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INFLUENCE OF GAMMA RADIATION PROCESSING ON THE NUTRITIONAL CHARACTERISTICS OF GRASS PEA (*Lathyrus Sativus* L.) SEEDS

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Abstract: This study investigated the effects of different gamma irradiation doses on the nutrient composition, fiber fractions, metabolizable energy values, and radical scavenging activity of grass pea (*Lathyrus sativus* L.) seeds. Grass pea seeds were subjected to gamma irradiation at doses of 100, 200, and 300 Gy, and changes in nutrient composition, cellulose-related fiber fractions, and radical scavenging activity were evaluated. Nutrient and fiber fraction analyses were performed using standard methods, while antioxidant capacity was determined using the DPPH radical scavenging assay. Gamma irradiation did not significantly affect moisture, crude ash, sugar, or nitrogen-free extract contents (P>0.05). In contrast, crude fat and crude protein contents were significantly influenced by irradiation (P<0.05), although the numerical changes in protein content were limited. Increasing irradiation doses resulted in a significant reduction in starch content (P<0.01). In addition, pronounced decreases were observed in crude cellulose, acid detergent fiber (ADF), and neutral detergent fiber (NDF) fractions, indicating structural modifications of cell wall components (P<0.01). In parallel with the reduction in fiber fractions, estimated metabolizable energy values for poultry increased significantly (P<0.05), whereas more limited changes were observed in metabolizable energy values for ruminants. Regarding antioxidant capacity, radical scavenging activity determined by the DPPH assay reached its highest level at the 100 Gy dose (P<0.01), while higher irradiation doses resulted in a decline in this activity. In conclusion, appropriately applied gamma irradiation improved the nutritional quality, energy availability, and antioxidant potential of grass pea seeds, enhancing their potential use as an alternative and value-added feed ingredient, particularly for monogastric animals. Further studies involving digestibility and in vivo performance are recommended to confirm these effects under practical feeding conditions.

Keywords: Gamma irradiation, Grass pea seeds, Nutritional modification, Fiber reduction, Feed processing

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1. Introduction

Grass pea (*Lathyrus sativus* L.) is an important legume crop cultivated in several regions of the world, particularly in Asia, Africa, and parts of the Mediterranean basin, due to its high adaptability to drought-prone and marginal environments (Yıldırım et al., 2023). The seeds of grass pea are characterized by relatively high protein content, appreciable energy value, and a favorable amino acid profile, making them a potential alternative protein source for both human food and animal feed. In recent years, increasing interest has been directed toward underutilized legumes such as grass pea as sustainable feed ingredients to reduce dependence on conventional protein sources (Youshanlouei et al., 2022; Dumanoğlu et al., 2023).

Despite its nutritional advantages, the utilization of grass pea seeds is limited by the presence of anti-nutritional factors and high levels of structural carbohydrates, which can negatively affect nutrient digestibility and energy utilization, particularly in monogastric animals. Fiber fractions such as neutral detergent fiber (NDF) and acid detergent fiber (ADF) are known to restrict nutrient availability by limiting enzyme accessibility and increasing intestinal transit time. In addition, grass pea seeds contain the neurotoxic compound β-ODAP (β-N-oxalyl-α,β-diaminopropionic acid), which necessitates restricted consumption despite the crop's high protein content (Sethi et al., 2021). Moreover, bioactive compounds present in grass pea seeds may exhibit both beneficial antioxidant properties and inhibitory effects, depending on their concentration and chemical structure.

Gamma irradiation has emerged as an effective non-thermal processing technology for improving the nutritional quality and safety of plant-based feed ingredients. Ionizing radiation has been shown to induce structural modifications in macromolecules such as proteins, carbohydrates, and phenolic compounds through radiolytic reactions, leading to changes in digestibility, functional properties, and antioxidant activity (Al-Bachir, 2015; Beyaz and Yıldız, 2017). Previous studies on various legumes, including chickpea, lentil, soybean, and lupin, have reported that gamma irradiation can reduce fiber fractions, modify protein structures, and enhance antioxidant capacity, thereby improving overall feed value (El-Niely, 2007).

However, information regarding the effects of gamma irradiation on the nutritional composition and bioactive properties of grass pea seeds remains limited. Given the structural and compositional similarities between grass pea and other legumes, it is hypothesized that irradiation may similarly influence fiber fractions, metabolizable energy, and antioxidant activity in grass pea seeds. Nevertheless, species-specific responses to irradiation necessitate direct investigation to elucidate these effects accurately (Sahu et al., 2025).

Therefore, the objective of the present study was to evaluate the effects of different gamma irradiation doses on the nutritional composition, fiber fractions, metabolizable energy values, and radical scavenging activity of grass pea (*Lathyrus sativus* L.) seeds. The findings of this study are expected to provide valuable insights into the potential application of gamma irradiation as a processing tool to enhance the nutritional value and functional properties of grass pea seeds for animal nutrition.

2. Materials and Methods

2.1. Plant Material and Gamma Irradiation

Grass pea (*Lathyrus sativus* L.) seeds were used as the plant material in the present study. The seed samples were supplied by the Department of Field Crops, Faculty of Agriculture, Kırşehir Ahi Evran University. Prior to irradiation, the seeds were manually cleaned to eliminate broken kernels, dust, and other extraneous materials to ensure sample uniformity.

The gamma irradiation doses (100, 200, and 300 Gy) were selected to induce mild physicochemical and structural modifications in seed components without causing excessive degradation of nutrients. In contrast to conventional food irradiation studies that typically use higher doses for microbial decontamination, the aim of the present study was to investigate subtle changes in nutrient composition, fiber fractions, and antioxidant capacity (Ahuja et al., 2014).

Gamma irradiation was applied to the seeds at doses of 100, 200, and 300 Gray (Gy) using a cobalt-60 (Co-60) gamma irradiation source (Ob-Servo Sanguis irradiator) at the Sarayköy Nuclear Research and Training Center (SANAEM), Turkish Atomic Energy Authority (TAEK). The irradiation system was calibrated using a dosimeter before treatment to ensure dose accuracy. During irradiation, the seed samples were placed on a rotating platform (360° rotation) to achieve uniform exposure, while gamma rays were emitted through an irradiation window set at a height of 30 cm. The dose rate during the irradiation process was 208 Gy per hour (Beyaz et al., 2016).

2.2. Chemical Analysis and Energy Calculations

The chemical composition of both raw and irradiated seed samples, including moisture, crude protein, crude fiber, ether extract, and crude ash contents, was analyzed following standard procedures described by AOAC (1990). Nitrogen-free extract (NFE) was calculated indirectly as the difference between 100% and the sum of crude protein, ether extract, ash, and crude fiber contents. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) fractions were determined according to the methodology outlined by Van Soest et al. (1991). All nutritional composition values were expressed on a dry matter basis. Chemical analyses were conducted at the laboratories of the Faculty of Agriculture, Kırşehir Ahi Evran University.

DPPH radical scavenging activity was determined using a methanolic DPPH solution (0.1 mM). Extracts at concentrations ranging from 0.2 to 1.0 were incubated with DPPH for 30 min in the dark, and absorbance was measured at 517 nm using a spectrophotometer (UVmini-1240, Shimadzu Corporation) (Gulcin and Alwasel, 2023). Antioxidant activity was expressed as percentage inhibition.

Metabolizable energy (ME) values of the seeds were estimated separately for poultry and ruminant animals using established prediction equations. For poultry, ME content was calculated based on the equation 1 recommended by the European Community and reported by Larbier and Leclercq (1994), which incorporates crude protein, ether extract, starch, and sugar contents:

$$ME\ (kcal/kg)=(37.07\times CP\ \%)+(82\times EE\ \%)+(39.89\times Starch\ \%)+(31.1\times Sugar\ \%) \quad (1)$$

For ruminant animals, ME values of the concentrate feed ingredients were estimated from proximate nutrient composition using the equation 2 proposed by MAFF (1976):

$$ME(kcal/kg)=(28.71\times CP)+(74.16\times EE)+(11.96\times CF)+(33.49\times NFE) \quad (2)$$

where CP represents crude protein (%), EE ether extract (%), CF crude fiber (%), and NFE nitrogen-free extract (%).

2.3. Statistical Analysis

All statistical evaluations were carried out using IBM SPSS Statistics (version 25.0). Each experimental treatment was replicated three times. A one-way analysis of variance (ANOVA) was applied to assess the effects of varying gamma irradiation doses on the nutrient composition, fiber fractions, and antioxidant properties of white lupin seeds. When significant differences were detected, mean comparisons were performed using Duncan's multiple range test. Statistical significance was accepted at $P<0.05$, and the data are presented as mean values accompanied by the standard error of the mean (SEM).

3. Results

This study aimed to evaluate the influence of varying gamma irradiation doses on the nutrient profile, cell wall fractions, and antioxidant potential of grass pea (*Lathyrus sativus* L.) seeds. The effects of gamma irradiation on the nutritional parameters and antioxidant capacity of grass pea seeds are presented in Table 1. Moisture content was not significantly affected by radiation treatments (P=0.530), with values remaining relatively stable across all irradiation doses. Similarly, crude ash, sugar, and nitrogen-free extract (NFE) contents did not show statistically significant differences among the experimental groups (P>0.05). In contrast, ether extract content was significantly influenced by gamma irradiation (P=0.010). Compared with the control group (0.41%), ether extract levels increased markedly in all irradiated samples, reaching similar values at 100, 200, and 300 Gy (0.65–0.67%).

Table 1. Effect of gamma radiation on the nutritional parameters and radical scavenging activity of grass pea seeds (%)

Parameters	Radiation Dose (Gy)				SEM	P value
	0	100	200	300		
Moisture	5.49	5.53	5.44	5.37	0.038	0.530
Ether extract	0.41^{b}	0.67^{a}	0.65^{a}	0.65^{a}	0.037	0.010
Crude protein	26.18^{c}	26.88^{a}	26.76^{b}	26.92^{a}	0.091	0.001
Crude ash	8.52	8.59	8.82	8.42	0.107	0.675
Starch	45.18^{a}	44.47^{c}	44.73^{b}	44.87^{b}	0.083	0.001
Sugar	2.13	2.02	2.06	2.51	0.080	0.101
NFE	54.81	54.31	54.18	54.93	0.128	0.073
RSA	27.14^{b}	63.81^{a}	34.44^{b}	26.89^{b}	2.810	0.001

$^{a-c:}$ Means in the same column bearing different superscript small letters are significantly different at P<0.05. SEM= standard error mean; NFE= nitrogen-free extract; RSA= radical scavenging activity.

Crude protein content was significantly affected by radiation dose (P<0.001). However, the magnitude of change was numerically small. Although statistically significant differences were detected among treatments, crude protein values varied within a narrow range. The highest crude protein content was observed at 300 Gy (26.92%), whereas the lowest value was recorded at 200 Gy (26.76%). These findings indicate that irradiation caused statistically significant but biologically limited changes in crude protein content.

Starch content exhibited a significant decrease in response to gamma irradiation (P=0.001). The control group showed the highest starch level (45.18%), while irradiated samples displayed reduced values, with the lowest starch content observed at 100 Gy (44.47%). Intermediate values were recorded at 200 and 300 Gy, indicating a dose-related modification of starch fractions.

Radical scavenging activity (RSA) of grass pea seeds, as determined by the DPPH assay, was significantly influenced by gamma irradiation (P=0.001). The DPPH method, which is based on the ability of antioxidants to donate hydrogen atoms or electrons to neutralize the stable DPPH radical, revealed a pronounced enhancement of antioxidant capacity at the 100 Gy irradiation dose. At this dose, RSA reached 63.81%, representing a significant increase compared with the control (27.14%) as well as the 200 Gy (34.44%) and 300 Gy (26.89%) treatments. In contrast, higher irradiation doses did not result in further improvement of DPPH radical scavenging activity, suggesting that excessive irradiation may lead to degradation or structural modification of antioxidant compounds. These findings indicate that moderate gamma irradiation effectively enhances the antioxidant potential of grass pea seeds, as measured by the DPPH assay, whereas higher doses may attenuate this effect.

The effects of gamma irradiation on fiber fractions and metabolizable energy values of grass pea seeds are presented in Table 2. Gamma irradiation significantly influenced all fiber-related parameters examined in the study (P<0.01).

Table 2. Changes in fiber components and metabolizable energy of grass pea seeds following gamma irradiation

Parameters	Radiation Dose (Gy)				SEM	P values
	0	100	200	300		
Crude fiber (%)	10.07^{a}	9.56^{b}	9.60^{b}	9.07^{c}	0.112	0.001
ADF (%)	8.79^{a}	7.72^{b}	7.69^{b}	7.50^{b}	0.162	0.001
NDF (%)	18.60^{a}	17.48^{a}	16.14^{b}	15.64^{b}	0.382	0.002
ME ruminant (kcal/kg)	2738.19^{b}	2754.46^{ab}	2745.56^{b}	2769.16^{a}	4.179	0.026
ME poultry (kcal/kg)	2874.24^{b}	2887.75^{b}	2887.17^{b}	2918.90^{a}	6.062	0.019

$^{a-c:}$ Means in the same column bearing different superscript small letters are significantly different at P< 0.05.

Crude fiber content showed a significant and progressive decrease with increasing radiation dose (P<0.001). The highest crude fiber value was observed in the control group (10.07%), whereas the lowest value was recorded at 300 Gy (9.07%). Intermediate values were obtained at 100 and 200 Gy, which did not differ significantly from each other but were significantly lower than the control.

Similarly, acid detergent fiber (ADF) content was significantly affected by irradiation (P=0.001). ADF levels decreased from 8.79% in the control group to 7.50% at 300 Gy. ADF content was significantly reduced in all irradiated groups (100, 200, and 300 Gy) compared with the control, while no significant differences were observed among the irradiated treatments.

Neutral detergent fiber (NDF) content also declined markedly in response to gamma irradiation (P=0.002). The control and 100 Gy group exhibited the highest NDF value, whereas other irradiated treatments (200, and 300 Gy) showed significantly lower and comparable values, indicating a strong effect of irradiation on structural carbohydrate fractions.

Regarding energy values, estimated metabolizable energy for ruminants (ME ruminant) was significantly influenced by radiation dose (P=0.026). The highest ME ruminant value was observed at 300 Gy (2769.16 kcal/kg), which differed significantly from the control and 200 Gy treatments, while the 100 Gy group showed an intermediate value.

In contrast, estimated metabolizable energy for poultry (ME poultry) increased significantly only at the highest irradiation dose (P=0.019). The 300 Gy treatment resulted in the highest ME poultry value (2918.90 kcal/kg), whereas the control, 100 Gy, and 200 Gy groups did not differ significantly from each other.

4. Discussion

The present findings indicate that gamma irradiation selectively modified certain nutritional parameters of grass pea seeds, while others remained largely unaffected. The absence of significant changes in moisture content across irradiation doses suggests that gamma treatment at the applied levels did not markedly alter the water-binding capacity or hygroscopic properties of the seeds. Similar stability has been reported in other irradiated legumes, where moderate radiation doses were insufficient to induce structural changes affecting moisture retention (Farkas, 2006; Lima et al., 2019).

The significant increase observed in ether extract content following irradiation may be attributed to radiation-induced alterations in lipid–protein or lipid–carbohydrate complexes, which can enhance lipid extractability during analysis. Gamma irradiation has been reported to disrupt cellular matrices and weaken physical associations between lipids and other macromolecules, thereby increasing the proportion of extractable lipids without necessarily promoting lipid synthesis (Aydar and Özbek, 2025). The comparable ether extract values observed at 100, 200, and 300 Gy suggest that this effect may reach a plateau at relatively low irradiation doses.

The statistically significant yet numerically limited variations observed in crude protein content are generally consistent with findings reported in the literature on irradiated legumes. Several studies have indicated that increasing doses of gamma irradiation do not significantly affect protein content in legumes such as pea, bitter vetch, chickpea, kidney bean, and lentil (El-Niely, 2007). In contrast, significant increases in crude protein content following gamma irradiation have been reported for whole soybeans (Taghinejad et al., 2009), pigeon pea flour (Bamidele and Akanbi, 2015), sesame seeds (Hassan et al., 2018), as well as maize and sorghum grains (Mohamed et al., 2009). These discrepancies among studies are likely attributable to differences in plant species, seed structure, chemical composition, and irradiation dose.

The increase in crude protein observed in the present study should not be interpreted as a result of enhanced protein synthesis. Rather, it is more plausibly explained by a relative concentration effect, whereby irradiation-induced degradation of carbohydrate fractions leads to an apparent increase in protein percentage on a dry matter basis. This mechanism has been previously reported by Stanca et al. (2023), who observed elevated protein proportions following reductions in carbohydrate content after gamma irradiation. Moreover, studies on legume seeds have demonstrated that gamma irradiation does not directly increase protein content but induces partial denaturation of protein molecules, thereby enhancing their solubility and analytical detectability (Maity et al., 2009; Bamidele and Akanbi, 2015). El-Niely (2007) also suggested that radiation-induced structural modifications in proteins may contribute to higher measured crude protein values. Therefore, the protein changes observed in grass pea seeds in the present study can be attributed to irradiation-related structural and compositional modifications rather than true protein enrichment.

The significant reduction in starch content with increasing radiation dose supports the notion that polysaccharides are among the most radiation-sensitive macromolecules. Starch, in particular, is highly susceptible to ionizing radiation due to its ordered polymeric structure composed of amylose and amylopectin chains. Gamma irradiation induces radiolytic cleavage of glycosidic bonds within starch granules, leading to depolymerization, a reduction in molecular weight, and the formation of smaller carbohydrate fragments (Sunder et al., 2022).

The decrease in starch content observed in the present study is consistent with findings reported for various cereal grains and legume seeds subjected to gamma irradiation. The pronounced reduction at 100 Gy, followed by intermediate values at higher doses, suggests that starch degradation may occur rapidly at lower irradiation levels, whereas further increases in dose result in comparatively limited additional breakdown. Similar irradiation-induced reductions in starch content and structural integrity have been documented in maize, rice, wheat, sorghum, and legume grains, where starch degradation was associated with granule disorganization and increased susceptibility to subsequent chemical or enzymatic hydrolysis (Zhiguang et al., 2023; Bhat et al., 2024). These observations collectively indicate that gamma irradiation primarily affects starch through early stage depolymerization, thereby altering carbohydrate structure and availability.

In contrast, crude ash, sugar, and nitrogen-free extract contents were not significantly affected by irradiation. The stability of ash content indicates that mineral composition remained largely unchanged, while the lack of significant variation in sugar content suggests that any starch degradation products may have undergone further transformation or were not accumulated in measurable quantities. Similarly, the relatively constant NFE values imply that the overall carbohydrate pool was redistributed rather than substantially reduced (Tresina and Mohan, 2011).

The enhancement of radical scavenging activity (RSA) at moderate gamma irradiation levels, as determined by the DPPH assay, suggests that irradiation-induced modifications in bioactive compounds play a key role in antioxidant capacity (Amiri et al., 2023). The pronounced increase observed at 100 Gy indicates that low-dose gamma irradiation may promote the release or activation of antioxidant constituents, such as phenolic compounds, by disrupting cell wall structures or breaking bonds between phenolics and macromolecules. Similar stimulatory effects of low-dose irradiation on DPPH radical scavenging activity have been reported in several legumes and cereal grains, where irradiation facilitated the liberation of bound antioxidants and increased their accessibility to react with free radicals (Aleksieva et al., 2025). The present results are in line with earlier studies reporting limited antioxidant activity in non-irradiated legume and seed materials, followed by a stimulation of radical scavenging capacity after irradiation. Bhagyawant et al. (2015) reported low antioxidant activity in untreated chickpea cultivars, which increased upon irradiation. Similarly, Variyar et al. (2004) observed enhanced scavenging activity in irradiated soybean extracts, while Abdelaleem and Elbassiony (2021) documented comparable improvements in quinoa seeds. Moosavi et al. (2014) further demonstrated a dose-dependent response in almond hulls, where moderate irradiation (2 kGy) increased radical scavenging activity, whereas higher doses (10 kGy) resulted in reduced antioxidant effectiveness. In contrast, the lack of further improvement in RSA at higher irradiation doses (200 and 300 Gy) suggests a dose-dependent dual effect of gamma irradiation on antioxidant compounds. While moderate irradiation may enhance antioxidant availability, excessive exposure can lead to degradation, polymerization, or structural modification of phenolic compounds and other radical scavengers, thereby reducing their effectiveness (Rao and Zheng, 2025). This phenomenon has been widely described in irradiated plant materials and is commonly attributed to the susceptibility of phenolic hydroxyl groups to oxidative and radiolytic reactions at higher doses.

The dose–response pattern observed in the present study, characterized by a peak antioxidant activity at 100 Gy followed by a decline at higher doses, supports the concept of an optimal irradiation threshold for maximizing antioxidant potential. Such a pattern highlights the importance of dose optimization when gamma irradiation is applied as a processing tool (Naikwadi et al., 2022).

The present results demonstrate that gamma irradiation markedly altered the fiber fractions of grass pea seeds, which was accompanied by significant changes in estimated metabolizable energy values. The progressive reduction observed in crude fiber content with increasing irradiation dose indicates that structural carbohydrates are particularly sensitive to ionizing radiation. Similar decreases in crude fiber following gamma irradiation have been reported for several legumes and cereal grains, where radiation-induced depolymerization and weakening of cell wall polysaccharides resulted in lower measurable fiber fractions (Zhu et al., 2022). This effect is generally attributed to the breakdown of complex cellulose–hemicellulose structures and partial disruption of lignocellulosic bonds. Cellulose and related cell wall components are among the primary factors limiting nutrient digestibility, particularly in monogastric animals, as they restrict the access of digestive enzymes to substrates and thereby negatively affect energy and protein utilization. Therefore, the reductions observed in fiber fractions following gamma irradiation can be considered a beneficial effect that enhances the nutritional availability of grass pea seeds.

The significant reductions in acid detergent fiber (ADF) and neutral detergent fiber (NDF) further support the hypothesis that gamma irradiation modifies cell wall integrity in grass pea seeds. NDF, which represents the total cell wall fraction including hemicellulose, cellulose, and lignin, showed a pronounced decrease even at the lowest irradiation dose, suggesting a strong susceptibility of these components to radiation (Saeid et al., 2024). Comparable irradiation-induced reductions in NDF and ADF have been documented in irradiated lupin, chickpea, and cereal grains, and are commonly associated with enhanced accessibility of carbohydrates to digestive enzymes (El-Niely, 2007). The lack of significant differences among irradiated treatments for NDF suggests that most of the structural breakdown occurs at relatively low doses, with higher doses producing limited additional effects (Taghinejad-Roudbaneh, 2016).

The pronounced reductions in crude cellulose, ADF, and NDF contents observed in the present study are consistent with previous findings showing that gamma irradiation disrupts plant cell wall structures, thereby reducing structural carbohydrates that limit nutrient digestibility and energy utilization in animal feeds (Yıldız and Ceylan, 2015; Taghinejad-Roudbaneh, 2016; Tresina et al., 2017).

Changes in fiber fractions were reflected in the metabolizable energy values, particularly for poultry. The significant increase in ME for poultry at 300 Gy indicates improved energy availability, which can be directly linked to the reduction in fiber content. In monogastric animals, high levels of crude fiber and NDF are known to limit nutrient digestibility and energy utilization by increasing digesta passage rate and reducing enzymatic access to nutrients. Therefore, the observed decrease in fiber fractions following irradiation likely contributed to the enhanced ME poultry values. Similar improvements in energy utilization have been reported in irradiated feed ingredients with reduced structural carbohydrate content (Jabeen et al., 2015).

β-ODAP (β-N-oxalyl-L-α,β-diaminopropionic acid) is the major anti-nutritional and neurotoxic compound limiting the use of grass pea in animal and human nutrition. Although the present study evaluated changes in nutrient composition, fiber fractions, and antioxidant activity, β-ODAP content was not determined. Previous studies have reported that processing methods, including soaking, heat treatment, fermentation, and in some cases irradiation, may reduce β-ODAP levels through structural degradation or leaching effects (Srivastava and Khokhar, 1996; Das et al., 2021). However, the effectiveness of gamma irradiation on β-ODAP reduction appears to depend on dose and processing conditions, and available data remain limited and sometimes inconsistent. Therefore, further studies are required to clarify the impact of gamma irradiation on β-ODAP content and to evaluate the safety and nutritional implications of irradiated grass pea seeds.

5. Conclusion

The present study demonstrates that gamma irradiation can effectively modify the nutritional composition, fiber fractions, and radical scavenging activity of grass pea (*Lathyrus sativus* L.) seeds. Gamma irradiation resulted in significant reductions in cellulose-related fiber components, including crude fiber, ADF, and NDF, which are known to limit nutrient digestibility, particularly in monogastric animals. These changes were accompanied by improvements in estimated metabolizable energy values, especially for poultry, indicating enhanced energy availability.

In addition, moderate gamma irradiation notably enhanced radical scavenging activity, as determined by the DPPH assay, with the highest antioxidant capacity observed at 100 Gy. Higher irradiation doses did not further improve radical scavenging activity, suggesting a dose-dependent response and highlighting the importance of optimizing irradiation levels.

Overall, these findings suggest that appropriately applied gamma irradiation may induce modest changes in the nutritional composition and functional properties of grass pea seeds. Therefore, gamma irradiation may contribute to enhancing their potential use as an alternative and value-added feed ingredient in animal nutrition. However, given the limitations of the present study, including the lack of β-ODAP determination and the use of estimated rather than directly measured ME values, the results should be interpreted cautiously. Further studies focusing on digestibility, bioavailability, and in vivo performance are required to better clarify the practical implications of these findings.

Author Contributions

The percentages of the author' contributions are presented below. The author reviewed and approved the final version of the manuscript.

	H.Ç
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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References

Abdelaleem, M. A., & Elbassiony, K. R. A. (2021). Evaluation of phytochemicals and antioxidant activity of gamma irradiated quinoa (*Chenopodium quinoa*). *Brazilian Journal of Biology*, *81*(3), 806–813.

Ahuja, S., Kumar, M., Kumar, P., Gupta, V. K., Singhal, R. K., Yadav, A., & Singh, B. (2014). Metabolic and biochemical changes caused by gamma irradiation in plants. *Journal of Radioanalytical and Nuclear Chemistry*, *300*(1), 199–212.

Al-Bachir, M. (2015). Quality characteristics of oil extracted from gamma irradiated peanut (*Arachis hypogea* L.). *Radiation Physics and Chemistry*, *106*, 56–60.

Aleksieva, K. I., Mladenova, R. B., Solakov, N. Y., Loginovska, K. K., & Dimov, K. G. (2025). Gamma radiation effects on free radicals, antioxidant activity, phenolic and flavonoid content in royal jelly. *Radiation Physics and Chemistry*, *226*, 112231.

Amiri, M., Arab, M., Sadrabad, E. K., Mollakhalili-Meybodi, N., & Fallahzadeh, H. (2023). Effect of gamma irradiation treatment on the antioxidant activity, phenolic compounds and flavonoid content of common buckwheat. *Radiation Physics and Chemistry*, *212*, 111127.

AOAC. (1990). *Official methods of analysis of the Association of Official Analytical Chemists* (15th ed.). Association of Official Analytical Chemists, Washington, DC.

Aydar, A. Y., & Özbek, Z. A. (2025). Alterations in lipid attributes upon irradiation. In *Non-thermal processing of major food macromolecules* (pp. 347–360). Academic Press.

Bamidele, O. P., & Akanbi, C. T. (2015). Effect of gamma irradiation on amino acids profile, minerals and some vitamins content in pigeon pea (*Cajanus cajan*) flour. *British Journal of Applied Science & Technology*, *5*(1), 90–101.

Beyaz, R., Kahramanogullari, C. T., Yildiz, C., Darcin, E. S., & Yildiz, M. (2016). The effect of gamma radiation on seed germination and seedling growth of *Lathyrus chrysanthus* Boiss. under in vitro conditions. *Journal of Environmental Radioactivity*, *162*, 129–133.

Beyaz, R., & Yildiz, M. (2017). The use of gamma irradiation in plant mutation breeding. In *Plant engineering* (pp. 33–46). InTech.

Bhagyawant, S. S., Gupta, N., & Shrivastava, N. (2015). Effects of gamma irradiation on chickpea seeds vis-a-vis total seed storage proteins, antioxidant activity and protein profiling. *Cellular and Molecular Biology*, *61*(5), 79–83.

Bhat, S. A., Singla, M., Goraya, R. K., Kumar, Y., Jan, K., & Bashir, K. (2024). Dose-dependent effects of gamma irradiation on microbiological, antioxidant, and functional properties of buckwheat, cowpea, oat, and brown rice flour. *Journal of Food Processing and Preservation*, *2024*(1), 1196594.

Das, A., Parihar, A. K., Barpete, S., Kumar, S., & Gupta, S. (2021). Current perspectives on reducing the β-ODAP content and improving potential agronomic traits in grass pea (*Lathyrus sativus* L.). *Frontiers in Plant Science*, *12*, 703275.

Dumanoğlu, Z., Özdemir, S., & Kökten, K. (2023). Determination of some physical and physiological properties of seeds of different grass pea (*Lathyrus sativus* L.) genotypes. *ISPEC Journal of Agricultural Sciences*, *7*(1), 27–35.

El-Niely, H. F. (2007). Effect of radiation processing on antinutrients, in-vitro protein digestibility and protein efficiency ratio bioassay of legume seeds. *Radiation Physics and Chemistry*, *76*(6), 1050–1057.

Farkas, J. (2006). Irradiation for better foods. *Trends in Food Science & Technology*, *17*(4), 148–152.

Gulcin, İ., & Alwasel, S. H. (2023). DPPH radical scavenging assay. *Processes*, *11*(8), 2248.

Hassan, A. B., Mahmoud, N. S., Elmamoun, K., Adiamo, O. Q., & Ahmed, I. A. M. (2018). Effects of gamma irradiation on the protein characteristics and functional properties of sesame (*Sesamum indicum* L.) seeds. *Radiation Physics and Chemistry*, *144*, 85–91.

Jabeen, N. M., Kola, M., & Reddy, K. J. (2015). Impact of irradiation on nutritional quality and functional properties of soy flour and sprouted soy flour. *International Journal of Advanced Research*, *3*(3), 1120–1129.

Larbier, M., & Leclercq, B. (1994). *Nutrition and feeding of poultry*. Nottingham University Press.

Lima, D. C., Miano, A. C., Augusto, P. E. D., & Arthur, V. (2019). Gamma irradiation of common beans: Effect on nutritional and technological properties. *LWT*, *116*, 108539.

MAFF. (1976). *Energy allowances and feeding system for ruminant* (Technical Bulletin-33). Ministry of Agriculture, Food and Fisheries.

Maity, J. P., Chakraborty, S., Kar, S., Panja, S., Jean, J. S., Samal, A. C., ... & Santra, S. C. (2009). Effects of gamma irradiation on edible seed protein, amino acids and genomic DNA during sterilization. *Food Chemistry*, *114*(4), 1237–1244.

Mohamed, A. R., Mohamed, M. E., Gammaa, A. O., Diab, E. E., & Amro, B. H. (2009). Effect of gamma irradiation on the nutritional quality of maize cultivars (*Zea mays*) and sorghum (*Sorghum bicolor*) grains. *Pakistan Journal of Nutrition*, *8*(2), 167–171.

Moosavi, K. S., Hosseini, S., Dehghan, G., & Jahanban-Esfahlan, A. (2014). The effect of gamma irradiation on phytochemical content and antioxidant activity of stored and none stored almond (*Amygdalus communis* L.) hull. *Pharmaceutical Sciences*, *20*(3), 102–106.

Naikwadi, A. T., Sharma, B. K., Bhatt, K. D., & Mahanwar, P. A. (2022). Gamma radiation processed polymeric materials for high performance applications: A review. *Frontiers in Chemistry*, *10*, 837111.

Rao, M. J., & Zheng, B. (2025). The role of polyphenols in abiotic stress tolerance and their antioxidant properties to scavenge reactive oxygen species and free radicals. *Antioxidants*, *14*(1), 74.

Saeid, S., Mollakhalili-Meybodi, N., Mohajeri, F. A., Madadizadeh, F., & Sadrabad, E. K. (2024). The effect of gamma irradiation treatment on quinoa flour: Quantification of saponin, phytic acid, antioxidant activity, and oxidative properties. *Radiation Physics and Chemistry*, *216*, 111429.

Sahu, M., Tiwari, A., Banerjee, S., & Jambhulkar, S. J. (2025). Impact of stimulation through gamma irradiation on seedlings of lathyrus (*Lathyrus sativus* L.). *Plant Archives*, *25*(1), 707–719.

Sethi, S., Yadav, D. N., Snigdha, S., & Gupta, A. (2021). Optimization of process parameters for protein isolates from Khesari dhal (*Lathyrus sativus* L.). *LWT*, *137*, 110433.

Srivastava, S., & Khokhar, S. (1996). Effects of processing on the reduction of β-ODAP (β-N-oxalyl-L-2,3-diaminopropionic acid) and anti-nutrients of Khesari dhal, *Lathyrus sativus*. *Journal of the Science of Food and Agriculture*, *71*(1), 50–58.

Stanca, M., Gaidau, C., Zaharescu, T., Balan, G. A., Matei, I., Precupas, A., ... & Ionita, G. (2023). Physico-chemical changes induced by gamma irradiation on some structural protein extracts. *Biomolecules*, *13*(5), 774.

Sunder, M., Mumbrekar, K. D., & Mazumder, N. (2022). Gamma radiation as a modifier of starch–Physicochemical perspective. *Current Research in Food Science*, *5*, 141–149.

Taghinejad, M., Nikkhah, A., Sadeghi, A. A., Raisali, G., & Chamani, M. (2009). Effects of gamma irradiation on chemical composition, antinutritional factors, ruminal degradation and in vitro protein digestibility of full-fat soybean. *Asian-Australasian Journal of Animal Sciences*, *22*(4), 534–541.

Taghinejad-Roudbaneh, M., Kazemi-Bonchenari, M., Salem, A. Z. M., & Kholif, A. E. (2016). Influence of roasting, gamma ray irradiation and microwaving on ruminal dry matter and crude protein digestion of cottonseed. *Italian Journal of*

Animal Science, *15*(1), 144–150.

Tresina, P. S., & Mohan, V. R. (2011). Effect of gamma irradiation on physicochemical properties, proximate composition, vitamins and antinutritional factors of the tribal pulse *Vigna unguiculata* subsp. *unguiculata*. *International Journal of Food Science and Technology*, *46*(8), 1739–1746.

Tresina, P. S., Paulpriya, K., Mohan, V. R., & Jeeva, S. (2017). Effect of gamma irradiation on the nutritional and antinutritional qualities of *Vigna aconitifolia* (Jacq.) Marechal: An underutilized food legume. *Biocatalysis and Agricultural Biotechnology*, *10*, 30–37.

Van Soest, P. V., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*(10), 3583–3597.

Variyar, P. S., Limaye, A., & Sharma, A. (2004). Radiation-induced enhancement of antioxidant contents of soybean (*Glycine max* Merrill). *Journal of Agricultural and Food Chemistry*, *52*(11), 3385–3388.

Yıldırım, İ., Gülümser, E., Mut, H., Başaran, U., & Doğrusöz, M. Ç. (2023). Mürdümük (*Lathyrus sativus* L.) genotiplerinin yem kalitesi ve besleme değeri. *Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Dergisi*, *10*(1), 33–38.

Yıldız, T., & Ceylan, N. (2015). Yumurta tavuğu yemlerinde gama ışınlanmış buğday ve arpa kullanılmasının yumurta verim kriterleri ve kalitesi üzerine etkileri. *Turkish Journal of Agriculture-Food Science and Technology*, *3*(9), 742–747.

Youshanlouei, Y. A., Kiani, H., Mousavi, M., & Mousavi, Z. E. (2022). Grass pea (*Lathyrus sativus* L.) protein yield and functionality as affected by extraction method: Alkaline, ultrasound-assisted, and ultrasound pretreatment extraction. *Cereal Chemistry*, *99*(4), 931–946.

Zhiguang, C., Rui, Z., Qi, Y., & Haixia, Z. (2023). The effects of gamma irradiation treatment on starch structure and properties: A review. *International Journal of Food Science and Technology*, *58*(9), 4519–4528.

Zhu, L., Yu, B., Chen, H., Yu, J., Yan, H., Luo, Y., & Chen, D. (2022). Comparisons of the micronization, steam explosion, and gamma irradiation treatment on chemical composition, structure, physicochemical properties, and in vitro digestibility of dietary fiber from soybean hulls. *Food Chemistry*, *366*, 130618.