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Impacts of Irradiated Distillers Dried Grains with Soluble (DDGS) as Dietary Supplement on Physiological and Biochemical Aspects of Growing Rabbits

A.M. Abdul Azeem [(1)#], U.M. Abdel-Monem [(2)] and Ashraf M. Mounir [(1)]

[(1)] Food Irradiation Research Department, National Center for Radiation Research and Technology (NCRRT), Atomic Energy Authority, Cairo, Egypt; [(2)] Department of Animal Production, Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

DISTILLERS dried grains with soluble (DDGS) are a co-product of ethanol production from starch cereals (mainly corn). Dietary fiber is the sum of carbohydrates and lignin that are resistant to digestion by the small intestine enzymes. DDGS contains approximately 3 times dietary fiber more than corn. Dietary fiber in DDGS consists mainly of insoluble dietary fiber. The present study was conducted to evaluate the effect of gamma (γ) irradiation on crude fiber, soluble fiber and non-soluble fiber of irradiated corn DDGs at different doses 0, 10, 20 and 30kGy, and to evaluate the effect of feeding irradiated DDGs for rabbits and their effects on 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 traits (carcass weight, dressing (%) and prime cuts (%) and blood biochemistry (AST, ALT, total protein, albumin, globulin, creatinine, total lipids, total cholesterol, and blood urea). Sixty New Zealand White weaned male rabbits of 35 days age were randomly divided to 4 treatment groups of approximately equal average weight (706g) with 15 animals each. The first group was fed the basal diet supplemented with 10% DDGS (non-irradiated) (control), 2nd, 3rd and 4th groups were fed the control diet supplemented with 10% irradiated DDGS at 10, 20 and 30kGy, respectively. The obtained results revealed a decrease in crude fiber and increases in soluble fiber and insoluble fiber. The increases were linearly correlated with the increasing irradiation dose. The supplemented irradiated 10% DDGS up to 30kGy in the diet of growing rabbits resulted in a significant improvement of body weight, gain weight, feed conversion, the apparent digestibility of dry matter, crude protein, crude fiber, carcass traits (carcass weight, dressing (%) and prime cuts(%)), and the improvement was parallel with increasing the radiation dose. While, feed intake, water intake, rectal temperature, respiration rate, ether extracts digestibility, AST, ALT, total protein, albumin, globulin, total lipids, total cholesterol, creatinine and blood urea were not altered by the treatments. Generally, it can be concluded that radiation processing with γ-rays improved the soluble and insoluble fiber and the digestibility of DDGS, and that DDGS supplemented diets fed to growing rabbits improved rabbits' growth performance without any deleterious effect on physiological and biochemical attributes.

Keywords: Growing rabbits, DDGS, Diet, Digestibility, Biochemical attributes, Gamma radiation.

Introduction

Dry-grind ethanol (bio-fuel) production is growing in the world market and is expected to continue to increase (Renewable Fuels Association, 2012). Ethanol from grains is a relatively clean and renewable source of energy. Increasing production of ethanol from corn has resulted in large quantities of the residue of grain fermentation, known as distillers dried grains with soluble (DDGS). DDGS are the nutrient rich co-product of the dry-mill ethanol industry; they are the dried residue that remains after the fermentation of corn (or other grains) mash by selected yeasts and enzymes of starch from corn to produce ethanol and carbon dioxide (Butzen & Haefele, 2008). Although corn is the major grain used in alcohol production, sorghum, barley and

#Corresponding author email: alyncrrt@yahoo.com
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wheat (milo) may also be used. DDGS contains much lower quantities of starch because most of the starch in the corn is converted to ethanol during the fermentation process; only small amounts of starch are present in DDGS. Since, the fiber in corn is not converted to ethanol, the concentration of fiber is high in DDGS than the original grain. The nutrient (protein, fat, fiber, ash and phosphorus) content of DDGS is 2 to 3 times more concentrated than in corn (Stein & Shurson, 2009). Generally, corn DDGS is utilized as a feed ingredient and recognized as a good source of crude protein (24-29%), exogenous amino acids, B-group vitamins, mineral compounds and biotin, including high available phosphorus. In addition, DDGS is considered a good source of energy supplement with a valuable source of xanthophyll and linoleic acid (Wang et al., 2007 and Purdum et al., 2014). The nutrient composition of DDGS varies depending on the source of grain and the methods used for ethanol and DDGS production (Min et al., 2008).

Dietary fiber is a key factor which determines nutrient utilization in the diet and more emphasis should be given to routine techniques that identify the nutritional and physiological "quality" of dietary fiber, where the impact of fiber level on digestibility may differ with the properties of the fiber (i.e. soluble vs. insoluble). Total dietary fiber (TDF) is the sum of the dietary carbohydrates that are resistant to digestion by mammalian enzymes in the small intestine, but it can be partially or completely fermented in the hindgut (Institute of Medicine, 2006). According to its solubility, TDF can be divided into: Soluble dietary fibers (SDF), the part of TDF that comprises the non-starch and non-neutral detergent fiber (NDF) polysaccharides, including pectin substances, β-glucans, fructans and gums (Hall, 2003), and the insoluble dietary and low-digested fiber fractions (IDF) including lignin's, cellulose and hemicelluloses (Gidenne, 2003 and Trocino et al., 2013).

Limitation of the dietary inclusion of DDGS in monogastric animals has been attributed to their high fiber content and to a marginal lysine deficiency associated with heat damage of this amino acid during DDGS manufacture (Stein et al., 2006). Dietary fiber in DDGS consists mainly of insoluble dietary fiber (Urriola et al., 2010) that may increase the water-binding capacity and bulkiness of the diet (Urriola & Stein, 2010). However, the knowledge available about the effect of dietary inclusion of DDGS on the performance of growing rabbits is still scarce (Soliman et al., 2010; Bernal-Barrágn et al., 2010 and Youssef et al., 2012). Soluble fiber (SF) is an important nutrient that enhances fermentative activity and gut health in rabbits (Maertens et al., 2014).

Food irradiation is a physical –cold process of food preservation by exposing the food to certain amount of ionizing radiation (gamma (γ) radiation, or high energy electrons, or X-rays). It has been recognized, approved and endorsed by international organizations (WHO, FAO, IAEA, Codex, etc.) as a reliable and safe method for food shelf-life extension, control of foodborne pathogens, disinfestations of insect pests, etc. It is also used for improving nutritional value and inactivation or removal of anti-nutritional factors in food and feed (Siddhuraju et al., 2002 and Farkas, 2006). It has been reported that treatment of soybean meal and canola meal with γ-radiation reduced degradation of protein by rumen microorganisms and increased intestinal protein digestibility (Shawrang et al., 2008 and Taghinejad et al., 2009). To our knowledge, there is scarcely information in the literature about the effect of γ- irradiation on the characteristics of dietary fiber and the apparent digestibility of irradiated DDGS. Therefore, this study aims to evaluate the possible use of γ- irradiation processing at different doses to improve the apparent digestibility of DDGS and to investigate its effects as a dietary supplement on New Zealand White weaned male rabbit's performance and nutrients utilization as a monogastric model.

Materials and Methods

The experimental work of the present study was carried out at Food Irradiation Research Department, National Center for Radiation Research and Technology (NCRRT), Atomic Energy Authority, Cairo, Egypt, in cooperation with Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

Radiation processing

DDGS was obtained from Cairo Poultry Company, packed in well-sealed polyethylene bags. Each bag contained about 5kg and was subjected to gamma (γ) - radiation from ^{60}Co source at dose levels of 0, 10, 20 and 30kGy, as monitored by FWT-60-00™ radio-chromic film at room temperature. The radio-chromic dosimeter was purchased from Far West Technology, Inc., Goleta, California, USA, (ASTM, 2012 [ISO/ASTM 51275:2012(E)]). The irradiation facility used was Egypt's Mega Gamma-1 Type J-65000 located at the National Center for Radiation Research and Technology (NCRRT), Nasr City, Cairo, Egypt. The non-irradiated and irradiated DDGS (0, 10, 20 and 30kGy) samples were stored at 4ºC until being used. Radiation dose rate during the experimental period was 2.69kGy/h.

Determination of crude fiber, soluble fiber and insoluble fiber of DDGS

The crude fiber analysis was determined according to AOAC (2012) approved procedure methods of analysis, No. 973.18 using ANKOM 2000 fiber analyzer. The soluble and insoluble fiber was determined using ANKOM dietary fiber analyzer technology method, USA.

Experimental animals

Sixty New Zealand White (NZW) weaned male rabbits of 35 days age were randomly divided into 4 treatment groups of approximately equal average weight (706g) with 15 animals each.

Experimental design and diets

Table 1 shows the chemical analysis of DDGS which were analyzed according to AOAC (1990). The first group fed control basal diet supplemented with 10% DDGS (non-irradiated), 2nd, 3rd and 4th groups were fed the control basal diet supplemented with 10% irradiated DDGS at 10, 20 and 30kGy, respectively. Averages of ambient temperature and relative humidity at midday inside the rabbitry building during the experimental period 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 are 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 the accepted standards for the humane treatment 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 through stainless steel nipples fixed in each cages. All rabbit cages were equipped with feeders and nipples. During the experiment, the total artificial light was about 16h/day. Feed intake was recorded weekly during the whole experimental period. The 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 calculated.

The rectal temperature and the respiration rate were measured in rabbits once every two weeks at 9-11a.m. The respiration rate was recorded using a hand counter, which counts the frequency of the flank movement per minute. Internal body temperature was taken using medicine thermometer inserted into the rectum for 2min at depth of 2cm. 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 and the serum was separated by centrifugation at 3000rpm for 20min and kept in a deep freezer at -20^0C until the time of analysis. AST, ALT, total protein, albumin, total lipids, total cholesterol, creatinine and urea concentration in serum were estimated using commercial kits (Bio Merieux, France) according to the procedure outlined by the manufacturer. The globulin concentrations were obtained by subtracting the values of albumin from the corresponding values of total protein.

Digestibility trails

At the end of the experimental period (8 weeks), three rabbits from each treatment were randomly selected and fastened for 24h. Each rabbit was housed in a metabolic cage 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 24h, 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 extract (EE) and ash were determined according to AOAC (1990). The nutrients digestibility coefficients and feeding value of the different ingredients were calculated.

TABLE 1. Chemical analysis of DDGS (As % DM basis).

Chemical analysis	DM	Ash	EE	CP	CF	Ca	P	DE (kcal/kg)
DDGS	90.0	4.1	9.0	27.4	9.2	0.17	0.72	2910

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	22
Wheat bran	22
Barley	19
DDGS	10
Soybean meal (44%)	16
Yellow corn	6
Molasses	3
Limestone	1.1
Sodium chloride	0.3
Vitamin and minerals premix*	0.6
Total	100
Calculated analysis**	---
Crude protein	18.37
Crude fiber	11.84
Ether extract	2.15
Digestible energy (kcal/kg)	2529

*10.000 IU Vit. A, 900 IU Vit. D3, 2mg Vit. K, 50mg Vit. E, 2mg Vit. B_1, 6mg Vit. B_2, 2mg Vit. B_6, 0.01mg Vit. B_{12}, 20mg Panathonic acid, 50mg Niacin, 5mg Folic acid, 1.2mg Biotin, 12000mg Choline, 3mg Copper, 0.2mg Iodine, 75mg Iron, 30 mg Manganese, 70mg Zinc, 0.1mg Selenium, 0.1mg Cobalt and 0.04mg 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) and Cheeke (1987)

Statistical analysis

The obtained data were statistically analyzed using the SPSS Program (2007). A simple one-way classification analysis was used. Mean differences among treatments were tested by Duncan's multiple range test (Duncan, 1955).

Results and Discussion

Effect of γ- radiation on crude fiber, soluble fiber and in soluble fiber of DDGS

The statistical analysis of the data in Table 3 demonstrated a significant decrease in crude fiber content of DDGS as a result of exposure to - irradiation treatments. The reduction in the crude fiber content was 2.12, 7.55 and 10.95% at the dose levels of 10, 20 and 30kGy, respectively. Also, a significant increase in the soluble dietary fiber content of DDGS was observed, and the increase was parallel with increasing the radiation doses.

The results also showed that the insoluble dietary fiber content of DDGS significantly increased, and the increase was proportional with the irradiation doses (30.82, 64.81 and 66.61%) at 10, 20 and 30kGy, respectively. Also from the above data, it was found that the total dietary fiber which is the sum of soluble fiber and insoluble fiber has increased by radiation, and the increase was parallel with increasing the doses of γ-irradiation used up to 30kGy. The observed decrease in crude fiber content of the irradiated DDGS could be attributed to the de-polymerization and delignification characteristics of γ- radiation (Sandev & Karaivanov, 1977). Bhat et al. (2008) found that γ- irradiation at various doses (0, 2.5, 5, 7.5, 10, 15 and 30kGy) decreased crude fiber of velvet bean seeds and the decrease was a function of the irradiation doses. Also, Murugan (2015) found that crude fiber, cellulose and acid detergent lignin contents of γ-irradiated (7 and 14kGy) Brewer's spent grain samples significantly decreased compared to non-treated grains. The dose-dependent decrease in fiber on irradiation has been attributed to depolymerization and delignification of the plant matrix (Bhat et al., 2008). Irradiation could be another explanation for the observed decrease in crude fiber content and the increase in soluble and insoluble fiber contents as this 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 (Shahbazi et al., 2008). 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 due to the radiolytic degradation of cellulose (Ershov, 1998). Irradiation itself facilitates the separation of polysaccharides from lignin by breaking up the compartmentalized, crystallized lignocellulosic structure (Woods & Pikaev, 1994).

Effect of experimental treatments on rabbit's performance

Live body weight and gain weight (g)

Data in Table 4 demonstrates that a significant ($P<0.05$) increase was observed in the mean live body weight of rabbits fed diets supplemented with 10% irradiated DDGS for 4 weeks. While, a highly significant (P<0.01) increase in live body weight of rabbits fed diets supplemented with 10% irradiated DDGS was observed at the end of the experiment (week 8), and the increase was parallel with increasing the radiation dose. Meanwhile, diets containing 10% irradiated DDGS significantly (P<0.01) improved weight gain of rabbits compared to those fed control diet supplemented with non-irradiated DDGS at 4 and 8 weeks and the improvement was parallel to the radiation dose. Bernal-Barrágn et al. (2010) and Youssef et al. (2012) reported that rabbits fed diets supplemented with 10 , 20 and 30% of maize DDGS showed improved growth, but did not show any differences in daily weight gains and slaughter weight compared to the control group. In this study, the observed improvement of weight gain in the irradiated DDGS could be due to the γ- irradiation that caused changes in the complex compound to more simple form (Murugan , 2015).

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

Data tabulated in Table 5 shows no significant (P>0.05) differences in feed intake and water intake of rabbits fed diet supplemented with irradiated corn DDGS compared to the control group fed diet supplemented with non-irradiated DDGS. However, there was a significant (P<0.05) difference in feed conversion ratio of rabbits fed diet supplemented with 10% irradiated corn DDGS compared to their control counterpart. An improvement in feed conversion was observed for those fed diets supplemented with irradiated DDGS and the improvement was proportional with increasing the radiation dose. The best feed conversion was recorded for rabbits fed diets supplemented with 10% DDGS and subjected to γ- ray at 30kGy. This is attributed to the observed higher weight gain and lower feed intake in rabbits fed diets supplemented with the irradiated DDGS. Also, there were no significant differences in rectal temperature and respiration rate among the studied groups.

TABLE 3. Effect of γ- irradiation at 10, 20 and 30kGy on crude fiber, soluble dietary fiber, insoluble dietary fiber of DDGS.

Item	Control DDGS (non-irradiated)	Irradiated DDGS (kGy)			Sig
		10	20	30	
Crude fiber %	$9.40^{a} \pm 0.03$	$9.20^{b} \pm 0.04$	$8.69^{c} \pm 0.05$	$8.37^{d} \pm 0.04$	**
Soluble dietary fiber %	$3.60^{b} \pm 0.80$	$5.35^{b} \pm 0.25$	$7.60^{a} \pm 0.20$	$8.10^{a} \pm 0.30$	**
Insoluble dietary fiber %	$33.25^{c} \pm 0.45$	$43.50^{b} \pm 0.70$	$54.80^{a} \pm 1.00$	$55.40^{a} \pm 0.70$	**
Total dietary fiber %	$36.85^{c} \pm 1.30$	$48.85^{b} \pm 0.95$	$62.40^{a} \pm 1.20$	$63.50^{a} \pm 1.00$	**

Means within the same row bearing different letters differ significantly (P≤0.05).
** = P<0.01, Sig: Significance.

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

Item	Basal diet supplemented with 10% DDGS (non-irradiated)	Basal diet supplemented with 10% irradiated DDGS (kGy)			Sig
		10	20	30	
W_0	708.4 ± 6.1	711.5 ± 5.9	698.1 ± 6.2	701.3 ± 9.8	N.S
W_4	$1305.5^{d} \pm 8.1$	$1403.6^{c} \pm 9.0$	$1426.5^{b} \pm 8.1$	$1471.3^{a} \pm 12.1$	*
W_8	$1673.3^{d} \pm 10.9$	$1817.9^{c} \pm 138$	$1949.7^{b} \pm 11.1$	$1999.6^{a} \pm 16.4$	**
G_{0-4}	$597^{c} \pm 20.7$	$692.1^{b} \pm 28.9$	$728.4^{a} \pm 35.4$	$770^{a} \pm 78.7$	**
G_{4-8}	$367.8^{c} \pm 40.5$	$414.3^{b} \pm 60.8$	$523.2^{a} \pm 0.7$	$528.5^{a} \pm 77.4$	**
G_{0-8}	$964.9^{c} \pm 66.7$	$1106.4^{b} \pm 0.6$	$1251.6^{a} \pm 50.5$	$1298.3^{a} \pm 80.4$	**

Means within the same row bearing different letters differ significantly (P≤0.05).
** = 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 4th 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 and water/feed ratio, rectum temperature and respiration rate of growing NZW rabbits as affected by dietary supplemented of irradiated DDGS at 0, 10, 20 and 30 kGy.

Item	Basal diet supplemented with 10% DDGS (non-irradiated)	Basal diet supplemented with 10% irradiated DDGS (kGy)			Sig
		10	20	30	
Feed intake (g/day)	97.2^{a}±4.1	97.1^{a}±3.9	96.7^{a}±4.2	98.5^{a}±3.0	N.S
Feed conversion (g feed/gain)	5.65^{a}±0.08	4.90^{b}±0.04	4.39^{c}±0.07	4.17^{d}±0.05	*
Water intake (ml/day)	105.7^{a} ±4.2	100.4^{a}±4.1	113.5^{a}±5.1	109.1^{a}±4.5	N.S
Water/ feed ratio	1.08	1.03	1.15	1.13	-
Rectum temperature (RT) (^{o}C)|	39.3^{a}±0.08	39.1^{a}±0.06	39.5^{a}±0.07	39.3^{a}±0.09	N.S
Respiration rate (RR) (Respirations/minute)	99^{a} ±2.45	100^{a}±2.71	96^{a} ±2.63	95^{a} ±1.68	N.S
RR/RT	2.51	2.55	2.43	2.42	-
RT (%)	100	99.5	100.5	100	-
RR (%)	100	101	96.9	96	-

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 shows a significant (P<0.05) improvement of the apparent digestibility of dry matter, crude protein and crude fiber of rabbits fed diets supplemented with 10% irradiated DDGS, while no remarkable effect on ether extracts. The highest significant (P < 0.05) increase in digestibility was observed in rabbits fed diet supplemented with 10% DDGS irradiated at the highest dose (30kGy) compared to those fed diet supplemented with non-irradiated DDGS.

The herein obtained result concerning the digestibility of dry matter, is in agreement with the study of Shahbazi et al. (2008) who reported that increasing γ- irradiation (at 50, 100 and 150kGy) had linearly increased the washout fraction of dry matter (DM) and neutral detergent fiber (NDF) of alfalfa hay. Shawraing et al. (2007) reported that γ- irradiation at a dose higher than 50kGy could increase ruminal dry matter degradability of feedstuffs. Where, γ-irradiation affects the complex bonds and causes the wander-valls power weakens, and consequently results in an extensive degradation of cellulose and increasing the degradability of cell wall constituents (Iller et al., 2002).

The concentration of free radicals and also the number of separated chains from cellulose increase with increasing the irradiation dose (Muto et al., 1995). Irradiation causes formation of carbonyl groups of cellulose in the presence of oxygen that helps cellulose break down (Muto et al., 1995). Furthermore, γ- rays lead to the hydrolysis of the glycoside bonds.

For apparent protein digestibility, similar findings were observed by (Zohreh et al., 2017) who found that irradiation at a dose of 30kGy significantly increased the apparent protein digestibility of cottonseed meal compared to raw meal (non-irradiated). Also, El-Niely (2007) studied the influence of irradiation on *in vitro* protein digestibility of broad beans irradiated at 2.5, 5, 10 and 20kGy, 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 water (Filali-Mouhim et al., 2000). The hydroxyl and superoxide anion radicals that are generated by radiation could modify the proteins molecular properties which result in alteration of proteins by covalent cross-linkages in proteins after irradiation. A higher protein digestibility after irradiation treatment may be due to the increased accessibility of the protein to enzymatic attack. However, this effect could also be due to inactivation of proteinaceous anti-nutritional factors (Van der Poel, 1990).

Cellulose is the most important source of carbon and energy in ruminant's diet. A plant fiber contains a 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 (Czerkawski, 1986). 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 (Krassig, 1993). γ- irradiation affects these glucosidal bonds with modification in hydro glucose ring (Takacs et al., 1999) and causes the wander-valls power weakens (Muto et al., 1995 and Iller et al., 2002). The breaking of hydrogenic bonds, formation of carbonyl groups of cellulose in the presence of oxygen helps cellulose breakdown and results in the degradation of the inter-linkages in lignin structure (Muto et al., 1995).

Carcass traits

Data in Table 7 shows the results of relative carcass weight, dressing % and prime cuts %. Statistical analysis revealed a significant (P<0.01) increase in carcass traits (carcass weight, dressing (%) and prime cuts (%) of rabbits fed diet supplemented with irradiated DDGS at 10, 20 and 30kGy compared to those fed diet supplemented with non-irradiated DDGS. Carcass weight, dressing (%) and prime cuts (%) increased gradually with the escalating radiation dose. This is attributed to the observed improvement of the apparent digestibility of dry matter, crude protein and crude fiber of irradiated DDGS and the consequent improvement of growth performance.

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 (Elamin, 2013). The results of blood chemistry are presented in Table 8. AST and ALT, total protein, albumin, globulin, total lipids, total cholesterol, creatinine and blood urea of rabbits fed control diet supplemented with 10% (non-irradiated) and those fed diet supplemented with DDGS subjected to γ- irradiation at 10, 20 and 30kGy did not show significant differences (P<0.05) in all studied blood parameters.

TABLE 6. Apparent digestibility of growing NZW rabbits as affected by dietary supplemented of irradiated DDGS at 0, 10, 20 and 30kGy

Item	Basal diet supplemented with 10% DDGS (non-irradiated)	Basal diet supplemented with 10% irradiated DDGS (kGy)			Sig
		10	20	30	
Dry matter (DM)	70.7^{c}±3.4	73.2^{bc}±4.5	75.9^{b}±3.6	79.4^{a} ±6.5	*
Crude protein (CP)	67.2^{c}±6.1	70.8^{bc}±5.1	76.0^{b}±6.2	80.1^{a} ±5.7	*
Crude fiber (CF)	59.4^{b}±2.6	61.4^{b}±1.7	64.9^{a}±3.0	65.3^{a} ±1.9	*
Ether Extract (EE)	72.0^{a}±13.1	73.6^{a}±11.3	74.5^{a}±16.4	74.8^{a} ±18.0	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.

TABLE 7. Carcass traits of growing NZW rabbits as affected by dietary supplemented of irradiated DDGS at 0, 10, 20 and 30kGy

Item	Basal diet supplemented with 10%DDGs (non-irradiated)	Basal diet supplemented with 10% irradiated DDGS (kGy)			Sig
		10	20	30	
Carcass weight (g)	925.3^{d}±60	1099.8^{c}±76	1206.9^{b}±66	1235.8^{a}±70	**
Dressing (%)	55.3	60.5	61.8	61.9	-
Prime cuts (%)	49.1	56.7	59.5	60.2	-

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 irradiated DDGS at 0, 10, 20 and 30kGy

Item	Basal diet supplemented with 10% DDGS (non-irradiated)	Basal diet supplemented with 10% irradiated DDGS (kGy)			Sig
		10	20	30	
AST(g/100ml)	15.6^a±2.1	16.1^a±2.5	15.8^a±2.6	15.9^a±2.8	N.S
ALT(g/100ml)	10.3^a±1.6	11.00^a±1.4	10.8^a±1.5	11.1^a±1.8	N.S
Total protein (g/100ml)	7.7^a±0.4	6.9^a±0.6	6.9^a±0.5	6.8^a±0.3	N.S
Albumin (g/100ml)	4.2^a±0.4	4.0^a±0.1	3.9^a±0.2	3.6^a±0.5	N.S
Globulin (g/100ml)	3.5^a ±02	2.9^a±0.4	3.0^a±0.5	3.2^a±0.3	N.S
Total lipids (mg/100ml)	680.3^a±57.5	659.7^{ab}±62.2	655.1^b±50.1	652.3 ^{b}±61.6	N.S
Total cholesterol (mg/100ml)	191.2^a±40.1	189.1^a±37.7	182.1^b±36.9	174.1^c±45.0	N.S
Creatinine(g/100ml)	1.4^a±0.7	1.4^a±0.6	1.5^a±0.4^a	1.7^a±0.3	N.S
Blood urea (mg/100ml)	20.4^a±3.2	18.8^a±4.0	16.9^b±5.2	18.1^{ab}±6.1	N.S

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

Conclusion

Based on the results obtained from the current study, it could be concluded that γ- irradiation (at 10, 20 and 30kGy) increased the soluble and insoluble fiber contents of DDGS, increased the apparent digestibility of DDGS and improved the growth performance of rabbits fed irradiated DDGS without any deleterious effects on their physiological and biochemical attributes compared to rabbits fed non-irradiated DDGS.

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تآثير تشعيع منتجات تقطير الحبوب المجففة مع الذوائب كمكمل غذائي على بعض الجوانب الفسيولوجية و البيوكيميائية للأرانب النامية

علي محمد عبد العظيم (1)، اسامه محمد عبد المنعم (2) و اشرف محمد منير (1)
(1) قسم بحوث تشعيع الأغذية – المركز القومى لبحوث وتكنولوجيا الإشعاع – هيئة الطاقة الذرية – القاهرة – مصر و (2) قسم الانتاج الحيواني – كلية الزراعة – جامعة الزقازيق – الزقازيق – مصر.

منتجات تقطير الحبوب المجففة مع الذوائب وهو منتج عرضي يمكن الحصول عليه بعد تخمير الحبوب للحصول على الإيثانول خاصة مع الذرة (DDGS). يحتوي DDGS على ٣ أضعاف نسبة الألياف الموجودة في الذرة خاصة الألياف الغير ذائبة. تم إجراء الدراسة بهدف تقييم تأثير الإشعاع على المحتوي العام من الألياف الخام و الألياف الذائبه والغير ذائبه ل DDGS بواسطة استخدام اشعة جاما عند جرعات اشعاعية 10 و20 و 30 كيلو جراي، بالإضافة لتقييم تأثير الاشعاع على DDGS بنفس الجرعات السبق ذكرها على التوالى فى علائق الأرانب كمكمل غذائي وذلك لتقيمها على الأداء الإنتاجي للأرانب من حيث (وزن الجسم - الوزن المكتسب، المأكول من العلف، معامل التحويل الغذائي، كمية الماء المتناول، درجة حرارة المستقيم، معدل التنفس)، معامل الهضم الظاهري (كمية المادة الجافة، البروتين الخام، الدهن الخام و الألياف الخام) وخصائص الذبيحة (وزن الذبيحة، نسبة التصافي % , القطع المميزة %), و المقاييس البيوكيميائية للدم (ALT, AST، تركيز البروتين الكلى، الألبيومين، الجلوبيولين، الدهن الكلي في الدم و الكولسترول، الكرياتينين واليوريا). وتم إجراء التجربة على سلالة الأرانب النيوزيلندى الأبيض نظرا لسرعة نموه الفائقة ومقدرته الجيدة على التأقلم وعموما -أجريت الداراسة على عدد 60 أرنب نيوزيلندى أبيض على عمر 35 يوم و كانت متقاربة فى الوزن الحى فى بداية التجربة (706 جرام).وقد تم تقسيم الأرانب إلى 4 مجموعات فى كل منها 15 أرنب، المجموعة الأولى: تغذت على العليقة التقليدية الخاصة باللأرانب مضاف اليها DDGS 10% (المجموعة الضابطه)، المجموعة الثانية: تغذت على العليقة التقليدية بالإضافة على DDGS 10% والتي تم معالجتها بجرعة اشعاعية 10 كيلو جراي، المجموعة الثالثة: تغذت على العليقة التقليدية بالإضافة على DDGS 10% والتي تم معالجتها بجرعة اشعاعية 20 كيلو جراي، المجموعة الرابعة: تغذت على العليقة التقليدية بالإضافة على DDGS 10% والتي تم معالجتها بجرعة اشعاعية 30 كيلو جراي. اظهرت النتائج إنخفاض المحتوي الكلي للألياف الخام وزيادة المحتوي من الأليالف الذائبة والغير ذائبة وزاد هذا التحسن بزيادة الجرعة الإشعاعية. و دلت النتائج أن الوزن و الوزن المكتسب، معامل التحويل الغذائي و كفاءة الهضم الظاهري للمادة الجافة و البروتين الخام و الألياف الخام وخصائص الذبيحة قد تحسنت للأرانب التي تغذت على علائق تم اضافة لها DDGS 10% والتي تم معالجتها بجرعات اشعاعيه 10، 20 و 30 كيلو جراي مقارنة بمجموعة الأرانب التي تغذت على نفس العليقة مضاف اليها DDGS 10% و الغير معاملة (المجموعة الضابطه). ووجد بزيادة الجرعات الإشعاعية زاد التحسن حيث وجد أن افضل جرعة اشعاعية مستخدمة كانت عند 30 كيلو جراي. ولم يحدث تغير في كمية المأكول ولا كمية الماء المتناول ولا درجة حرارة المستقيم ولا معدل التنفس ولم يحدث اختلاف في معامل هضم الدهون الظاهري ولم تحدث تغيرات في المقايس البيوكيميائية للدم مقارنة بالمجاميع التي تغذت على عليقة تحتوي على DDGS 10% والغير معامة (المجموعة الضابطه). يتضح من هذه الدراسة أن DDGS و الذي تم معالجتة بجرعات أشعاعية تصل حتى 30 كيلو جراي يمكن إستخدامها بأمان و بكفاءة حيث حدث تحسن في المحتوي من الألياف الذائبة والغير ذائبة وتحسن في الإداء وخصائص الذبيحة ومعاملات الهضم دون حدوث أى تأثير سلبي على المقايس الفسيولوجية و البيوكيميائية للأرانب.