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Effect of Gamma Radiation on Protein Content of Honey Bee Queen After Mating (*Apis mellifera)*

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ABSTRACT

This study investigated the effects of low doses of gamma irradiation on the biological activity and fertility of honeybee queens *(Apis mellifera)* by examining brood production and protein profiles. Queens exposed to 20 and 30 rad showed a significant increase in brood area, with the 20 rad dose yielding the highest mean brood area, reflecting a stimulatory effect on reproductive activity. In contrast, higher doses of 40 and 50 rad caused a marked decline in brood production, suggesting a threshold beyond which radiation becomes detrimental. Biochemical analyses revealed that total protein content was highest at 20 rad, with a gradual decrease at higher doses, indicating dose-dependent effects on protein synthesis or stability. Electrophoretic profiling confirmed these biochemical changes, showing enhanced protein band intensity and diversity at low radiation levels and suppression at higher doses. Overall, the findings suggest that sub-lethal doses of gamma radiation can enhance certain physiological and reproductive functions in honeybee queens, while excessive exposure impairs these processes.

Introduction and methodology

Honeybees (*Apis mellifera*) are eusocial, holometabolous insects that form large colonies comprising a single reproductive queen, thousands of female worker bees, and several hundred male drones. Colony sizes can vary, typically ranging from 20,000 to 80,000 individuals, depending on factors such as seasonal conditions, resource availability, and colony health (Glenny *et al.*, 2017). In honeybees (*Apis mellifera*), the differentiation between queens and workers is primarily determined by nutrition during the larval stage. All larvae are initially fed royal jelly for the first three days. However, larvae destined to become queens continue to receive royal jelly throughout their development, while those fated to become workers are transitioned to a diet of pollen and nectar after the initial period. This sustained consumption of royal jelly by queen-destined larvae triggers epigenetic modifications, such as DNA methylation changes, leading

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to the development of reproductive organs and other queen-specific characteristics (Kucharski *et al.*, 2008; Mao *et al.*, 2015; Yin *et al.*, 2018). In honeybee (*Apis mellifera*) colonies, reproductive roles are distinctly divided among the castes. The queen and drones serve as the primary reproductive individuals, while worker bees are generally sterile females responsible for various non-reproductive tasks. These tasks include in-hive activities such as brood care and hive maintenance, as well as foraging for pollen, nectar, and water (Page, *et al.*, 2001; Johnson *et al.*, 2010). The queen bee is the sole fertile female in the colony, responsible for laying all the eggs. She can lay up to 2,000 eggs per day during peak seasons, ensuring the colony's growth and sustainability. In addition to her reproductive role, the queen produces pheromones that regulate the behavior and social structure of the hive (Slessor *et al.*, 2005; Smith *et al.*, 2022). Drones are male bees whose primary function is to mate with a virgin queen from another colony. They do not participate in nectar or pollen gathering, hive maintenance, or defense. After mating, drones die, and those that do not mate are often expelled from the hive before winter to conserve resources (Page, *et al.*, 2001; Boomsma *et al.*, 2005). Worker bees, which make up the majority of the colony, are sterile females that perform all the essential tasks needed for the colony's survival. These tasks include cleaning the hive, feeding larvae, producing wax for comb construction, guarding the hive, and foraging for nectar and pollen. Workers exhibit temporal polyethism, meaning their roles change as they age, starting with in-hive duties and progressing to foraging activities (Amdam *et al.*, 2005; Münch *et al.*, 2010). In natural conditions, a honey bee (*Apis mellifera*) colony typically contains a single queen who serves as the primary reproductive individual. The queen's primary role is to lay eggs, producing both fertilized eggs that develop into female workers and unfertilized eggs that become male drones. Beyond reproduction, the queen exerts significant influence over colony dynamics through the continuous release of pheromones. These chemical signals, particularly the queen mandibular pheromone (QMP), regulate various aspects of worker bee behavior, including the suppression of worker ovary development, inhibition of queen rearing, and coordination of foraging and brood care activities. The queen's pheromonal communication is essential for maintaining social harmony and the hierarchical structure within the colony. Furthermore, since the queen is the sole egg-layer, all genetic characteristics of the colony's members are directly derived from her, underscoring her pivotal role in the colony's genetic continuity and overall health (Slessor *et al.*, 2005; Le Conte *et al.*, 2008; Abou-Shaara *et al.*, 2021). Recent studies have investigated the impact of non-ionizing electromagnetic radiation (EMR) on the behavior of honeybees (*Apis mellifera*), particularly in light of the increasing prevalence of wireless technologies in modern environments. For instance, Kimmel *et al.* (2007) conducted a study examining the influence of non-ionizing radiation on honeybee behavior, noting changes in foraging patterns and homing abilities This research focuses on understanding how exposure to gamma radiation, administered after queen emergence and prior to mating, may influence the physiological protein levels that are critical for reproductive function and colony development. By analyzing protein content variations post-mating, the study seeks to determine whether gamma radiation alters biochemical pathways related to queen fertility and vitality. Additionally, this work aims to explore the potential application of gamma radiation as a controlled tool to enhance or regulate queen bee productivity, while also assessing any associated risks. The findings are expected to contribute to a better understanding of how environmental and artificial stressors can affect the health and performance of honeybee queens, which play a central role in the stability and sustainability of bee colonies.

Materials and Methods

Materials

Honey bee queens

The honey bee (*Apis mellifera*) queens used in the present study were obtained from colonies headed by open-mated local Italian queens, located at the apiary of the Faculty of Agriculture, Ain Shams University.

Chemicals

Chemicals for electrophoresis were purchased from Sigma-Aldrich Chemical Co. The other chemicals were of analytical grade.

Methods

Irradiation procedures

The Cesium-137 gamma irradiation unit at the National Center for Radiation Research and Technology was used to irradiate virgin *Apis mellifera* honey bee queens. At the time of the experiment, the dose rate was calibrated to one gray per 56 seconds. To measure the dose at the sample position within the gamma cell, professional beekeeping tools, specifically bee queen cages with honey storage compartments, were used to hold the queens during irradiation. Five gamma radiation doses were applied: 20, 30, 40, and 50 rad, along with a control group of non-irradiated virgin queens. Each dose group included three queens (replicates). The queens were collected from their colonies, placed in the queen cages for irradiation, and then returned to their respective colonies after exposure.

Protein determination

Protein concentration was determined using the Bradford method (1976), with Bovine Serum Albumin (BSA)

employed as the standard (Kruger, 2022; Olson and Markwell, 2023; Nielsen, 2024).

Polyacrylamide Gel Electrophoresis (PAGE)

Polyacrylamide gels consist of polymerized acrylamide chains cross-linked by a bifunctional agent, typically N,N′-methylenebisacrylamide. Native gel electrophoresis separates proteins based on both their size and charge. The pore size of the acrylamide gel acts as a molecular sieve, while proteins with higher net charge at the gel's pH exhibit greater mobility (Smith, 1969; Westermeier, 2016; Gallagher and Wiley, 2021; Kurien and Scofield, 2022).

Sodium Dodecyl Sulfate Polyacrylamide Gel Electrophoresis (SDS-PAGE)

The strongly anionic detergent SDS, together with a reducing agent (a sulfhydryl compound) and heat, is used to denature proteins before they are loaded onto the gel. The denatured polypeptides bind SDS molecules, acquiring a negative charge. Because the amount of SDS bound is generally proportional to the molecular weight of the polypeptide and independent of its amino acid sequence, the SDS-polypeptide complexes migrate through the polyacrylamide gel based primarily on the size of the polypeptide. At saturation, about 1.4 grams of SDS bind to every 1 gram of polypeptide (Laemmli, 1970; Gallagher, 2023; Rivera and Patel, 2024).

Gel Documentation

Gel images were captured using the Syngene InGenius3 Gel Documentation System (Syngene, UK), equipped with a high-resolution 3-megapixel CCD camera and a manual zoom lens (6.5–39 mm, f/1.4). White light illumination was used for imaging Coomassie-stained gels inside the system's integrated darkroom to minimize ambient light. GeneSys software was used for image acquisition, and GeneTools software was employed for band intensity analysis and molecular weight estimation.

Result

Exposure of honeybee queens to low doses of gamma irradiation had a variable impact on their biological activity and fertility, as reflected by the number and area of sealed brood cells. As shown in (Table. 1), both virgin and mated queens irradiated at 20 and 30 rad demonstrated an increase in brood production compared to the non-irradiated control group. Specifically, queens treated with 20 rad produced the highest mean brood area (613.1 cm^2), showing a 19.2% increase over the control (514.5 cm^2). Queens exposed to 30 rad also exhibited enhanced brood area (569.5 cm^2), indicating a 10.7% improvement. However, exposure to higher doses (40 and 50 rad) led to a noticeable reduction in brood production, with mean brood areas decreasing to 477.1 cm^2 and 429.4 cm^2, representing declines of 7.3% and 16.5%, respectively. These results suggest that low-dose gamma irradiation (particularly 20 and 30 rad) may stimulate reproductive activity in honeybee queens, while higher doses (≥40 rad) may have detrimental effects. The significant differences observed across treatments (F = 26.25, LSD = 35.2) further confirm the dose-dependent nature of gamma radiation effects on queen activity and confirming that radiation dose influenced brood area production. Notably, the negative impact at 50 rad implies a threshold beyond which radiation impairs queen fertility. This pattern supports the hypothesis that sub-lethal doses of gamma radiation can enhance certain physiological functions, whereas excessive exposure compromises reproductive performance.

Table (1): The effect of low doses of gamma radiation on the fertility and activity of honeybee queens represented by area of worker brood cells (cm^2).

Month	Treatment				
	20 rad	30 rad	40 rad	50 rad	Control
1st	601.3	537.2	435.5	386.3	505.1
2nd	595.9	568.5	492.1	439.7	514.6
3rd	618.1	606.1	477.1	468.4	553.5
4th	637.2	566.3	503.7	423.2	484.8
mean	613.1[a]	569.5[b]	477.1[d]	429.4[e]	514.5[c]
% Inc./Dec.	+19.2	+10.7	-7.3	-16.5	
F	26.25 (1.273)				
LSD 5%	35.2				

A comparative biochemical analysis was conducted to evaluate the total protein content in honeybee queens following exposure to different doses of gamma radiation (20, 30, 40, and 50 rad). As shown in Table 2, radiation exposure resulted in dose-dependent variations in protein concentration. The queens irradiated with 20 rad exhibited the highest protein content, reaching 3.167 mg/ml, which represented a substantial increase compared to the non-irradiated control group (1.605 mg/ml). Protein levels declined with increasing radiation doses beyond 20 rad, measuring 2.125 mg/ml at 30 rad, 1.855 mg/ml at 40 rad, and 1.739 mg/ml at 50 rad. This trend suggests that low-dose gamma irradiation, particularly at 20 rad, may enhance protein synthesis or stability in queen honeybees, while higher doses may exert inhibitory effects, potentially due to oxidative stress or damage to cellular machinery. These findings align with earlier reports that low-level ionizing radiation can stimulate certain metabolic activities through hormetic effects, whereas higher exposures tend to disrupt biochemical functions (Calabrese and Baldwin, 2000; Yamada *et al*., 2012). Electrophoretic profiling using 7% native polyacrylamide gel electrophoresis (PAGE) further confirmed the biochemical changes induced by radiation (Fig. 1). Distinct differences were observed in the banding patterns of proteins extracted from queens exposed to various radiation doses. The most pronounced band intensity and diversity were observed in queens irradiated with 20 rad (lane 1), followed by those exposed to 30 rad (lane 2), 40 rad (lane 3), and 50 rad (lane 4), while the control group (lane 5) exhibited fewer and less intense bands. These differences in electrophoretic profiles suggest that gamma radiation influences not only the quantity but also the composition or conformation of expressed proteins in honeybee queens.

Table (2): Protein measurements in queen honeybee before and after radiation exposure

Doses	Protein mg/ ml
20 rad	3.167
30 rad	2.125
40 rad	1.855
50 rad	1.739
control	1.605

Electrophoretic protein profiles of honeybee queens following gamma radiation exposure at different doses, separated on a 7% native polyacrylamide gel (Fig.1). Lane 1: 20 rad; Lane 2: 30 rad; Lane 3: 40 rad; Lane 4: 50 rad; Lane 5: control (non-irradiated). The most intense and diverse protein bands were observed in the 20 rad treatment group, indicating enhanced protein expression or stability. A progressive reduction in band intensity and number was evident at higher radiation doses (40 and 50 rad), suggesting radiation-induced suppression or degradation of protein expression.

The protein profiles of queen honeybees were analyzed using native polyacrylamide gel electrophoresis (PAGE), and the band intensities were quantitatively assessed with the Syngene InGenius3 Gel Documentation System software. The results are summarized in (Table. 3) and illustrated in (Fig. 2). Protein samples from queens exposed to gamma radiation doses of 20 rad (Lane 1), 30 rad (Lane 2), 40 rad (Lane 3), and 50 rad (Lane 4) were compared to non-irradiated controls (Lane 5). By comparing intensity of bands, lane1 (20 rad) > lane2 (30 rad) > lane3 (40 rad) > lane4 (50 rad) > lane5 (control) (Table 1). After analysis, 5 bands were identified per lane; bands 1, 2, 3, 4 and 5 in descending arrangement. Band 1 (lane1) intensity is 229, band 1 (lane 2) 218, band 1 (lane 3) 186, band 1 (lane 4) 193 and band 1 (lane 5) 144. The band 1 intensity for 20 rad was increased 1.590 fold over the band1 intensity of control. Band 2 (lane 1) intensity is 267, band 2 (lane 2) 253, band 2 (lane3) 241, band 2 (lane4) 219 and band 2 (lane 5) 168. The band 2 intensity for 20 rad was increased 1.589 fold over the band2 intensity of control. Band 3 (lane 1) intensity is 184, band 3 (lane 2) 171, band 3 (lane3) 159, band 3 (lane 4) 142 and band 3 (lane5) 96. The band 3 intensity for 20 rad was increased 1.916 fold over the band 2 intensity of control. Band 4 (lane 1) intensity is 165, band 4 (lane 2) 156, band 4 (lane3) 150, band 4 (lane4) 133 and band4 (lane 5) 72. The band4 intensity for 20 rad was increased 2.291 fold over the band2 intensity of control. Band 5 (lane 1) intensity is 138, band5 (lane 2) 127, band5 (lane 3) 118, band 5 (lane 4) 99 and band5 (lane 5) 48. The band5 intensity for 20 rad was increased 2.875 fold over the band2 intensity of control (Table.3). Bands 1, 2, 3, 4 and 5 intensity for 20 rad was increased over intensity of control bands (Fig. 2). Analysis revealed that all five major protein bands exhibited higher intensity values in irradiated samples compared to the control group. The 20 rad dose (Lane 1) consistently showed the highest band intensities across all bands, with values of 229, 267, 184,

165, and 138 for Bands 1 through 5, respectively. Intensity values decreased gradually with increasing radiation doses, with the 50 rad group (Lane 4) displaying intermediate intensities and the control group (Lane 5) exhibiting the lowest values, ranging from 144 to 48 across the five bands. These observations indicate that low-dose gamma radiation (particularly 20 rad) enhances the expression or stability of specific proteins in queen honeybees, whereas higher doses attenuate these effects. The documented protein pattern changes reflect a dose-dependent biochemical response to radiation exposure, potentially linked to alterations in protein synthesis, folding, or degradation pathways. The precise quantification of band intensities using the Syngene system provides robust evidence supporting the stimulatory effects of low-dose radiation on queen honeybee protein profiles.

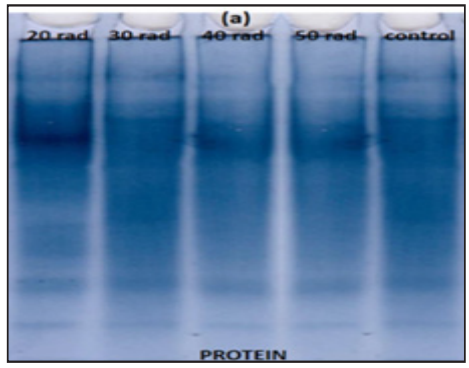

Figure (1): Electrophoretic analysis of Queen honeybees protein before and after radiation exposure on 7% native polyacrylamide gel; (a) protein pattern,20 rad (lan1), 30 rad (lan2), 40 rad (lan3), 50 rad (lan4) and control (lan5)

Table (3): Band intensity of Native PAGE protein gel electrophoresis of honeybee Queen analysis by Syngene Ingenius3 Gel Documentation System software.

		Lane (1) (20 rad)	Lane (2) (30 rad)	Lane (3) (40 rad)	Lane (4) (50 rad)	Lane (5) (control)
Intensity	Band 1	229	218	186	193	144
	Band 2	267	253	241	219	168
	Band 3	184	171	159	142	96
	Band 4	165	156	150	133	72
	Band 5	138	127	118	99	48

The protein profiles of queen honeybees before and after exposure to gamma radiation doses of 20, 30, 40, and 50 rad were analyzed using 12% SDS-polyacrylamide gel electrophoresis (SDS-PAGE). The electrophoretic patterns are presented in (Fig. 3). After SDS-PAGE and comparing intensity of bands, lane1 (20 rad) > lane 2 (30 rad) > lane 3 (40 rad) > lane 4 (50 rad) > lane 5 (control) (Table 4). Molecular weights of SDS-PAGE protein gel electrophoresis of honeybee queen analysis (Fig 4). Band 1 (lane 1, 20 rad) molecular weight is 108.426 kD, band 1 (lane 2, 30 rad) is 112.567, band 1 (lane 3, 40 rad) is 116.127, band 1 (lane 4, 50 rad) is 117.295 and band 1 (lane 5, control) is 119.364. Band 2 (lane 1, 20 rad) molecular weight is 91.471 kD, band 2 (lane 2, 30 rad) is 90.128, band 2 (lane 3, 40 rad) is 94.327, band2 (lane 4, 50 rad) is 92.076 and band 2 (lane 5, control) is 93.578. Band 3 (lane1, 20 rad) molecular weight is 53.357 kD, band 3 (lane 2, 30 rad) is 54.129, band 3 (lane 3, 40 rad) is 56.066, band 3 (lane 4, 50 rad) 59.874 and band 3 (lane 5, control) is 58.154. Band 4 (lane 1, 20 rad) molecular weight is 44.574 kD, band4 (lane 2, 30 rad) is 46.282, band 4 (lane 3, 40 rad) is 46.357, band 4 (lane 4, 50 rad) is 48.159 and band 4 (lane 5, control) is 47.346. Band 5 (lane1, 20 rad) molecular weight is 38.369 kD, band 5 (lane 2, 30 rad) is 38.124, band 5 (lane 3, 40 rad) is 39.978, band 5 (lane4, 50 rad) is 39.463 and band 5 (lane 5, control) is 38.931. Band 6 (lane 1, 20 rad) molecular weight is 20.365 kD, band 6 (lane 2, 30 rad) is 20.147, band 6 (lane 3, 40 rad) is 18.624, band 6 (lane 4, 50 rad) is 19.875 and band 6 (lane 5, control) is 18.547 (Table. 5). The molecular weight (MW) data for different radiation doses (20 rad, 30 rad, 40 rad, 50 rad) comparing to the control shows insignificant changes. The mean MW of Band 1 is 114.76 kDa with standard deviation of 3.86 kDa, the mean MW of Band 2 is 92.32 kDa with standard deviation of 1.50 kDa, the mean MW of Band 3 is 56.32 kDa with standard deviation of 2.43 kDa, the mean MW of Band 4 is 46.54 kDa with standard deviation of 1.20 kDa, the mean MW of Band 5 is 38.97 kDa with standard deviation of 0.68 kDa and the mean MW of Band 6 is 19.51 kDa with standard deviation of 0.77 kDa (Table. 5). Lane 1 shows the molecular weight marker proteins, followed by lanes 2 to 5 representing samples exposed to 20, 30, 40, and 50 rad, respectively, with lane 6 as the non-irradiated control. Quantitative analysis of the SDS-PAGE protein bands was performed using the Syngene InGenius3 Gel Documentation System software, with results summarized in (Tables 4 and 5) and visualized in (Fig. 4).

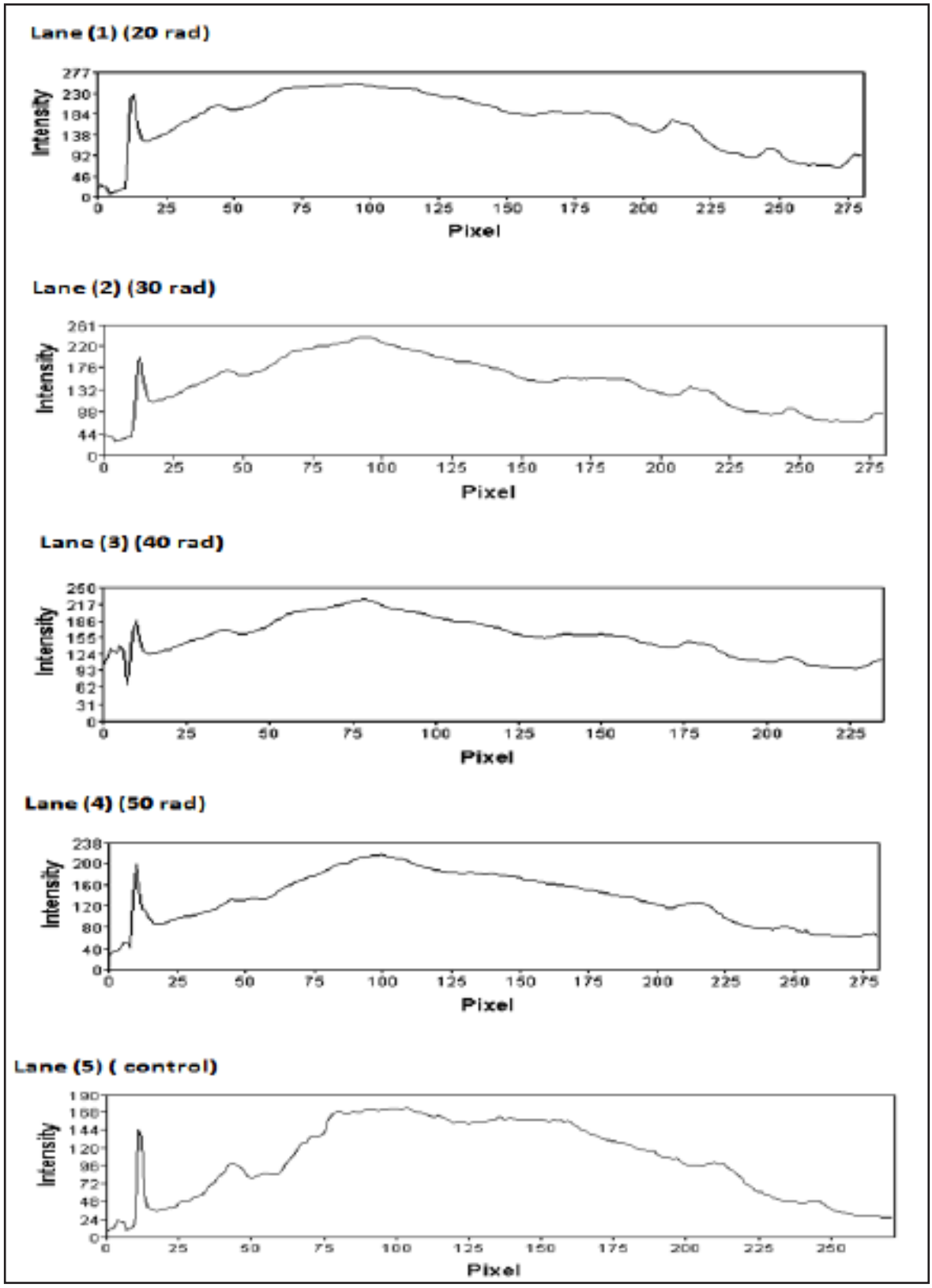

Figure (2): Native PAGE protein gel electrophoresis of honeybee Queen analysis by Syngene Ingenius3 Gel Documentation System software, (a) Lane1(20 rad), (b) Lane2(30 rad), (c) Lane3(40 rad), (d) Lane4(50 rad), (e) Lane5(control) and (f) Intensity honeybee Queen PAGE protein

The band intensities varied with radiation dose, showing the highest intensity values predominantly in the 20 rad sample (Lane 1), followed by fluctuating intensities in the 30 rad and 40 rad treatments, and a marked decrease at 50

rad compared to the control. Specifically, band intensities in the 20 rad group ranged from 136 to 192 across six major bands, while the control group exhibited significantly lower intensities between 61 and 83. These results indicate a stimulatory effect of low-dose radiation (20 rad) on protein expression or stability in queen honeybees, which diminishes as radiation dose increases. Molecular weight estimation of the protein bands (Table 5) revealed consistent profiles across all samples, with average molecular weights ranging from approximately 20 kDa to 119 kDa. Minor shifts in molecular weights were observed but remained within experimental variation, suggesting that radiation did not induce significant protein fragmentation or major post-translational modifications detectable by SDS-PAGE. Overall, these findings demonstrate that low doses of gamma radiation can enhance protein abundance in queen honeybees, whereas higher doses tend to suppress protein expression, potentially reflecting cellular stress or damage mechanisms. The use of Syngene InGenius3 software enabled precise quantification and comparison of protein profiles, supporting the biochemical impact of gamma irradiation on honeybee queens.

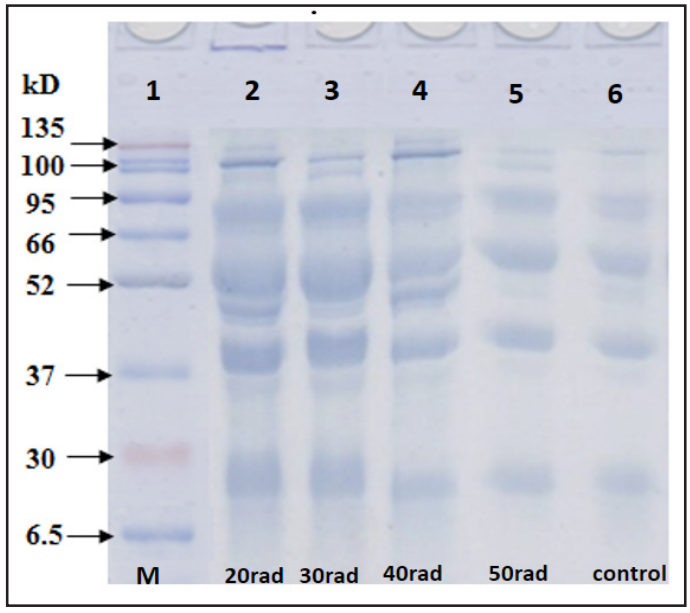

Figure (3): Electrophoretic analysis of protein pattern of honeybee Queen on 12% SDS-polyacrylamide gel: (1) molecular weight marker proteins, (2) 20 rad, (3) 30 rad, (4) 40 rad, (5) 50 rad and (6) control

Table (4): Band intensity of SDS-PAGE protein gel electrophoresis of honeybee queen analysis by Syngene Ingenius3 Gel Documentation System software.

		Lane (1) (20 rad)	Lane (2) (30 rad)	Lane (3) (40 rad)	Lane (4) (50 rad)	Lane (5) (control)
Intensity	Band 1	192	115	188	81	67
	Band 2	158	12٤	106	84	71
	Band 3	187	159	118	103	83
	Band 4	176	161	132	75	61
	Band 5	149	138	12٦	102	80
	Band 6	136	117	109	96	79

Table (5): Molecular weights of SDS-PAGE protein gel electrophoresis of honeybee queen analysis by Syngene Ingenius3 Gel Documentation System software, Lane2(20 rad), Lane3(30 rad), Lane4(40 rad), Lane5 (50 rad) and Lane6(control).

Band No.	MWvalue (kDa) of each band					The MW mean
	20 rad	30 rad	40 rad	50 rad	Control	
1	108.426	112.567	116.127	117.295	119.364	114.76 ± 3.86
2	91.471	90.128	94.327	92.076	93.578	92.32 ± 1.50
3	53.٣٥٧	54.١٢٩	56.٠٦٦	59.٨٧٤	58.١٥٤	56.32 ± 2.43
4	44.574	46.282	46.357	48.159	47.346	46.54 ± 1.20
5	38.369	38.124	39.978	39.463	38.931	38.97 ± 0.68
6	20.365	20.147	18.624	19.875	18.547	19.51 ± 0.77

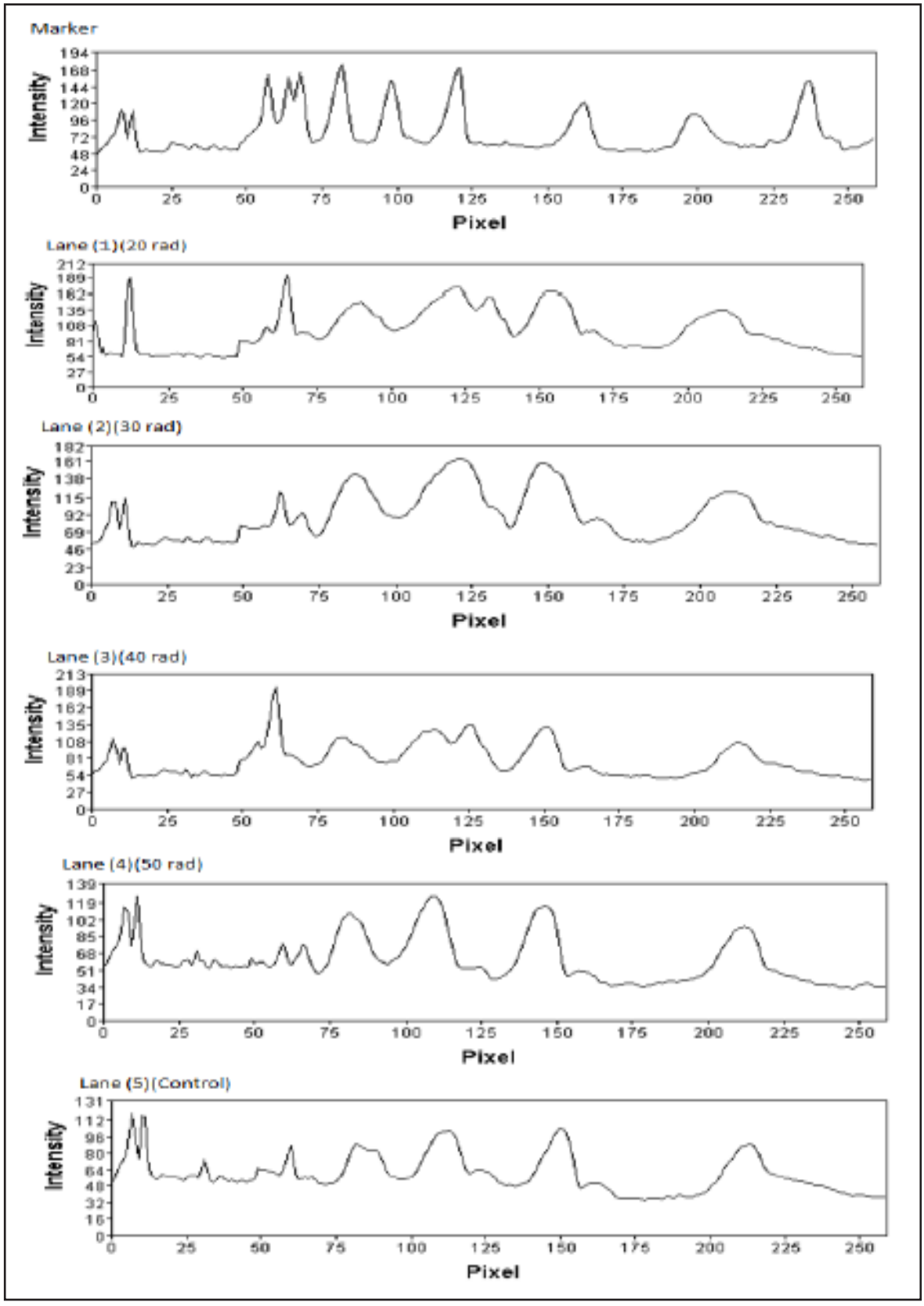

Figure (4): SDS-PAGE protein gel electrophoresis of honeybee queen analysis by Syngene Ingenius3 Gel Documentation System software, (a) Marker, (b) Lane1(20 rad), (c) Lane2(30 rad), (d) Lane3(40 rad), (e) Lane4(50 rad) and (f) Lane5(control)

Discussion

The present study attempted to evaluate the effect of different doses of gamma radiation (20, 30, 40 and 50 rad) on protein content variations post-mating, the study seeks to determine whether gamma radiation alters biochemical pathways related to queen fertility and vitality and also metabolic activities. These findings suggest that low-dose irradiation may enhance certain physiological and reproductive functions in honeybee queens, consistent with previous reports on radiation-induced hormesis in insects (Calabrese and Baldwin, 2000; Yamada et al., 2012). Similar stimulatory effects of low-dose gamma irradiation on biological functions have been reported in *Drosophila melanogaster*, where low levels of radiation enhanced longevity and stress resistance (Sharma and Sharma, 2017). However, the reduced fertility observed at 50 rad supports evidence that higher radiation doses impair reproductive performance due to cellular and genetic damage (Zhang et al., 2014). Sawires et al. (2021) found that the irradiation with a low dose (20 rad) of gamma radiation resulted in an increased metabolic rate of honey bee workers and this may cause an increase in their hoarding behavior or foraging activity either for gathering nectar, pollen or scouting new food sources. Rehab et al (2017) found that increase in the expression of Amfor, JH, OctR1, HSP-70 and TpnT genes in the bees irradiated with the low dose of radiation (0.2Gy) as compared to the non-irradiated control workers and those irradiated with the higher dose (2Gy). In addition, CS, PK and ATPase activities were significantly elevated in workers treated with 0.2Gy when compared to the control workers and workers irradiated with the higher dose (2Gy). Building on this, Lopatina *et al*. (2019) explored the effects of Wi-Fi router EMR on honey bees, finding that a 24-hour exposure led to significant inhibitory effects on food excitability and short-term memory, although long-term memory was slightly enhanced. Further research by Treder *et al*. (2023) involved exposing honey bee colonies to simulated radiofrequency electromagnetic fields (RF-EMF) at frequencies commonly used in wireless technologies (2.4 and 5.8 GHz). Their findings indicated that long-term exposure negatively affected the homing ability of foraging bees, though brood development and adult worker longevity remained unaffected. Additionally, Asa *et al*. (2024) conducted an experimental study assessing the effects of non-ionizing electromagnetic fields on honey bees. They observed that exposure to EMF in the Wi-Fi frequency band (2.4 GHz) and high-voltage line frequency (50 Hz) influenced various physiological and behavioral aspects, including aggressiveness and brood area. These studies collectively suggest that non-ionizing EMR, particularly from common sources like Wi-Fi routers and mobile communication devices, can have measurable effects on honey bee behavior and physiology. As wireless technology continues to proliferate, understanding and mitigating these impacts becomes increasingly important for the conservation of pollinator populations. Exposure to low doses of gamma radiation has been shown to influence the physiology and behavior of certain insects, including honey bees (*Apis mellifera*) and silkworms (*Bombyx mori*). For instance, Sawires and Abdelmegeed (2016) reported that irradiating honey bee queens with low doses of gamma radiation shortly after emergence affected their egg-laying capacity and the subsequent colony activity, including honey production and brood development. Abdelmegeed and Sawires, (2018) similarly, studies on silkworms have demonstrated that low-dose gamma irradiation can enhance silk production and reproductive parameters. Abdel-Salam and Mahmoud (1995) found that exposing silkworms to low levels of cobalt-60 gamma rays stimulated silk filament length and increased fecundity.

Conclusion

These findings suggest that controlled exposure to low-dose gamma radiation may have beneficial effects on certain insect species, potentially enhancing productivity traits such as foraging activity in honey bees and silk production in silkworms. The aim of this study is to examine the effect of low-dose gamma radiation on the protein content of mated honey bee queens (*Apis mellifera*). The results demonstrate a clear dose-dependent impact of gamma irradiation on honeybee queen fertility and biochemical activity. Low doses, particularly 20 rad, significantly stimulated brood production and increased total protein content, likely enhancing reproductive and physiological functions. Conversely, exposure to doses of 40 rad and above resulted in reduced fertility and suppressed protein expression, indicating cellular stress or damage. Electrophoretic analysis further supported these observations, highlighting changes in protein expression patterns with radiation dose. These findings align with the concept of radiation hormesis, where low-level exposure induces beneficial effects, while higher doses are harmful. Understanding this balance may provide insights into improving queen bee management and resilience through controlled irradiation.

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