Arab J. Nucl. Sci. Appl., Vol. 56, 5, 41-52 (2023)

ISSN 1110-0451

Arab Journal of Nuclear Sciences and Applications

Web site: ajnsa.journals.ekb.eg

(E S N S A)

Impacts of Gamma-Irradiated Date Seed (DS) as Dietary Supplement on Productive and Physiological Traits in Growing Rabbits

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ARTICLE INFO

Article history:

Received: 1st Mar. 2023

Accepted: 12th July 2023

Available online: 12th Aug. 2023

Keywords:

Growing rabbits;
Date seed;
Diet;
Digestibility;
Biochemical indices;
γ-Irradiation.

ABSTRACT

The present study was conducted to explore the effect of different gamma (γ) irradiation doses (0,10,20 and 30 kGy) on, soluble dietary fiber (SDF), in-soluble dietary fiber (IDF), hemicelluloses, cellulose, lignin, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL)of date seed (DS). In addition, this work to evaluate the impact of gamma irradiation DS on biochemical, physiological as well as productive traits of rabbits. Parameters studied were rabbit's performance (body weight, gain weight, feed intake, feed conversion, water intake, rectum temperature and respiration rate), apparent digestibility (dry matter, crude protein, crude fiber and ether extracts), carcass characteristics (carcass weight, dressing (%) and prime cuts (%) and blood biochemistry (AST and ALT, total protein, albumin, globulin, glucose, urea, creatinine and Blood hematology such as RBCs, WBCs and HB %). 60 New Zealand White weaned male rabbits of 35 days age were randomly divided to 4 treatment groups of approximately the same average weight (15 animals each). The 1st group was kept on the control diet supplemented with 10% DS (non- irradiated), 2nd, 3rd and 4th groups were kept on the control diet supplemented with 10% irradiated DS at 10, 20 and 30k Gy, respectively. The obtained results revealed a increases in SDF and IDF. The increases were linearly correlated as function of radiation dose in kGy. On the other hands, there was significantly diminished in hemicelluloses, cellulose, lignin, NDF, ADF and ADL with escalating the radiation dose. Feeding on control diet supplemented with 10 % irradiated DS resulted in a significant enhancement of body weight, gain weight, feed conversion, the apparent digestibility of dry matter, crude protein, crude fiber and carcass characteristics. While, feed intake, water intake, rectal temperature, respiration rate, ether extracts digestibility, AST and ALT, total protein, albumin, globulin, glucose, urea, creatinine and blood hematology such as RBCs, WBCs and HB % were not altered by the treatments. Generally, it can be concluded that radiation processing with γ-rays seems to be an effective procedure to upgrade the digestibility of DS. Consequently, irradiated DS supplemented diets fed to growing rabbits improved rabbits' growth performance without detrimental effects.

INTRODUTION

Agri-food industry produces massive amounts of fruit and vegetable processing wastes, which opens up a significant research area aimed towards reducing and managing them effectively to support zero wastes and/or circular economy notion [1]. Novel study trends are to seek the utilization of by-product from food industry, which could provide economic gain to the producer, industry, food safety, environmental protection and sustainability. Yearly, 1.5 billion tons of several kinds' food wasted throughout the supply chain which could feed as many as two billion people without any extra impact on the environment [2].

Date seed (DS) is regarded as a by-product of many date processing plants that produce dates stone or seed, date syrup and date confectioneries. On an average, mass of date stone or seed varies from 10 to 15% of total date fruit mass [3] and contains about 5-10% crude oil [4].

Their chemical analysis is variable depending on the type and way of treatment. The date stone or seed fruits are good source of carbohydrates, dietary fiber (70-80 %), protein (6-8 %), lipids (10-12 %), vitamins (C, E),

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DOI: 10.21608/ajnsa.2023.197044.1728

minerals, other component, cellulose (24-46 %), hemicellulose (7-28%), lignin (7-26%), amino acids, fatty acids and lauric acid (5.4%) [5] and [6].

Bouhlali *et al., (2017*) [4] reported that DS are considered a significant source of antioxidants especially that contained phenolic compounds and flavonoid which ranged from 2697-5342 mg gallic acid equivalent/100 g DS 1224-1844 mg and Routine equivalent/100 g DS, respectively. Preceding studies pointed that the date stone or seed extract can be efficient used in scavenging free radicals and to treat particular diseases as supplement [7]. Date seed (DS) are generally used as complementary feed ingredients for animals and poultry or as a conventional soil fertilizer [8]. They are also used for extracting oil for cosmetic and pharmaceutical purposes [4]. In addition, its extract is used as a functional ingredient in many food recipes such as ground beef [9], bakery products [10], non-caffeinated drinks [5] and chocolate [11].

Fundamentally, dietary fibers are carbohydrate polymers like cellulose, hemicellulose, lignin and pectin, which provide structural rigidity to the plant cell wall. Depending on the water solubility, dietary fibers are categorized as soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) [12]. Date seed are a very rich source of dietary fiber, the total dietary fiber found in date seed was 58%, with 53% of it was IDF namely as hemicelluloses, cellulose and lignin [13]. Conclusively, SDF is found to have more functional perspectives than IDF. However, the level of IDF is more as compared to SDF.IDF is a fiber that cannot be digested or absorbed by human bodies and is insoluble in water [14].

There are many physical, chemical and biological treatments have been applied to increase the degradation of the cellulosic components of agri by-products. The diminish in cell wall constituents like (NDF), (ADF), and (ADL) of the agri by-products would result in an increase of more soluble and easily digestible forms of carbohydrates with a clear increase of inorganic matter digestibility and glucose yield [15].

Gamma irradiation of foods/feed is now legally recognized in numerous countries as a safe and efficient procedure for amelioration food safety [16]. Food irradiation is a method in which food or feed is subjected to ionizing radiations, such as gamma (γ-) rays, which are emitted from the radioisotopes ^{60}Co and ^{137}Cs, Electron beam and X-rays, which are produced by machine sources [17]. The use of irradiation technique is promising since its effect on nutrients is minimal if suitable doses are applied. Advantages of irradiation include less deterioration to nutrients, especially proteins, non-formation of indigestible products, elimination of microbial and fungal contaminations from feed, and not having residual effects after irradiation [18]. Moghaddam *et al., (2017)* [19] reported that irradiation improved the digestibility through creating cross links, denaturing proteins, and gelatinizing starch. Irradiation of γ rays was generally used to diminish cell wall constituents and de-lignified the fiber of agro by- products. An increase in-vitro organic matter digestibility with a diminish in NDF, ADF and ADL, crude fiber and reducing sugar were reported through cell wall degradation [20]. Subsequently, the goal of this research was to evaluate the potential use of γ- irradiation processing at various doses to upgrading the apparent digestibility of DS. In addition to studying its impacts as a dietary supplement on performance and nutrients utilization of New Zealand White weaned male rabbits as a monogastric experimental animal model.

MATERIAL AND METHODS

Date seeds:

The DS were obtained from El-Wadi El-Gaded Governorate, Egypt and processed in accordance with (Al-Harthi *et al., 2009*) [21] by sun-drying for 72 hrs and ground in a heavy-duty high rotation hammer mill to pass through 1 mm. mesh sieve, producing a fine powder suitable for chemical analysis before mixing to the diets.DS packages were subjected to gamma radiation doses of 0,10,20 and 30 kGy. Irradiation process was carried out using Indian ^{60} Co Gamma chamber,4000 A, located at the National Center for Radiation Research and Technology (NCRRT), Cairo, Egypt. The dose rate of this irradiator was 2.45kGy/h at the time of irradiation. irradiation was achieved at room temperature. Alanine dosimeters (Traceable to the National Physical Laboratory in the United Kingdom) was used to measure the average absorbed dose into samples.

Determination of Soluble dietary fiber (SDF), Insoluble dietaryfiber (IDF), Hemicellulose, Cellulose, Lignin, NDF, ADF and ADL of DS.

The SDF and IDF were determined according to AOAC *(1990*) [22] using ANKOM 2000 dietary fiber analyzer technology method, USA. Neutral Detergent Fiber (NDF) 21st No 973.1was analyzed according to AOAC *(2019)* [23] 21th No 973.1, Acid detergent fiber (ADF) and (ADL) were analyzed according AOAC Official method of Analysis *(2019)* [23] 21sted.

Cellulose, hemicellulose and SDF were obtained from (János *et al.,2017*) [24].

Determination of total phenolic content.

The total phenolic content of DS extracts was determined using theFolin-Ciocalteu reagent [25], and the results were expressed as mg of gallic acid equivalent (GAE) per gram of dry weight using spectrophotometer UV/VIS Analytikjena Spectro D250, Germany.

Experimental animals.

A total of 60 New Zealand White (NZW) weaned male rabbits of 35 days of age were randomly distributed to 4 treatment groups of approximately equal average weight (706 g of each) each group contained 15 rabbits.

Experimental design and diets.

Table (1) shows the chemical analysis of DS which were analyzed according to AOAC *(1990)* [22]. The 1st group fed control basal diet supplemented with 10 % DS (non-irradiated) (control), 2nd, 3rd and 4th groups were fed the control basal diet supplemented with 10 % irradiated DS at 10, 20 and 30 kGy, respectively. Averages of ambient temperature and relative humidity at midday inside the rabbit try building during the experimental duration were 19.95^0C and 70.3% in the mild period and 27.45^0C and 75.3% in the hot period, respectively. The ingredients and nutrient content of basal diet were presented in Table (2).

Management and housing.

All the animals were healthy and clinically free of external and internal parasites and were kept, maintained and treated in adherence to accepted standards for the humane handling of animals. All rabbits were kept under the same managerial, hygienic and environmental condition. Rabbits were reared in wire cages as groups, in a well-ventilated building, fresh water was automatically available all the time by stainless steel nipples fixed in each cage. All rabbit cages were equipped with feeders and nipples. During the experiment the total artificial light was about 16 hours/day. Feed intake was recorded weekly during the whole experimental period according to [26]. Rabbits were weighed weekly from the beginning till the end of the experiment. Live body weight (g), gain weight (g), feed intake (g), and feed conversion ratio (g feed/g gain) were recorded during studied period according to (27). The rectal temperature (RT) and respiration rate (RR) were measured in rabbits once every two weeks at 9-11 a.m. RR (breath/min) was recorded by a hand counter, which counts the frequency of the flank movement per minute. Internal body temperature was taken by medicine thermometer (depth of 2 cm) in to rectum for 2 min. At the end of the experimental period three male rabbits from each group were randomly taken for slaughtering. After complete bleeding, pelt, viscera and tail were removed and the carcass and some carcass components were weighted. The blood samples were collected from rabbits during the slaughter. Hemoglobin concentration, red blood cells count and white blood cells count were examined immediately (Red blood cells (RBC's) and white blood cells (WBC's) were counted using hemocytometer. Hemoglobin concentration (Hb) was determined calorimetrically in fresh blood samples' using readymade kits (Diamond Diagnostics, Egypt) according to [30].Glucose was measured in plasma and the serum was separated by centrifugation at 3000 rpm for 20 minutes and kept in a deep freezer at -20 0C until the time of biochemical analysis. AST and ALT were determined according to [31], total protein, albumin, urea and creatinine concentration in serum were estimated using commercial kits (Bio Merieux, France) according to the procedure outlined by the manufacturer by [32]. The globulin concentrations were obtained by subtracting the values of albumin from the corresponding values of total protein.

Digestibility trails.

After 8 weeks of the experimental period, 3 rabbits from each treatment were randomly selected and fastened for 24 hours. Each rabbit was housed in a metabolic cage according to [27]and fed on group respective weighed diet for three days to determine the nutrients digestion coefficients and the feeding values of the experimental diets. Feeds and fresh water were offered *ad labium*. The scattered refused feed was collected and deducted from the amount offered to obtain the quantity of feed consumed. The feces of individual rabbits falling on a tray covered by aluminum foil was quantitatively collected every 24 hours, cleaned from hair and scattered feed, dried and weighed. The dried feces from each rabbit were put in screw top glass jar for analysis. Dry matter (DM), crude protein (CP), ether extracts (EE) and ash were determined according to AOAC *(1990)* [22]. The nutrients digestibility coefficients and feeding value of the different ingredients were calculated.

Statistical analysis.

Data were statistically analyze using the SPSS Program (2007) [33]. A simple one-way classification analysis was used. Mean differences among treatments were tested by Duncan's multiple range tests [34].

Table (1): Chemical analysis of DS (As % DM basis)

Chemical analysis	DM	Ash	EE	CP	CF	Ca	P	DE kCal/kg)
Date seed	89.30	3.20	7.80	6.00	13.90	0.17	0.72	3468

DM= Dry Matter, EE = Ether Extract, CP=Crude Protein, CF = Crude Fiber,
Ca = Calcium, P =Total Phosphorus, DE= Digestible Energy.

Table (2): Composition of experimental basal diet

Ingredients	%
alfalfa hay	30%
Date seed (DS)	10%
Soybean meal (44%)	19.7%
wheat bran	18.87%
yellow corn	15%
Molasses	3 %
Limestone	0.22%
sodium chloride	0.5%
vitamin and mineralspremix*	0.3 %
Di Ca phosphate	2.27%
DL- Methionine	0.14%
Total	100
Calculated analysis**	---
Crude protein	17.47 %
Crude fiber	13.60%
Ether extract	2.68%
Digestible energy (kcal/kg)	2699.00

*10.000 IU Vit. A, 900 IU Vit.D3, 2mg Vit.K, 50 mg Vit.E, 2mg Vit.B_1, 6 mg Vit.B_2, 2 mg Vit.B_6, 0.01 mg Vit. B_{12}, 20 mg Panathonic acid, 50 mg Niacin, 5mg Folic acid, 1.2 mg Biotin, 12000 mg Choline, 3 mg Copper, 0.2 mg Iodine, 75 mg Iron, 30 mg Manganese, 70 mg Zinc, 0.1 mg Selenium, 0.1 mg Cobalt and 0.04 mg Magnesium. The basal diet contained of 18.18 % crude protein, 13.43% crude fiber, 2.29% ether extract, 2656.00 digestible energy (kcal/kg). **Calculated according to NRC (1977) [28] and Cheeke (1987) [29].

RESULTS AND DISCUSSION

Effect of gamma radiation on Soluble dietary fiber, Insoluble dietary fiber, Hemicelluloses, Cellulose, Lignin, NDF, ADF, ADL of DS

The impact of gamma-irradiation on the IDF, SDF, TDF, hemicelluloses, cellulose, NDF, ADF, ADL and total phenol compound of DS were presented in Table (3). The obtained results demonstrate a considerable increase in the SDF and IDF contents of date seeds, and the increase was proportional to the irradiation dose, being 4.60, 5.00, 5.9, 66.17,67.00 and 69.1% at 10, 20, and 30 kGy, respectively. Also, from the above data it was found that the TDF which is the sum of SDF and IDF has improved by gamma radiation, and the improved was parallel with the escalating doses of irradiation used up to 30 kg. On the other hands, there was significantly diminished in hemicelluloses, cellulose and lignin as a function of irradiation doses when compared with control. In addition, there were significantly decrease in cell wall constituents such as NDF, ADF and ADL with escalating irradiation doses when compared with non-irradiated DS. Murugan *(2015)* [35] found that crude fiber, cellulose and acid detergent lignin contents of gamma irradiated (7 and 14 kGy) Brewer's spent grain samples were significantly diminished compared to non-treated grains. The dose-dependent diminish in fiber on irradiation has been attributed to de-polymerization and de-lignifications of the plant matrix. Cellulose was the greatest source of carbon and energy in the diet. Fiber contains a higher ratio of cellulose, hemicellulose and lignin compound which were the important for digestion of high-fiber content due to not formed of cellulose-hydrolyzing enzymes. Each glucose of cellulose has two hydrogenic bonds and these bonds firm the long and parallel chains of cellulose. Gamma irradiation has high penetration power which caused damage of *ß*-bonding of the radical which break down of glucoside bond and formed carbonyl groups that helps cellulose breakdown and lignin. Lignin was attached with cellulose and hemicelluloses which formed two compounds that inhibit of solution and enzymes. So, the decreased of lignin content resulting from increased digestibility and decreased of ADF, NDF and ADL which caused de-polymerization and delignification [35]. Other explication for the observed in the raise in SDF and IDF contents due to gamma irradiation could be attributed to the breaking of the hydrogenic bonds between cellulose and hemicelluloses as well as the degradation of the inter-linkages in lignin structure [36].

Table (3): Effect of γ- irradiation at 0,10, 20 and 30 kGy on, Insoluble dietary fiber, Soluble dietary fiber, Hemicelluloses, Cellulose, Lignin, NDF, ADF, ADL and Total phenolic compound DS

Item	Control DS (non-treated)	Gamma irradiated DS (kGy)			Sig
		10	20	30	
Soluble dietary fiber (SDF)%	4.10^{d}±0.057	4.60^{c}±0.033	5.00^{b}±0.033	5.9^{a}±0.088	**
Insoluble dietary fiber (IDF) %	63.17^{d}±0.120	66.17^{c}±0.120	67.00^{b}±0.176	69.1^{a}±0.057	**
Total dietary fiber %(TDF)	67.27^{d}±0.088	70.77^{c}±0.145	72.00^{b}±0.185	74.9^{a}±0.133	**
Hemicellulose	18.64^{a}±0.27	18.19^{a} ±0.005	17.34^{b}5±0.04	16.58^{c}±0.13	**
Cellulose	34.40^{a} ±0.22	32.61^{b}±0.16	31.72^{c}±0.10	29.85^{d} ±0.19	**
Lignin	5.04^{a}±0.02	4.63^{b}±0.003	4.16^{c}±0.011	3.87^{d}±0.08	**
NDF	56.36^{a}±0.04	55.28^{b}±0.08	55.11^{b}±0.11	54.39^{c}±0.14	**
ADF	39.53 ^{a}±0.21	38.86^{b}±0.04	36.91^{c}±0.12	35.75^{d}±0.13	**
ADL	6.00^{a}±0.023	5.90^{a}±0.06	5.19^{b}±0.02	5.13^{b}±0.014	**
Total phenolic compound|(TPC) (mg/100g-gallicacid equivalent)	50.7^{d}±0.27	64.5^{c}±0.61	70.33^{b}±0.71	78.5^{a}±0.3	**

Soluble dietary fiber **(SDF)**, Insoluble dietary fiber **(IDF)** %, Total dietary fiber %**(TDF)**, neutral detergent fiber (**NDF**), acid detergent fiber **(ADF),** acid detergent lignin (**ADL),** Cellulose content = ADF – ADL (%), Hemicellulose content = NDF- ADF (%), Soluble dietary fiber = TDF – IDF (%). [24] Means within the same raw bearing different letters differ significantly (P≤0.05), ** = P<0.01, sig: *Significance*

Gamma irradiation of plant raw materials enhances the solubility of the plant cellulose and enhances the ability of this cellulose to undergo acid hydrolysis. This is owing to the radiolytic degradation of cellulose [37]. The irradiation itself facilitates the separation of polysaccharides from lignin by breaking up the compartmentalized, crystallized lignocellulosic structure [38]. On the other hands, Fiesoni *et al., (2019*) [39] disagreed with these results and reported that gamma irradiation at dose levels of 5 and 10 kGy of rice straw has not been able to effect on fiber content but was increasing hemicelluloses due to irradiation treatment.

Data of total phenolic content (TPC) is also presented in Table (3) it is clear that the TPC of the irradiated DS was significantly (p < 0.01) higher than that for non-irradiated ones, TPC tended to increase (p < 0.01) with an escalating in irradiation doses. The highest value of TPC was observed in irradiated at 30 kGy as compared to the lowest in the control (non-treated) sample. Abolhasani *et al., (2018)* [40] reported from their study on the TPC extract of Pistachio green hull that gamma irradiation at 30 kGy was significantly more than non-irradiated sample. An increase in TPC prompt by γ- irradiation, might be attributed to a rise in the availability of TPC due to breakdown of large molecules into tiny phenolic molecules. In addition, our results were agreement with Mansour *et al., (2018)* [41] who reported that irradiation of fenugreek and lupine seeds at 10 and 20 kGy increased fiber content and total phenol compound with increasing irradiation doses when compared with non-irradiated seeds due to increased solubility and digestibility of this seeds by irradiation which enhanced the performance of fiber and antioxidant contents.

Effect of irradiation treatments on rabbit's performance

1-Live body weight and gain weight (g)

Live body weight was the good indicator of the health performance of the rabbits fed on control diet supplemented with 10% irradiated DS. Data in Table (4) indicates that a significant (P<0.05) increase was observed in the mean live body weight of rabbits fed diets supplemented with 10 % irradiated DS for 4 weeks. While, highly significant (P<0.01) increase in live body weight of rabbits fed diets supplemented with 10 % irradiated DS was observed at the end of the experiment (week 8), and the increase was parallel with the increasing radiation dose. Meanwhile, diets containing 10 % irradiated DS considerably (P<0.01) improved weight gain of rabbits compared to those fed control diet supplemented with non-irradiated DS at 4 and 8 weeks, and the improvement was parallel to the radiation dose. The herein observed improvement of weight gain feeding on irradiated DS could be due to the γ- irradiation caused modifications in the complex compound to simpler form and the protein content of DS which have higher concentration of lysine amino acid in meals depends on cereals [35].

El-Far *et al., (2016)* [42] represented the effect of date palm seeds (2 % and 6%) dietary supplementation on broilers. The increase in body weight and higher body weight gain might be due to the presence of mannan-oligosaccharides and β-glucans which increase in body weight gain and improvement of the feed efficiency. These results indicated improvement of intestinal mucosal integrity and increase in the absorption and utilization of the dietary nutrients in addition to selenium, phenolic, and carotenoid compounds of date palm seeds.

2- Feed intake, feed conversion, water intake, rectal temperature and respiration rate

Data tabulated in Table (5) indicates no significant ($P > 0.05$) variation in feed intake and water intake of rabbits fed diet supplemented with gamma irradiated DS compared with control group fed diet supplemented with non-irradiated DS. However, there was a significant ($P<0.05$) variation in feed conversion ratio of those fed diet supplemented with 10 % gamma irradiated DS compared to those fed control counterpart. An improvement in feed conversion was observed for those fed diets supplemented with irradiated DS, and the improvement was proportional with the escalating radiation dose. The better feed conversion was listed for rabbits fed diets supplemented with 10% DS that subjected to γ- ray at 30 kGy. This is attributed to the recorded higher weight gain and lower feed intake in rabbits fed diets supplemented with gamma irradiated DS. Also, there were no significant differences in rectal temperature and respiration rate amongst the studied group. Sujatha *et al., 2017* [43] reported that irradiation was cleaved disulphed bonds in sorghum prolamin proteins, resulting in un folding of protein structure which open protein network and exposed to proteolytic and improved digestibility.

Table (4): Body weight and gain weight (0-8 weeks; ±SE) of growing NZW male rabbits as affected by dietary supplemented of γ-irradiated DS at 0, 10, 20 and 30 kGy

Item	Basal diet supplemented with 10%DS (non-irradiated)	Basal diet supplemented with 10% irradiated DS (kGy)			Sig
		10	20	30	
W_0	559.8±5.1	571.4±7.3	568.5±8.2	573.8±7.4	N.S
W_4	1234.1^b±13.1	1353.1 ^{a} ±10.7	1374.9 ^{a}±12.3	1384.4^a ±13.1	*
W_8	1657.4^c ±16.7	1799.2 ^{b}±11.8	1890.6 ^{a} ±17.1	1893.9^a±14.9	**
G_{0-4}	674.3 ^{c}±1.2	781.7^{ab}±0.9	806.4 ^{a} ±0.7	810.6^a ±1.4	**
G_{4-8}	423.3^b±0.4	446.1 ^{b}±0.6	515.7 ^{a}±0.9	509.5 ^{a} ±0.7	**
G_{0-8}	1097.6^c±1.3	1227.8 ^{b}±1.5	1322.1 ^{a} ±1.2	1320.1 ^{a} ±1.6	**

Means within the same row bearing different letters differ significantly ($P\leq0.05$).
** = $P<0.01$, * = $P<0.05$, W: week, w_0: initial body weight, w_4: body weight at 4th week, w_8: body weight at 8th week, G: gain, G_0-G_4: body weight gain from the beginning of experimental until the 4 th week, G_{4-8} body weight gain from 4th week of the experiment till week 8, G_0-8 the overall body weight gain (body weight gain from beginning of experimental till the end of the experiment), Sig: Significance, N.S. = Not significant.

Table (5): Feed intake, feed conversion, water intake, rectum temperature and respiration rate of growing NZW rabbits as affected by dietary supplemented ofγ-irradiated DS at 0, 10, 20 and 30 kGy

Item	Basal diet supplemented with 10%DS (non-irradiated)	Basal diet supplemented with 10%γ-irradiated DS (kGy)			Sig
		10	20	30	
Feed intake (g/day)	94.9 ±2.2	95.6±3.9	97.4±3.0	99.1±4.2	**N.S**
Feed conversion (g feed /gain)	4.8±0.06	4.4±0.07	4.1±0.08	4.2±0.09	*****
Water intake (ml /day)	140.3 ±6.1	138.7±4.9	143.1±56.1	149.1±4.5	**N.S**
Water/ feed ratio	1.47	1.45	1.47	1.50	**-**
RT°C	39.5±0.07	39.4±0.06	39.5±0.07	39.8±0.08	**N.S**
(RR)(Respirations/min)	99.4 ^{b}±1.8	98.2±1.6	99.1 ±1.7	98.7 ±1.6	**N.S**
RR/RT	2.52	2.49	2.51	2.48	-
RT (%)	100	99.7	100	101	-
RR (%)	100	98.8	99.7	99.3	-

Rectum temperature (RT), Respiration rate (RR) (Respirations/min,means within the same row bearing different letters differ significantly ($P\leq0.05$) * = $P<0.05$ and Sig: Significance, N.S = Not significant

Table (6): Rabbit Digestibility as influenced by feeding non-irradiated and γ-irradiated DS supplements at 10,20 and 30 kGy

Item	Basal diet supplemented with 10 % DS (non-irradiated)	Basal diet supplemented with 10% γ-irradiatedDS(kGy)			Sig
		10	20	30	
Dry matter (DM)	74.5 ^{c}±4.1	76.1 ^{bc}±5.3	78.7 ^{ab}±4.9	80.8 ^{a} ±5.7	*
Crude protein (CP)	70.6 ^{c}±8.3	78.1 ^{bc}±9.7	79.9 ^{b}±9.3	82.1 ^{a} ±7.1	*
Crude fiber (CF)	61.3 ^{b}±2.9	63.1 ^{b}±2.4	66.3 ^{a}±3.7	67.8 ^{a} ±4.2	*
Ether Extract (EE)	68.4±8.2	70.1±9.6	71.9±10.1	72.8 ±7.4	N.S

Means within the same row bearing different letters differ significantly (P≤0.05).
* = P<0.05 and Sig: Significance, N.S = Not significant

Apparent digestibility

Table (6) displays a significant (P < 0.05) betterment for the apparent digestibility of dry matter, crude protein and crude fiber of rabbits fed diets supplemented with 10% irradiated DS **(**positive response**)**, while no remarkable effect on ether extracts were observed. The highest significant (P < 0.05) rise in digestibility was observed in those fed diet supplemented with 10% DS irradiated at the highest dose (30 kGy) compared with those fed diet supplemented with non-irradiated DS. This increase in digestibility can be due to the decreasing NDF and ADF in irradiated DS compared to raw DS. The obtained result concerning the digestibility of dry matter, is in agreement with the study of **Shahbazi *et al., (2008)*** [36] who reported that escalating γ- irradiation (at 50, 100 and150 kGy) had linearly increased the washout fraction of dry matter (DM) and neutral detergent fiber (NDF) of alfalfa hay. **Shawraing *et al., (2007)*** [18] reported that γ- irradiation at dose higher than 50 kGy could increase ruminal dry matter degradability of feedstuffs. Where, γ-irradiation affects the complex bonds and cause the wander-valls power weakens, and consequently result in extensive degradation of cellulose and increasing the degradability of cell wall constituents [44].

The concentration of free radicals and also, the number of separated chains from cellulose increases with increasing gamma irradiation dose [45]. The irradiation causes formation of carbonyl groups of cellulose of the presence of oxygen that helps cellulose break down [45]. Furthermore,γ- rays leads to the hydrolysis of the glycoside bonds.

For apparent protein digestibility, similar findings were recorded by *(*Zohreh *et al.,2017)* [46] who found that irradiation at a dose of 30 kGy significantly increased apparent protein digestibility of cottonseed meal compared to raw (non-irradiated). Shawrang *et al.* [47] (2013) reported that the protein digestibility of barley increased by increasing electron beam irradiation dose of it. Also, [48] Bahraini *et al.* (2017) reported gamma-ray irradiation at a dose of 30 kGy, and electron beam irradiation at a dose of 10 kGy in cottonseed meal significantly increased the apparent digestibility of protein compared to raw in Leghorn cockerels. El-Niely *(2007)* [49] investigated the impact of ionized doses (2.5, 5, 10 and 20 kGy) on *in vitro* protein digestibility of broad beans and observed that the *in vitro* protein digestibility improved by 4.5, 10, 16 and 20%, respectively. Generally, four types of radiation effects on protein are observed: fragmentation, cross-linkage, aggregation and oxidation by oxygen radicals that are generated in the radiolysis of water [50]. The hydroxyl and superoxide anion radicals that are generated by radiation could modify the proteins molecular properties which result alteration of proteins by covalent cross-linkages in proteins after irradiation. Proteins can be converted to higher molecular weight aggregates owing to the generation of inter-protein cross-linking reactions, hydrophobic and electrostatic interactions, as well as the formation of disulfide bonds. The cross-linking process results in the formation of chemical bonds between two adjacent protein molecules [51]. Protein-Protein interaction increases because the electrostatic forces of molecules are at the minimum and less water interactions with the protein. This is favorable condition for the protein molecules to approach each other and possibly precipitate [52]. Moreover, cross-linked proteins are hydrophobic, therefore are compact and could pass to the intestine [53]. The higher protein digestibility after irradiation treatment may be due to increase accessibility of the protein to enzymatic attack. However, this effect could also be due to inactivation of proteinaceous anti-nutritional factors [54]. Cellulose is the most important source of carbon and energy in animal's diet. Plant fiber contains higher proportion of cellulose and hemicellulose as ligno-cellulosic compound which is the main factor restricting animal's digestion of high-fiber content forage because the animal itself does not produce effective cellulose-hydrolyzing enzymes [55].Each glucose residue of cellulose has inter and intra molecular of two hydrogenic bonds and these bonds stabilize the long and parallel chains of cellulose [56].γ- irradiation affects these glucosidal bonds with modification in hydro glucose ring [57] and causes the wander-valls power weakens [45] and [44].The breaking of hydrogenic bonds, formation of carbonyl groups of cellulose at the presence of oxygen helps cellulose breakdown and results in the degradation of the inter-linkages in lignin structure [44].

Carcass characteristics

Data in Table (7) manifests the results of relative carcass weight, dressing % and prime cuts %. Statistical analysis manifested a significant (P<0.01) elevation in carcass traits (carcass weight, dressing (%) and prime cuts (%) of rabbits fed diet supplemented with irradiated DS at 10, 20 and 30 kGy compared to those fed diet supplemented with non-irradiated DS. Carcass weight, dressing (%) and prime cuts (%) rose progressively with the escalating radiation dose. This is owing to the amelioration of apparent digestibility of dry matter, crude protein and crude fiber of irradiated DS and the consequent enhancement of growth performance.

Results are accordance with those obtained by El-Far *et al.* 2016's [42] who stated that fed broilers on diet supplemented with palm seeds (6%) showed increase of carcass characteristics as a results of antioxidant status of animals improves their growth performance, production, and reproduction. Due to mannan-oligosaccharides are not digested, they stimulate the lymphatic system of the gastrointestinal tract and general immunity.

Blood biochemical attributes

Blood biochemical attributes are used to estimate the health condition of rabbits. The plasma indices are important measures of protein adequacy. The plasma proteins which are, easily obtainable in the animal body are of value in diagnosis of many diseases [58]. The results of blood chemistry in the present study are presented in Table (8). AST and ALT, total protein, albumin, globulin, glucose, urea, creatinine and blood hematological traits such as (RBCs, WBCs and HB %) of rabbits fed on diet supplemented with 10% (non-irradiated DS) and those fed diet supplemented with DS subjected to γ- irradiation at 10, 20 and 30 kGy did not show significant difference (P<0.05). Radiation did not have a significant effect on blood parameters of rabbits. The results of hematological traits represent an index of response to a stressor and strong indicators of assessing clinical and nutritional health status of rabbits in feeding trial. The hematological values obtained for DS either irradiated or raw inclusion were good indication that DS was well utilized by rabbits attributed to the nutritional adequacy and composition.

Table (7): Rabbit carcass characteristics as influenced by feeding the dietary supplement with non-irradiated and γ-irradiated DS at 10,20 and 30 kGy

Item	Basal diet supplemented with 10%DS (non-γ- irradiated)	Basal diet supplemented with 10% γ- irradiated DS (kGy)			Sig
		10	20	30	
Carcass weight (g)	1010.7^{d}	1162.7^{c}	1222.3^{b}	1249.7^{a}	**
Carcass weight (%)	100	115.4	120.9	123.6	-
Dressing (%)	60.98	64.6	64.7	66.0	-
Prime cuts (%)	51.9	56.6	58.9	59.7	-

Means within the same row bearing different letters differ significantly (P≤0.05).
** = P<0.01, Sig: Significance, N.S = Not significant

Table (8): Blood attributes (±SE) of growing NZW rabbits as affected by dietary supplemented of γ- irradiated DS at 0, 10, 20 and 30 kGy

Item	Basal diet supplemented with 10%DS (non-γ- irradiated)	Basal diet supplemented with 10%γ- irradiated DS (kGy)			Sig
		10	20	30	
Serum enzymes					
AST (U/L)	57.9ᵃ±1.8	53.6ᵃ±1.7	56.3ᵃ±2.8	52.9ᵃ±1.1	N.S
ALT(U/L)	26.3ᵃ±2.1	28.8ᵃ±1.2	24.8ᵃ±1.7	26.8ᵃ±1.3	N.S
Serum analysis					
Total protein (g/dL)	7. 4ᵃ±0.8	7.0ᵃ±0.4	6.9ᵃ±0.4	7.2ᵃ±0.6	N.S
Albumin ((g/dL)	4.0ᵃ±0.3	3.5ᵃ±0.2	3.4ᵃ±0.2	3.8ᵃ±0.23	N.S
Globulin (g/dL)	3.4ᵃ±0.2	3.5ᵃ±0.7	3.5ᵃ±0.1	3.4ᵃ±0.17	N.S
Glucose(mg/100)	90.01ᵃ±6.2	91.2ᵃ±7.2	95.1ᵃ±5.9	97.0ᵃ±8.9	N.S
Urea (mg/dL)	44.1ᵃ±1.8	46.9ᵃ±1.7	40.9ᵃ±1.1	42.6ᵃ±2.2	N.S
Creatinine (mg/dL)	1.4ᵃ±0.03	1.2ᵃ±0.09	1.3ᵃ±0.08	1.1ᵃ±0.04	N.S
Blood hematology					
RBCs	5.4ᵃ±0.5	5.5ᵃ±0.3	5.3ᵃ±0.3	5.0ᵃ±0.2	N.S
WBCs	5.7ᵃ±1.9	6.3ᵃ±1.6	6.1ᵃ±1.8	6.0ᵃ±1.7	N.S
HB	12.8ᵃ±1.5	13.3ᵃ±1.7	12.3ᵃ±1.0	11.9ᵃ±1.3	N.S

Means within the same row bearing different letters differ significantly Sig: Significance, N.S = Not significant.

These results were agreement with [59] who reported that supplementation of date waste at (0, 50, 100 and 200 g/kg diets) to replace the same percentage of wheat bran in broiler diets from 21 to 40 days had no adverse influences on productive performance, digestibility of nutrients, blood serum constituents such as (serum protein, albumin, globulin, ALT, AST, urea and creatinine) However, the best growth performance and production index was obtained when date waste was fed at 50 g/kg.

In conclusion, DS are a very rich source of dietary fiber, the total dietary fiber found in DS was 58%, with 53% of it was IDF, the level of IDF is more as compared to SDF.IDF is a fiber that cannot be digested or absorbed by human bodies and is insoluble in water. Based on the current study, it was found that the TDF which is the sum of SDF and IDF has improved by gamma radiation, and the improved was parallel with the escalating doses of irradiation used up to 30 kGy. Also, there were significantly diminished in hemicelluloses, cellulose and lignin as a function of irradiation doses when compared with control. Subsequently,γ- irradiation at 10, 20 and 30 kGy improved the digestibility of DS, consequent, enhanced the growth performance of rabbits kept on irradiated DS without any harmful influence on their biochemical constituents comparable to rabbits kept on non-γ-irradiated DS.

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