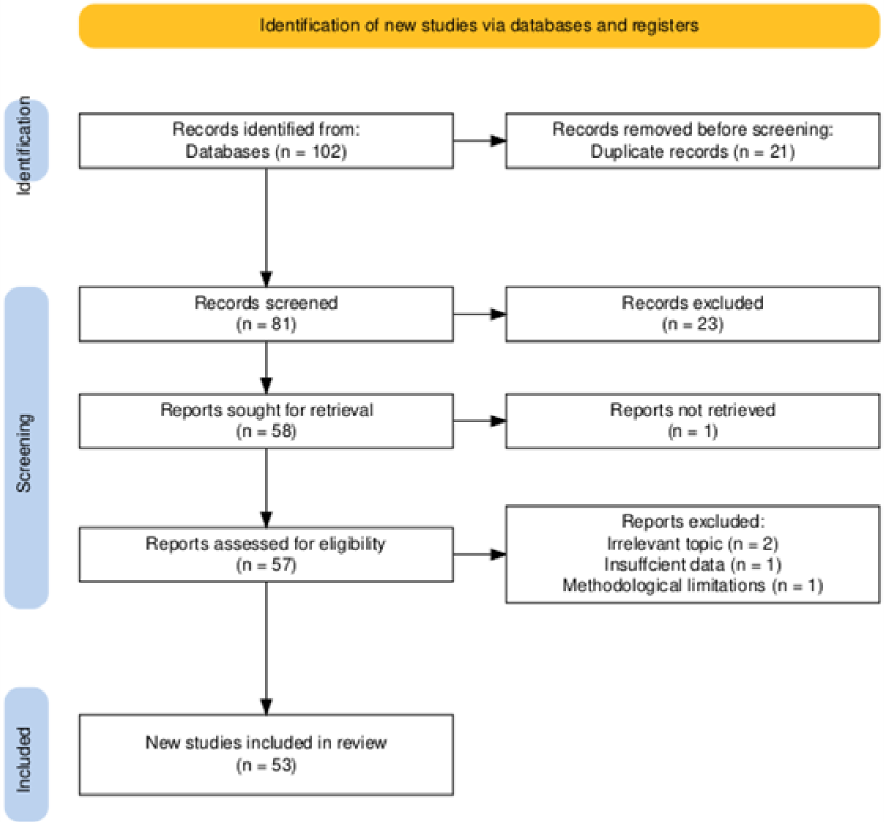
The inclusion criteria were:

a) studies focusing on *Arachis hypogaea* L. or its sprouts;
b) quantitative or qualitative data on nutritional composition or bioactive compounds;
c) clear description of germination or post-harvest processes; and
d) peer-reviewed, English-language publications.

Studies without methodological detail, duplicate sources, or unrelated topics were excluded.

The screening process was conducted in two stages: title and abstract screening followed by full-text evaluation. Two independent reviewers performed the screening, and discrepancies were resolved through discussion to reach consensus. After initial screening, 58 articles were assessed for full-text eligibility, of which 5 studies were excluded. Ultimately, 53 studies were included in the final analysis.

A PRISMA-style flow diagram summarizing (Hadaway *et al.*, 2022) the study selection process is provided in Fig. 1.



1: *PRISMA flow diagram of the study selection process*

Supplementary Search and Reference Tracking

To ensure comprehensive coverage, additional relevant works were identified using the snowballing technique by checking the reference lists of the initially selected papers. This step allowed the retrieval of older or specialized studies not indexed in major databases.

Data Extraction and Analytical Framework

Information from selected studies was extracted and categorized into the following analytical themes:

- Germination conditions: duration, temperature, soaking time, and light exposure;
- Nutritional composition: proteins, amino acids, lipids, and minerals;
- Bioactive compounds: total phenolics, flavonoids, resveratrol, and antioxidant capacity (DPPH, ABTS, FRAP assays);
- Processing techniques: drying (freeze-drying, oven-drying) and extraction methods (ultrasonic, solvent-assisted);
- Functional applications: potential use in health foods and nutraceuticals.

Comparative Analysis and Synthesis

Selected studies were systematically compared to identify convergent findings, conflicting evidence, and gaps in knowledge. The comparative synthesis focused on: the impact of germination conditions on the enhancement of nutritional and antioxidant properties; variation in methodologies and analytical approaches; and potential industrial applications of peanut sprouts in functional food development. The final synthesis provides a comprehensive and critical overview of current scientific understanding, while outlining research priorities for future investigations.

Germination Conditions of Peanut Sprouts

The peanut sprouting process usually includes the main stages: pretreatment and sterilization of seeds, soaking and absorbing water, and germination under controlled conditions of temperature, humidity, and light (Tab. I). These parameters have a great influence on the germination rate and biomass, as well as the content of biological compounds accumulated in the sprouts. However, the optimal conditions may vary depending on the bean variety, climate zone, equipment used, and research objectives.

In Tab. II, studies on the process of collecting and making powder from peanut sprouts as well as other seeds show clear differences in harvesting time, post-germination treatment methods, and drying techniques — factors that directly affect the nutrient content and biological activity of the final product.

Regarding the time of germination, most studies choose the period of 3–7 days of germination for cereals and oilseeds such as peanuts, millet, I: *Comparison of germination conditions for peanut (Arachis hypogaea L.) sprouts in some countries*

Countries	Pre-treatment	Soaking conditions	Germination conditions	Environment	Germination time	References
China (Liaoning province)	1% NaOCl, 15–20 minutes; rinse with sterile water	6–8 h at 25°C (in the dark)	28°C, RH 90%, complete darkness	Growth chamber RDN-300G	5 days	Yu *et al.* (2016)
China (Henan province)	No details, clean seed treatment	Soak in water at 30–35 °C for 8–10 hours	25–29 °C, RH ~100%	Standard incubation room	-	Xu *et al.* (2025)
Korea	Commercial seed cleaning	Soak in normal water for 1 day	25 ± 1 °C, 9 days	Shinchang Inc. Automatic Incubator	9 days	Kang *et al.* (2010)
Thailand	NaCl 0.5% 0.5 h, rinse with tap water	Soak for another 3 hours to absorb water.	Humid, spray water every 15 minutes, rest for 15 minutes; in the dark	Continuous water spray chamber	1–4 days	Limmongkon *et al.* (2017)

II: *Process of collecting and creating bean powder in peanuts and some other nuts*

Countries	Harvesting sprouts	Drying methods	References
Peanut (China)	After 5–6 days	Frozen at -80 °C × 12 h → freeze dried 72 h	Yu et al. (2022)
Peanut (Thailand)	After 1–4 days	Dry in oven at 60 °C	Limmongkon et al. (2017)
Millet (United States)	After 3 days	Frozen at -80 °C → Freeze dried → Grind into powder.	Al-Taher and Nemzer (2023)
Seasame (Pakistan)	After 7 days	Freeze dried in a Christ Alpha 1-14 LD freeze dryer and ground to powder.	Shabbir et al. (2015)
Barley (Serbia)	After 7 days	Freeze dried → Grind into powder.	Aborus et al. (2017)
Onion (India)	After 3 weeks	Frozen at -20 °C, lyophilized and ground into powder.	Majid and Nanda (2017)

sesame, and barley. This stage is considered the optimal physiological stage for bioactive compound accumulation, when endogenous enzyme activities (amylase, protease, lipase) reach a high level, helping to enhance the hydrolysis process and accumulate bioactive compounds such as polyphenols, flavonoids, peptides, and free amino acids. For peanuts, studies of Yu *et al.* (2022) and Limmongkon *et al.* (2017), it has been shown that harvesting within the first 4–6 days helps to achieve the highest antioxidant and nutritional values, while prolonging the germination period may lead to a gradual decrease of some sensitive compounds due to increased oxidation and respiration. Regarding drying methods, the two main approaches noted are freeze-drying and oven-drying. Freeze-drying, commonly applied in studies of Yu *et al.* (2022), Shabbir *et al.* (2015), Aborus *et al.* (2017), and Majid and Nanda (2017), is considered superior due to its ability to maintain the cell structure, preserve volatile and heat-sensitive compounds, such as vitamin C, polyphenols, and antioxidant enzymes (superoxide dismutase, catalase). However, the major limitations of this technique are the high cost of equipment and the long processing time (usually 48–72 h), making it difficult to apply on an industrial scale. In contrast, the heat drying method at 60 °C, as Limmongkon *et al.* (2017), may cause some reduction of biological activity but is more suitable for commercial application due to its low cost and ease of scale-up.

A comparison among different nuts shows that peanuts and sesame are typically subjected to processing techniques that preserve bioactive compounds, such as freezing and freeze-drying. In contrast, barley and millet are generally processed using simpler methods, primarily to obtain stable dry powders for research or food applications. Especially for non-traditional subjects like sprouted onions (Majid and Nanda, 2017), a longer germination period (3 weeks) was chosen to optimize the formation of characteristic compounds, such as quercetin and anthocyanin, suggesting that the target of bioactive compounds is a decisive factor in the choice of harvest time and drying technology.

Taken together, these results show that the current peanut sprout powder production process is moving towards a combination of germination physiology and modern nutrient preservation technology. Among them, freeze-drying remains the ideal option for in-depth research, while thermal drying can be improved (e.g., vacuum drying, infrared drying, or microwave drying) to balance energy efficiency and bioactivity preservation. Future research should focus on standardizing the harvesting and drying process to ensure stable peanut sprout powder quality for applications in functional foods, fermented products or protein-rich food alternatives.

Resveratrol content, total polyphenol content (TPC), and antioxidant activity (AA) are important indicators reflecting the biological value of bean sprouts. As shown in Tab. III, the resveratrol content in bean sprouts varies greatly among countries, from 0.28–47.1 μg/g dry weight (DW), depending significantly on the bean variety, germination conditions, and quantification method. The study of Yu *et al.* (2016) in China recorded 2.55–4.02 μg/g, while Kang *et al.* (2010) in Korea and Wang *et al.* (2005) in Taiwan reached 7.83–21.47 and 1.42–15.05 μg/g, respectively. Notably, the study by Limmongkon *et al.* (2017) in Thailand showed a very large variation (0.28–47.1 μg/g), suggesting that the ability to accumulate resveratrol strongly depends on lighting conditions, humidity, and germination time.

However, beyond these environmental factors, the observed variability can also be explained by differences in metabolic regulation during germination. Resveratrol is synthesized via the phenylpropanoid pathway, in which the activity of key enzymes such as phenylalanine ammonia-lyase (PAL) and stilbene synthase (STS) is highly sensitive to external stimuli, including light exposure and abiotic stress (Hasan and Bae, 2017). Variations in germination conditions may therefore lead to differential activation of these enzymes, resulting in inconsistent accumulation patterns across studies.

In addition, the efficiency of resveratrol extraction depends strongly on solvent polarity (e.g., methanol, ethanol, acetone), extraction temperature, and time, which can affect the recovery of both free and bound phenolic forms (Galanakis *et al.*, 2012). Furthermore, analytical techniques such as high-performance liquid chromatography (HPLC) and spectrophotometric assays differ in specificity and sensitivity; while HPLC enables more accurate quantification of individual compounds, spectrophotometric methods may overestimate total phenolics due to interference from co-extracted substances (Wolfender, 2009). Consequently, these methodological inconsistencies can significantly influence the reported concentrations and limit direct comparison between studies.

The general trend is that the resveratrol content increases rapidly in the first 3–5 days and gradually decreases thereafter due to the biooxidation of phenolics. Compared to other nuts, peanut sprouts exhibit typical levels of resveratrol, but their total polyphenol content and antioxidant activity (DPPH) are superior under certain conditions. Specifically, the TPC of peanut sprouts in Korea ranged from 10.7–22.4 mg GAE/100 g DW, which was significantly higher than the original value of raw nuts and comparable to or exceeding that of some other sprouts such as barley sprouts (479.02–713.25 mg GAE/100 g) according to Aborus *et al.* (2017), or soybean sprouts (10.02–53.17 mg GAE/g) according to Sun *et al.* (2018). Similarly, the AA estimated by DPPH (2,2-diphenyl-1-picrylhydrazyl) assay of peanut sprouts increased sharply after germination, with values ranging from 15.45% to 61.62%, which was many times higher than that of ungerminated seeds (Wang *et al.*, 2005; Limmongkon *et al.*, 2017). The magnitude of this increase, however, varies considerably among studies, likely due to differences in assay conditions and methodological approaches.

Notably, when comparing between species, the increase in antioxidant activity (DPPH) of peanut sprouts was comparable to or even higher than that of sesame sprouts, which recorded an increase from 15.00% to 93.37% after germination (Shabbir *et al.*, 2015). This suggests that germination plays a crucial role in activating phenolase enzymes and promoting the biosynthesis of new phenolic compounds, among which resveratrol is considered as a characteristic marker of peanut sprouts (Xu *et al.*, 2020).

The wide variation among reports suggests that environmental factors and germination techniques have a key influence on the bioactivity of peanut sprouts. Factors such as light intensity, relative humidity, incubation solution pH, and germination time can strongly alter the final results. Specifically, low light (50–100 lux) and high humidity (85–90%) conditions are considered optimal for resveratrol formation, while high or prolonged light exposure can cause degradation of this compound.

III: *Resveratrol, total polyphenol content (TPC) and antioxidant activity (AA) of peanut seeds and sprouts in different countries*

	Liaoning province, China (Yu *et al.*, 2016)		Korea (Kang *et al.*, 2010)		Taiwan (Wang *et al.*, 2005)		Thailand (Limmongkon *et al.*, 2017)	
	Seeds	Sprouts	Seeds	Sprouts	Seeds	Sprouts	Seeds	Sprouts
Resveratrol (μg/g DW)	2.55–4.02	7.83–21.47	1.42	15.05	2.3–4.5	12.0–47.1	1.20–2.88	0.28–1.34
TPC (mg GAE/g DW)	-	-	5.6–6.3	10.7–22.4	-	-	15.65–36.85	12.06–28.72
AA (%)	-	-	-	-	10.69–10.89	15.45–37.67	29.36–46.85	43.60–61.62

Note: “-“ not tested

Taken together, the available data confirm that peanut sprouts are a highly potent source of resveratrol and polyphenols in the legume family, with strong antioxidant capacity, easy absorption, and can be controlled through growth factors during germination. This potential opens up a wide range of applications in functional foods, natural antioxidant products, and research on metabolic disease prevention.

Amino Acids

The germination process causes significant fluctuations in the amino acid content of both essential and non-essential amino acids (Tab. IV). For peanut sprouts (Xu *et al*., 2025), most amino acids tended to decrease slightly or remained the same, except for methionine (Met), which increased sharply (+133.33%). This decrease is thought to be due to the amino acids being mobilized as raw materials for the biosynthesis of structural proteins, enzymes, and secondary metabolites during the early stages of germination. In contrast, in flax (Kraevska *et al*., 2017) and broccoli seeds (López-Cervantes *et al*., 2013), germination generally resulted in a slight to strong increase in the contents of most amino acids, reflecting a stronger proteolytic activity in these species. Lentils sprouts also showed a marked increase (3.97–32.22%) in some amino acids such as valine, leucine, phenylalanine, and lysine, suggesting that germination in lentils is highly metabolically efficient (Fouad and Rehab, 2015).

In the essential amino acid group, peanut sprouts showed a relatively uniform decrease in threonine (-13.25%), valine (-10%), isoleucine (-10.20%), leucine (-11.62%), phenylalanine (-12.78%), and histidine (-12.12%), while methionine increased more than two-fold (Xu *et al*., 2025). This may involve the activation of methyltransferase enzymes and methionine synthesis from cysteine when the seeds begin to respire vigorously (Amir *et al*., 2019). Meanwhile, in flaxseed and quinoa sprouts, most essential amino acids increased slightly by 3–15%, especially lysine (+12.82%) and threonine (+7.38%) in flaxseed, as well as leucine and isoleucine in quinoa (up to ~15%). Notably, lentil sprouts exhibited a remarkable increase in branched-chain amino acids (valine, leucine) and phenylalanine, which may reflect the high protease activity and storage protein degradation typical of legumes (de Carvalho *et al*., 2001). Thus, peanuts tend to “preserve” protein during the germination phase, while quinoa and lentils show a stronger ability to mobilize endogenous nitrogen sources.

IV: *Changes in amino acid during germination of some seeds (g/100 g of protein, %)*

	Peanut (Xu *et al*., 2025)		Flax (Kraevska *et al*., 2017)		Broccoli* (López-Cervantes *et al*., 2013)		Lentil (Fouad and Rehab, 2015)	
	Essential amino acid							
	Seeds	Sprouts	Seeds	Sprouts	Seeds	Sprouts	Seeds	Sprouts
Thr	1.51	1.31	3.66	3.93	6.90	4.85	3.0	2.54
Val	1.80	1.62	3.48	3.72	3.76	2.62	4.5	5.95
Met	0.09	0.21	2.13	2.11	1.55	0.99	0.8	0.42
Iso	1.47	1.32	2.68	2.76	2.93	1.94	3.80	3.60
Leu	2.84	2.51	6.15	6.37	5.01	2.94	7.8	8.25
Phe	2.66	2.32	4.31	4.06	3.19	2.06	4.50	5.60
Lys	1.28	1.20	3.90	4.40	-	-	7.3	7.59
His	1.32	1.16	1.89	1.75	-	-	2.50	1.96
	Non-essential amino acid							
	Seeds	Sprouts	Seeds	Sprouts	Seeds	Sprouts	Seeds	Sprouts
Asp	4.77	4.58	9.09	14.01	18.98	17.39	13.70	14.02
Ser	3.22	2.77	5.83	5.79	-	-	3.5	3.5
Glu	8.61	7.69	24.14	23.58	26.68	33.53	21.4	21.2
Gly	1.64	1.48	7.15	6.32	2.72	1.65	3.6	3.4
Ala	1.73	1.65	5.58	6.16	0.84	0.65	4.70	4.88
Tyr	2.01	1.72	2.66	3.96	3.47	2.40	3.3	3.16
Arg	6.36	5.43	9.57	7.26	1.41	0.00	7.60	7.66
Pro	2.02	1.88	6.16	1.64	8.54	7.18	4.9	4.6

Note: “*” Converted to g/100 g of protein, “-” not detected

In the non-essential amino acid group, the changes in peanuts were mainly slight decreases: aspartic acid (-3.98%), glutamic acid (-10.69%), glycine (-9.76%), serine (-13.98%), and arginine (-14.62%) (Xu *et al.*, 2025). These decreases suggest that these amino acids are actively used in new protein synthesis and in energy metabolism. In contrast, peanut methionine and alanine tended to increase, possibly due to enhanced transamination reactions. Compared to other nuts, flaxseed sprouts exhibited mixed fluctuations—some increased (aspartic acid +54.13%; tyrosine +48.87%), while some decreased (arginine -24.14%) (Kraevska *et al.*, 2017). Broccoli seeds and sprouts showed a strong increase in only glutamic acid (up to 26%), while most other amino acids, including serine, aspartic acid, threonine, valine, leucine, isoleucine, and phenylalanine, decreased during germination when expressed per 100 g of protein, indicating that total protein accumulation outpaces amino acid synthesis in this species (López-Cervantes *et al.*, 2013). Lentils, similar to flaxseeds, showed less variation, mostly within ±5–10%.

Overall, it can be seen that peanut sprouts tend to maintain or slightly decrease the amino acid content, which is clearly different from quinoa and lentils, which have a strong increase. This suggests that the physiological mechanism in peanut germination is more oriented towards restructuring and efficient use of available protein sources, rather than increasing the amount of free amino acids. In addition, the sudden increase in methionine in peanut sprouts is a rare feature, which may play an important role in antioxidant responses and growth regulation in the early stages of germination (Li *et al.*, 2014).

Fatty Acids

Germination is a complex physiological stage in which hydrolysis, oxidation, and biosynthesis reactions take place vigorously to provide energy and raw materials for the development of young shoots. Changes in Tab. V fatty acids composition directly reflect changes in lipid metabolism in cells, and significantly affect the nutritional value, sensory, and stability of seed oil after germination (Cao *et al.*, 2023).

For peanuts sprouts, germination significantly increased the proportion of saturated fatty acids; specifically, palmitic acid increased by 14.2%, stearic acid increased by 10.5%, behenic acid increased by 28.0% and arachidic acid increased by 21.4% (Xu *et al.*, 2025). This increase may be related to the increased activity of lipase and acyl-CoA oxidase enzymes, leading to triglyceride hydrolysis and fatty acid reesterification, in which saturated long-chain acids are synthesized predominantly to ensure cell membrane stability under conditions of increased germinal respiration (Muslimov *et al.*, 2022). In contrast, polyunsaturated fatty acids such as linoleic (C18:2) and linolenic acid (C18:3) decreased significantly (decreased by 11.2% and 55.6%, respectively), indicating their high oxidation potential and easy degradation during energy production.

Notably, oleic acid (C18:1) – the main monounsaturated fatty acids of peanut oil – increased by 7.75% (Xu *et al.*, 2025). This is a positive development, as oleic acid is considered a heart-healthy fatty acids, and it also increases the oil's oxidative stability by reducing the linoleic/oleic ratio. The lower the ratio, the more heat-resistant and less rancid the oil is, suggesting that germination may have some effect on the lipid quality of peanuts (Deng *et al.*, 2025).

Compared to flaxseed sprouts, the trend was less pronounced. Palmitic and stearic acid contents fluctuated slightly, while oleic and linoleic acid increased very little (about 1–3%) (Xu *et al.*, 2025). Flaxseeds are rich in α-linolenic acid (C18:3) – an omega-3 fatty acid that is prone to oxidation – but during germination, the internal lipid protection mechanism, involving high peroxidase enzyme activity and natural antioxidants like lignans and phenolics, helps prevent the loss of α-linolenic acid. This explains why the level of unsaturated fatty

V: *Changes in fatty acid composition during germination of some seeds (%)*

	Peanut (Xu *et al.*, 2025)		Flax (Zhang *et al.*, 2023)		Millet (Al-Taher and Nemzer, 2023)	
	Seeds	Sprouts	Seeds	Sprouts	Seeds	Sprouts
Palmitic acid	10.70	12.20	5.19–5.70	4.86–5.45	7.60	9.25
Arachidic acid	1.40	1.70	-	-	-	-
Behenic acid	2.50	3.20	-	-	-	-
Stearic acid	3.80	4.20	3.79–4.65	3.84–4.77	2.59	2.21
Arachidonic acid	0.70	0.70	-	-	-	-
Oleic acid	37.40	40.30	18.55–21.31	18.63–21.91	11.94	13.85
Linoleic acid	41.80	37.10	15.32–16.05	15.76–16.68	73.64	70.97
Linolenic acid	1.80	0.80	-	-	1.08	0.14

Note: “-” Not detected

acids in flaxseeds remains stable after germination, demonstrating the effectiveness of this species' antioxidant enzyme system (Zhang *et al.*, 2023).

Meanwhile, millet showed a similar trend to peanuts, but more pronounced in the saturated fatty acid group. Palmitic acid increased by 21.7%, oleic acid increased by 16.0%, while linoleic acid decreased slightly (-3.6%) and linolenic acid decreased very sharply (-87.0%) (Al-Taher and Nemzer, 2023). This sharp decrease in polyunsaturated fatty acids reflects the intense oxidation of storage lipids under the influence of lipoxygenase enzymes – characteristic of germinated cereal grains. In addition, the increase in saturated fatty acids also helps stabilize cell membranes and reduces the risk of lipid peroxidation, a process that damages membrane structure under the high aerobic respiratory conditions of germinated cereals (Nemzer and Al-Taher, 2023).

In general, it can be seen that germination causes a general trend of increasing saturated fatty acids and decreasing polyunsaturated fatty acids, although the degree of variation varies between species. Seeds with high oil content, such as peanuts, often record more pronounced changes than seeds with low oil content, such as millet. This difference stems from the initial lipid ratio, lipase/lipoxygenase enzyme activity, the respiration rate of the germ, as well as the time and conditions of germination.

In terms of nutritional significance, the germination process reduces easily oxidized fatty acids, thereby increasing lipid stability, but at the same time can reduce the ratio of linoleic acid and linolenic acid - two essential fatty acids. However, the slight increase in oleic acid along with the ability to form some biologically active lipid derivatives (such as oxylipin, jasmonate) opens up new applications for peanut sprouts in the field of functional foods and biomaterials (Nemzer and Al-Taher, 2023).

Overall, the fatty acid fluctuations during germination not only reflect lipid metabolism restructuring for germination cell development, but can also be exploited to adjust oil composition to enhance the sensory, nutritional, and product stability values of germinated seeds.

Mineral Nutrients

Minerals play an essential role in the metabolism, enzyme activity, and cell structure of germinating plants. During this stage, physiological reactions take place vigorously - especially the activation of hydrolytic enzymes, protein, and nucleic acid synthesis - causing significant changes in the absorption and distribution of mineral elements in the seed (Dobrowolska-Iwanek *et al.*, 2022). Comparisons between sprouts show that each species has a unique mineral profile, reflecting its own physiological mechanism and nutritional value (Tab. VI).

However, despite all values being expressed on a dry weight (DW) basis, substantial variability among studies may still arise due to differences in plant genotype, cultivation conditions, and analytical techniques, which should be considered when interpreting cross-species comparisons.

In peanut sprouts, potassium (K) content ranges from 573.32–646.82 mg/100 g, accounting for the highest proportion of minerals recorded (Xu *et al.*, 2025). K is the major ion in the cytosol, participating in the regulation of osmotic balance, enzyme activity and membrane potential conduction, and also plays an important role in maintaining the respiratory and photosynthesis activities of the germ (Mostofa *et al.*, 2022). Compared with other sprouts, K in peanuts was significantly lower than that in soybean sprouts (1,017 mg/100 g) but was similar to the average level in sprouted cereals (Ghani *et al.*, 2016). Nevertheless, this large difference should be interpreted with caution, as variations in mineral accumulation and experimental conditions may influence the reported values.

Although the phosphorus content in chickpea sprouts ranged from 416 mg/100 g, reflecting the strong phosphorus mobilization ability of legumes during germination (Erba *et al.*, 2019), peanut sprouts showed an even higher level, reaching

VI: *Mineral content (mg/100 g dry weight, DW) of peanut sprouts and others*

	Peanut (Xu *et al.*, 2025)	Barley (Dobrowolska-Iwanek *et al.*, 2022)	Soybean (Ghani *et al.*, 2016)	Chickpea (Erba *et al.*, 2019)
P	519.81–522.20	-		416
Na	12.52–13.82	-	860	-
K	573.32–646.82	-	1,017	-
Ca	9.52–15.50	25	277	54.5
Mg	102.94–106.83	94	151	97.8
Fe	2.80–3.31	15.9	3.53	6.3
Zn	2.85–3.46	3.71	8.59	2.7
Cu	0.86–1.05	7.54	1.96	-
Mn	1.17–1.56	1.53	1.96	-

Note: “-” Not tested

approximately 519.81–522.20 mg/100 g, which corresponds to organic phosphate reserves for ATP synthesis and membrane phospholipids in early development (Xu *et al.*, 2025).

Trace elements, such as iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) in peanut sprouts, are quite low compared to other types of sprouts. Specifically, Fe only reaches 2.80–3.31 mg/100 g, significantly lower than chickpea (6.3 mg/100 g) and soybean (3.53 mg/100 g) (Ghani *et al.*, 2016; Erba *et al.*, 2019; Xu *et al.*, 2025). Zn fluctuates 2.85–3.46 mg/100 g, also much lower than that of soybean sprouts (8.59 mg/100 g). Such differences may be related to species-specific mineral uptake capacity and the redistribution of micronutrients during germination.

Notably, calcium (Ca) and magnesium (Mg) in peanut sprouts fluctuate at relatively stable levels (Ca: 9.52–15.50 mg/100 g; Mg: 102.94–106.83 mg/100 g) (Xu *et al.*, 2025). Mg is the center of chlorophyll molecules, so during the light germination stage, Mg content may increase slightly due to chlorophyll synthesis (Cakmak and Yazici, 2010).

When compared as a whole, soybean and chickpea sprouts stand out for their very high trace minerals content (Fe, Zn, Cu, and Mn), while peanut sprouts have an advantage in the balanced ratio of P, K, and Mg—a group of minerals directly related to energy metabolism and cell growth. Despite the lower total minerals content, peanut sprouts are still highly valued for their better digestibility and the reduction of anti-nutritional factors such as phytic acid and tannin during the germination process, making minerals more easily absorbed (Zayed *et al.*, 2025). However, the bioavailability of these minerals may differ significantly among species and processing conditions, which warrants further investigation.

From the above data, it can be seen that the germination process not only changes the absolute content but also improves the nutritional quality of minerals in peanuts. Compared with other sprouts, peanut sprouts exhibit a relatively good mineral balance, being a valuable natural source of phosphorus (P), magnesium (Mg), and potassium (K), while providing small amounts of trace elements that support enzyme function and cellular antioxidant defence. These characteristics contribute to the potential use of peanut sprouts as a mineral-rich ingredient suitable for nutritional and functional food preparations.

Applications of Peanut Sprouts

The application of bean sprouts in food has shown many outstanding potentials in both nutritional value and biological activity. Research by Yu *et al.* (2022) showed that the yogurt formula supplemented with 2% bean sprout powder showed outstanding advantages compared to traditional yogurt. In terms of biological activity, this product has significantly stronger antioxidant capacity, with 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) free radical reduction rates reaching 25.07% and 24.75%, respectively, while conventional yogurt only reached 17.10% and 17.03%. In addition, bean sprouts also act as a favorable biological substrate for the fermentation process, helping the number of lactic acid bacteria to nearly double, reaching 3.6 × 109 CFU/g compared to 1.9 × 109 CFU/g in the control sample. In addition to the field of fermented foods, bean sprout extract is also noted to have many positive biological effects on human health.

According to Ha *et al.* (2015), this clinical study demonstrated that 4 weeks of peanut sprout supplementation improved waist circumference, reduced abdominal fat, and lowered serum LDL-cholesterol and triglyceride levels, indicating its potential role in managing obesity and dyslipidemia. Peanut sprout extract also reduced systolic blood pressure (in the low-dose group) and improved liver function, as indicated by decreased liver enzyme activity. These findings support the potential application of peanut sprouts as a functional food ingredient or dietary supplement for metabolic health improvement.

In particular, the study also confirmed the high biosafety of peanut sprout extraction, as no abnormal changes in hematological indices, such as red blood cell and white blood cell counts, were observed. Thus, peanut sprouts are not only a potential source of raw materials for functional foods and nutritional fermented products, but can also be exploited as a supporting agent for regulating metabolism, preventing obesity, and diseases related to metabolic disorders.

Allergenicity and Safety of Peanut Sprouts

Peanut allergenicity is primarily associated with several well-characterized storage proteins, including Ara h 1 (vicilin-type 7S globulin), Ara h 2 and Ara h 6 (2S albumins), and Ara h 3 (legumin-type 11S globulin), which are recognized as major allergens due to their strong IgE-binding capacity and resistance to thermal and enzymatic degradation (Guo and Barkla, 2025). Among these, Ara h 2 is considered one of the most potent allergens and is strongly associated with severe allergic reactions in sensitized individuals (Kukkonen *et al.*, 2015).

Germination may influence the allergenic potential of peanut proteins through structural and biochemical modifications (Li *et al.*, 2016). During sprouting, endogenous proteases are activated, leading to partial degradation of storage proteins and potential alteration of IgE-binding epitopes (Soh *et al.*, 2023). In addition, changes in protein conformation and increased enzymatic hydrolysis may reduce the accessibility of allergenic sites. However, the extent of allergenicity reduction remains inconsistent across studies, as some allergenic proteins, particularly Ara h 2, exhibit high stability and may persist even after germination (Soh *et al.*, 2023).

Cross-reactivity between peanut allergens and proteins from other legumes (e.g., soybean, lupin, and pea) has been widely reported due to structural homology among seed storage proteins (Bublin and Breteneder, 2014). While serological assays (e.g., IgE-binding or EAST inhibition) demonstrate significant cross-reactivity, the clinical relevance of these findings is variable. Not all cross-reactive responses result in clinical symptoms, as allergenic potential depends on factors such as protein digestibility, exposure level, and individual immune sensitivity (Popescu, 2015). Therefore, clinical validation is essential to determine the actual risk associated with cross-reactive proteins in peanut sprouts and related products.

Potential and Challenges in Peanut Sprouts

Bean sprouts may contain proteins that are similar in structure to peanut allergens. Because of this similarity, the immune system of a peanut-allergic individual can mistakenly identify these proteins as a threat and trigger an allergic reaction. Clinically, very small doses (44 to 311 mg of peanut protein), are sufficient to induce allergic reactions in sensitized patients. Serologically, cross-reactivity has been demonstrated by the Enzyme-AllergoSorbent Test (EAST) inhibition test: protein extracts from lupins, soybeans, and green peas at concentrations ranging from 1 mg/mL to 744 µg/mL significantly inhibited (56–63%) IgE binding to peanut protein. These findings confirm the potential for cross-reactivity, even at low concentrations (Jensen *et al*., 2008).

However, in parallel with this risk, peanut sprouts are still considered a potential source of raw materials for the food industry thanks to their high nutritional value, good digestibility, and strong antioxidant content. Some recent studies have shown that peanut sprout powder can be applied in the production of baked goods, snacks, or plant protein supplements, helping to improve the sensory and nutritional value without changing the product structure. In addition, the germination process also reduces anti-nutritional factors such as phytic acid and tannin, thereby increasing the ability to absorb minerals and protein. Most of these findings are based on experimental or pilot-scale studies, and their applicability at industrial or clinical levels remains limited.

In the future, research should focus on optimizing the germination process and heat treatment to reduce the allergenicity of peanut protein while maintaining high nutritional value. Methods such as fermentation, protease enzymes, or ultrasonic treatment can help change the allergenic epitope structure, opening up opportunities for safer application of peanut sprout powder in functional foods and animal protein substitutes. Nevertheless, current evidence for allergenicity reduction is largely derived from in vitro or model systems, and further in vivo and clinical studies are required to confirm these effects.

CONCLUSION

Peanut sprouts are a potential source of high nutritional and biological value, superior to regular peanuts. The germination process is a key stage in increasing the content of resveratrol, total polyphenols, and antioxidant capacity, while improving the amino acid and mineral composition. Technical factors, such as temperature, humidity, germination time, and drying method, play a decisive role in the final quality of the product. The application of peanut sprouts in food – especially fermented products such as yogurt or health drinks – opens up new directions in the development of natural functional foods, supporting cardiovascular health, lipid metabolism, and obesity control. In the future, further in-depth studies on the biochemical mechanisms during germination, as well as the optimization of the production process of sprout powder on an industrial scale, are needed. This not only contributes to diversifying nutrient-rich food products but also increases the economic value of peanuts in the sustainable agricultural production chain.

REFERENCES

ABORUS, N. E., ČANADANOVIĆ-BRUNET, J., ĆETKOVIĆ, G., ŠAPONJAC, V. T., VULIĆ, J., ILIĆ, N. 2017. Powdered barley sprouts: composition, functionality and polyphenol digestibility. *International Journal of Food Science and Technology*. 52(1), 231–238. https://doi.org/10.1111/ijfs.13274

AKHTAR, S., KHALID, N., AHMED, I., SHAHZAD, A., SULERIA, H. A. R. 2014. Physicochemical characteristics, functional properties, and nutritional benefits of peanut oil: a review. *Critical Reviews in Food Science and Nutrition*. 54(12), 1562–1575. https://doi.org/10.1080/10408398.2011.644353

AKRAM, N. A., SHAFIQ, F., ASHRAF, M. 2018. Peanut (*Arachis hypogaea* L.): a prospective legume crop to offer multiple health benefits under changing climate. *Comprehensive Reviews in Food Science and Food Safety*. 17(5), 1325–1338. https://doi.org/10.1111/1541-4337.12383

AL-TAHER, F., NEMZER, B. 2023. Effect of germination on fatty acid composition in cereal grains. *Foods*. 12(17), 3306. https://doi.org/10.3390/foods12173306

AMIR, R., COHEN, H., HACHAM, Y. 2019. Revisiting the attempts to fortify methionine content in plant seeds. *Journal of Experimental Botany*. 70(16), 4105–4114. https://doi.org/10.1093/jxb/erz134

ARKSEY, H., O'MALLEY, L. 2005. Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*. 8(1), 19–32. https://doi.org/10.1080/1364557032000119616

ARYA, S. S., SALVE, A. R., CHAUHAN, S. 2016. Peanuts as functional food: a review. *Journal of Food Science and Technology*. 53(1), 31–41. https://doi.org/10.1007/s13197-015-2007-9

BUBLIN, M., BREITENEDER, H. 2014. Cross-reactivity of peanut allergens. *Current Allergy and Asthma Reports*. 14(4), 426. https://doi.org/10.1007/s11882-014-0426-8

CAKMAK, I., YAZICI, A. M. 2010. Magnesium: a forgotten element in crop production. *Better Crops*. 94(2), 23–25.

CAO, D., MA, Y., CAO, Z., HU, S., LI, Z., LI, Y., WANG, K., WANG, X., WANG, J., ZHAO, K., LI, Z., REN, R., MA, X., ZHANG, X., GONG, F., JUNG, M. Y., YIN, D. 2023. Coordinated lipid mobilization during seed development and germination in peanut (*Arachis hypogaea* L.). *Journal of Agricultural and Food Chemistry*. 72(6), 3218–3230. https://doi.org/10.1021/acs.jafc.3c06697

DE CARVALHO, M. H. C., D'ARCY-LAMETA, A., ROY-MACAULEY, H., GAREIL, M., EL MAAROUF, H., PHAM-THI, A. T., ZUILY-FODIL, Y. 2001. Aspartic protease in leaves of common bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna unguiculata* L. Walp): enzymatic activity, gene expression and relation to drought susceptibility. *FEBS Letters*. 492(3), 242–246. https://doi.org/10.1016/S0014-5793(01)02259-1

DENG, J., HOU, M., CUI, S., LIU, Y., LI, X., LIU, L. 2025. Integrative analysis of transcriptome and metabolome reveals molecular mechanisms of dynamic change of storage substances during dehydration and drying process in peanuts (*Arachis hypogaea* L.). *Frontiers in Plant Science*. 16, 1567059. https://doi.org/10.3389/fpls.2025.1567059

DOBROWOLSKA-IWANEK, J., ZAGRODZKI, P., GALANTY, A., FOŁTA, M., KRYCZYK-KOZIOŁ, J., SZLÓSARCZYK, M., RUBIO, P. S., DE CARVALHO, I. S., PAŚKO, P. 2022. Determination of essential minerals and trace elements in edible sprouts from different botanical families—application of chemometric analysis. *Foods*. 11(3), 371. https://doi.org/10.3390/foods11030371

ERBA, D., ANGELINO, D., MARTI, A., MANINI, F., FAORO, F., MORREALE, F., PELLEGRINI, N., CASIRAGHI, M. C. 2019. Effect of sprouting on nutritional quality of pulses. *International Journal of Food Sciences and Nutrition*. 70(1), 30–40. https://doi.org/10.1080/09637486.2018.1478393

FOUAD, A. A., REHAB, F. M. 2015. Effect of germination time on proximate analysis, bioactive compounds and antioxidant activity of lentil (*Lens culinaris* Medik.) sprouts. *Acta Scientiarum Polonorum Technologia Alimentaria*. 14(3), 233–246. https://doi.org/10.17306/J.AFS.2015.3.25

GALANAKIS, C. M., GOULAS, V., TSAKONA, S., MANGANARIS, G. A., GEKAS, V. 2013. A knowledge base for the recovery of natural phenols with different solvents. *International Journal of Food Properties*. 16(2), 382–396. https://doi.org/10.1080/10942912.2010.522750

GHANI, M., KULKARNI, K. P., SONG, J. T., SHANNON, J. G., LEE, J. D. 2016. Soybean sprouts: a review of nutrient composition, health benefits and genetic variation. *Plant Breeding and Biotechnology*. 4(4), 398–412. https://doi.org/10.9787/PBB.2016.4.4.398

GUO, Q., BARKLA, B. J. 2025. Proteomic insights into edible nut seeds: nutritional value, allergenicity, stress responses, and processing effects. *Agronomy*. 15(10), 2353. https://doi.org/10.3390/agronomy15102353

HA, A. W., KIM, W. K., KIM, J. H., KANG, N. E. 2015. The supplementation effects of peanut sprout on reduction of abdominal fat and health indices in overweight and obese women. *Nutrition Research and Practice*. 9(3), 249–255. https://doi.org/10.4162/nrp.2015.9.3.249

HADDAWAY, N. R., PAGE, M. J., PRITCHARD, C. C., MCGUINNESS, L. A. 2022. PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and *Open Synthesis Campbell Systematic Reviews*. 18, e1230. https://doi.org/10.1002/cl2.1230

HASAN, M. M., BAE, H. 2017. An overview of stress-induced resveratrol synthesis in grapes: Perspectives for resveratrol-enriched grape products. *Molecules*. 22(2), 294. https://doi.org/10.3390/molecules22020294

HUNG, C. H., CHEN, S. D. 2022. Study of inducing factors on resveratrol and antioxidant content in germinated peanuts. *Molecules*. 27(17), 5700. https://doi.org/10.3390/molecules27175700

JENSEN, L. B., PEDERSEN, M. H., SKOV, P. S., POULSEN, L. K., BINDSLEV-JENSEN, C., ANDERSEN, S. B., TORP, A. M. 2008. Peanut cross-reacting allergens in seeds and sprouts of a range of legumes. *Clinical & Experimental Allergy*. 38(12), 1969–1977. https://doi.org/10.1111/j.1365-2222.2008.03129.x

KANG, H. I., KIM, J. Y., KWON, S. J., PARK, K. W., KANG, J. S., SEO, K. I. 2010. Antioxidative effects of peanut sprout extracts. *Journal of the Korean Society of Food Science and Nutrition*. 39(7), 941–946.

KRAEVSKA, S., STETSENKO, N., KOROL, O. 2017. Comparing between the amino acid composition of flax seeds before and after germination. *Agrobiodiversity for Improving Nutrition, Health and Life Quality*. 2017(1), 253–257. https://doi.org/10.15414/agrobiodiversity.2017.2585-8246.253-257

KUKKONEN, A. K., PELKONEN, A. S., MÄKINEN-KILJUNEN, S., VOUTILAINEN, H., MÄKELÄ, M. J. 2015. Ara h 2 and Ara 6 are the best predictors of severe peanut allergy: a double-blind placebo-controlled study. *Allergy*. 70(10), 1239–1245. https://doi.org/10.1111/all.12671

KUO, Y. H., ROZAN, P., LAMBEIN, F., FRIAS, J., VIDAL-VALVERDE, C. 2004. Effects of different germination conditions on the contents of free protein and non-protein amino acids of commercial legumes. *Food Chemistry*. 86(4), 537–545. https://doi.org/10.1016/j.foodchem.2003.09.042

LI, Y. C., QIAN, H., SUN, X. L., CUI, Y., WANG, H. Y., DU, C., XIA, X. H. 2014. The effects of germination on chemical composition of peanut seed. *Food Science and Technology Research*. 20(4), 883–889. https://doi.org/10.3136/fstr.20.883

LI, Y., SUN, X., MA, Z., CUI, Y., DU, C., XIA, X., QIAN, H. 2016. Beneficial influence of short-term germination on decreasing allergenicity of peanut proteins. *Journal of Food Science*. 81(1), T255–T261. https://doi.org/10.1111/1750-3841.13161

LIMMONGKON, A., JANHOM, P., AMTHONG, A., KAWPANUK, M., NOPPRANG, P., POOHADSUAN, J., SOMBOON, T., SAIJEN, S., SURANGKUL, D., SRIKUNMMOOL, M., BOONSONG, T. 2017. Antioxidant activity, total phenolic, and resveratrol content in five cultivars of peanut sprouts. *Asian Pacific Journal of Tropical Biomedicine*. 7(4), 332–338. https://doi.org/10.1016/j.apjtb.2017.01.002

LÓPEZ-CERVANTES, J., TIRADO-NORIEGA, L. G., SÁNCHEZ-MACHADO, D. I., CAMPAS-BAYPOLI, O. N., CANTU, E., NÚÑEZ-GASTÉLUM, J. A. 2013. Biochemical composition of broccoli seeds and sprouts at different stages of seedling development. *International Journal of Food Science & Technology*. 48(11), 2267. https://doi.org/10.1111/ijfs.12213

LUO, Y. W., XIE, W. H., JIN, X. X., WANG, Q., ZAI, X. M. 2013. Effects of germination and cooking for enhanced *in vitro* iron, calcium and zinc bioaccessibility from faba bean, azuki bean and mung bean sprouts. *CyTA-Journal of Food*. 11(4), 318–323. https://doi.org/10.1080/19476337.2012.757756

MAJID, I., NANDA, V. 2017. Effect of sprouting on the physical properties, morphology and flowability of onion powder. *Journal of Food Measurement and Characterization*. 11(4), 2033–2042. https://doi.org/10.1007/s11694-017-9586-2

MENG, T., XIAO, D., MUHAMMED, A., DENG, J., CHEN, L., HE, J. 2021. Anti-inflammatory action and mechanisms of resveratrol. *Molecules*. 26(1), 229. https://doi.org/10.3390/molecules26010229

MOSTOFA, M. G., RAHMAN, M. M., GHOSH, T. K., KABIR, A. H., ABDELRAHMAN, M., KHAN, M. A. R., MOCHIDA, K., TRAN, L. S. P. 2022. Potassium in plant physiological adaptation to abiotic stresses. *Plant Physiology and Biochemistry*. 186, 279–289. https://doi.org/10.1016/j.plaphy.2022.07.011

MUSLIMOV, N., OSPANOV, A., DALABAEV, A., TIMURBEKOVA, A., MOLDAKARIMOV, A. 2022. Changes in lipase activity during germination of oil seeds. *Journal of Hygienic Engineering and Design*. 40, 633–685.

NEMZER, B., AL-TAHER, F. 2023. Analysis of fatty acid composition in sprouted grains. *Foods*. 12(9), 1853. https://doi.org/10.3390/foods12091853

ORTIZ, C., MARTIROSYAN, D. 2024. Bioactive compounds in peanuts (*Arachis hypogaea* L.): A review of their anti-inflammatory and antioxidant effects. *Agriculture and Food Bioactive Compounds*. 1(12), 1–18. https://doi.org/10.31989/afbc.v1i12.1525

OZDEN, E., LIGHT, M. E., DEMIR, I. 2021. Alternating temperatures increase germination and emergence in relation to endogenous hormones and enzyme activities in aubergine seeds. *South African Journal of Botany*. 139, 130–139. https://doi.org/10.1016/j.sajb.2021.02.015

PARK, S. K., LEE, H. L., KANG, J. Y., KIM, J. M., HEO, H. J. 2022. Peanut (*Arachis hypogaea*) sprout prevents high-fat diet-induced cognitive impairment by improving mitochondrial function. *Scientific Reports*. 12(1), 6213. https://doi.org/10.1038/s41598-022-10520-5

POPESCU, F. D. 2015. Cross-reactivity between aeroallergens and food allergens. *World Journal of Methodology*. 5(2), 31. https://doi.org/10.5662/wjm.v5.i2.31

SHABBIR, M. A., IFTIKHAR, F., KHAN, M. R., MURTAZA, M. A., SAEED, M., MAHMOOD, S., SIRAJ, N. 2015. Effect of sesame sprouts powder on the quality and oxidative stability of mayonnaise. *Journal of Food and Nutrition Research*. 3(3), 138–145. https://doi.org/10.12691/jfnr-3-3-2

SOH, W. T., ZHANG, J., HOLLENBERG, M. D., VLIAGOFTIS, H., ROTHENBERG, M. E., SOKOL, C. L., ROBINSON, C., JACQUET, A. 2023. Protease allergens as initiators–regulators of allergic inflammation. *Allergy*. 78(5), 1148–1168. https://doi.org/10.1111/all.15678

SUN, W. X., ZHANG, R. J., FAN, J., HE, Y., MAO, X. H. 2018. Comprehensive transformative profiling of nutritional and functional constituents during germination of soybean sprouts. *Journal of Food Measurement and Characterization*. 12(2), 1295–1302. https://doi.org/10.1007/s11694-018-9743-2

WALIAT, S., ARSHAD, M. S., HANIF, H., EJAZ, A., KHALID, W., KAUSER, S., AL-FARGA, A. 2023. A review on bioactive compounds in sprouts: extraction techniques, food application and health functionality. *International Journal of Food Properties*. 26(1), 647–665. https://doi.org/10.1080/10942912.2023.2176001

WANG, K. H., LAI, Y. H., CHANG, J. C., KO, T. F., SHYU, S. L., CHIOU, R. Y. Y. 2005. Germination of peanut kernels to enhance resveratrol biosynthesis and prepare sprouts as a functional vegetable. *Journal of Agricultural and Food Chemistry*. 53(2), 242–246. https://doi.org/10.1021/jf048804b

WOLFENDER, J. L. 2009. HPLC in natural product analysis: the detection issue. *Planta medica*. 75(07), 719–734. https://doi.org/10.1055/s-0028-1088393

XU, H., MA, H., TIAN, Z., GUO, H., FENG, L., WANG, Y., JIANG, C., ZHEN, Z. 2025. Research progress on nutritional composition changes and processing utilization of peanut sprouts. *Journal of Northern Agriculture*. 53(2), 109–118. https://doi.org/10.12190/j.issn.2096-1197.2025.02.11

XU, M., RAO, J., CHEN, B. 2020. Phenolic compounds in germinated cereal and pulse seeds: classification, transformation, and metabolic process. *Critical Reviews in Food Science and Nutrition*. 60(5), 740–759. https://doi.org/10.1080/10408398.2018.1550051

YU, M., LIU, H., SHI, A., LIU, L., WANG, Q. 2016. Preparation of resveratrol-enriched and poor allergic protein peanut sprout from ultrasound treated peanut seeds. *Ultrasonics Sonochemistry*. 28, 334–340. https://doi.org/10.1016/j.ultsonch.2015.08.008

YU, M., MA, J., WANG, X., LU, M., FU, X., ZHANG, L., SHI, T., XU, L., ZHANG, L., XIE, T. 2022. Peanut sprout yogurt: Increased antioxidant activity and nutritional content and sensory evaluation by fuzzy mathematics. *Journal of Food Processing and Preservation*. 46(7), e16663. https://doi.org/10.1111/jfpp.16663

ZAYED, A., ABDELKAREEM, S., TALAAT, N., DAYEM, D. A., FARAG, M. A. 2025. Tannin in foods: classification, dietary sources, and processing strategies to minimize anti-nutrient effects. *Food and Bioprocess Technology*. 18, 9221–9249. https://doi.org/10.1007/s11947-025-04020-3

ZHANG, X., ZHANG, Y., SUN, P., SU, W., QU, Z., DONG, Y., DU, S., YU, X. 2023. Effect of germination pretreatment on the physicochemical properties and lipid concomitants of flaxseed oil. *RSC Advances*. 13(5), 3306–3316. https://doi.org/10.1039/D2RA07458C

ZHOU, Z., FAN, Z., MEENU, M., XU, B. 2021. Impact of germination time on resveratrol, phenolic acids, and antioxidant capacities of different varieties of peanut (*Arachis hypogaea* Linn.) from China. *Antioxidants*. 10(11), 1714. https://doi.org/10.3390/antiox10111714

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