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Article

Effect of dietary inclusion of distiller's dried grains with solubles (DDGS) on carcass and meat quality in growing rabbits

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Abstract:

Distiller's dried grains with solubles (DDGS) are widely in livestock diets to replace costly ingredients. An evaluation was done of the effect of dietary inclusion of different levels (0, 10, 20 and 30 %) of DDGS on carcass and meat quality in rabbits. At 96 d, after the growth period, a sample of 56 rabbits (Negro Azteca x Chinchilla) were slaughtered. Carcass characteristics were measured and calculated using twenty rabbits (5 per treatment): carcass proportions of anterior limbs, posterior limbs, ribs and loins; weight of meat, bone and loin fat; and the meat:bone ratio. A sensory evaluation of rabbit meat acceptance was done with a panel of 46 untrained evaluators who expressed their perceptions of meat aroma, color, flavor and texture. Color of the *Longissimus dorsi* muscle was quantified with the CIELAB system, and texture measured via shear force. Carcass and meat quality results were analyzed with an ANOVA. Sensory evaluation results were assessed with non-parametric statistics. No differences (P>0.05) were present in the carcass, organoleptic and meat texture results. The b* chromatic parameter was higher (P<0.05) in the treatments containing 10, 20 and 30 % DDGS (11.77, 12.17 and 12.22, respectively) than in the control diet (9.68). Sensory evaluation showed that rabbit meat with or without DDGS was perceived as having an agreeable aroma and taste, pale color and soft texture. Dietary inclusion of DDGS at up to 30 % had no effect on carcass or meat characteristics in rabbits.

Key words: DDGS, Rabbits, Carcass quality, Meat quality.

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Introduction

Ethanol production has grown notably worldwide. From 16.6 million liters in 2001 production it has boomed to 83.4 million in 2011[1], and will continue expanding in response to global demand for biofuels[2,3]. The raw materials used to produce ethanol vary by region and country. In general, the European Union produces ethanol from different grains, while Brazil generates it from sugar cane[4,5] and the United States from corn. The largest ethanol producer in the world is the United States, which reached a total production of 60 billion liters in 2014. Distiller's dried grains with solubles (DDGS) are a biofuels industry byproduct, the nutritional value, availability and costs of which provide an opportunity for their use in animal feeds[6].

Ethanol production in Mexico is based on sugarcane and sweet sorghum, neither of which produce DDGS[7]. However livestock producers in Mexico have found DDGS to be a valuable resource that can replace grains such as maize and sorghum, as well as soy flour, in animal diets. Their financial and sustainability advantages have led to heavy consumption and consequent importation of DDGS from the U.S.[8]. Imported, competitively-priced DDGS represent a source of protein, amino acids, fat, energy and minerals that can replace conventional ingredients, many of which are also used for human food.

In the United States, DDGS is mostly used in ruminants (66 % beef cattle and 14 % dairy cattle), but pig production has reached 12 % of total DDGS consumption, while poultry production uses about 8 % of available DDGS[9]. Use of DDGS in animal feed is expected to increase in coming years due positive results when included in poultry feed[10,11].

Very little research has been done on DDGS in diets for rabbits. Studies have been done on productive performance[12-15], nutrient digestibility[16,17], morphometry and other carcass traits[18,19,20]. Even if DDGS can replace grains and oilseed byproducts in rabbit diets, with corresponding benefits for producers, evaluations are still needed on the effect dietary inclusion of DDGS may have on marketable portions of the carcass and rabbit meat sensory characteristics. The present study objective was to evaluate the effects of dietary inclusion of DDGS on carcass and meat quality in growing rabbits.

Materials and methods

The research was done at the rabbit production facilities of the La Ascension Unit of the Faculty of Agronomy of the Autonomous University of Nuevo Leon (Universidad Autonoma de Nuevo León – UANL) in Aramberri, Nuevo Leon, Mexico. Some analyses were done at the Sensory Evaluation Laboratory of the Food Industries Research and Development Center of the UANL. Animals were 56 hybrid rabbits (Negro Azteca x Chinchilla) weaned at 40 days of age, with an average live weight of 752 ± 39 g. Management and feeding conditions were similar for all animals, with free access to water and feed. All animals were housed at a density of two rabbits per cage in galvanized wire cages (840 x 330 x 400 mm) provided with a feeder and water bottle. Each cage was treated as an experimental unit. Four DDGS inclusion levels (0, 10, 20 and 30 %) were tested, and each level was considered a treatment (n = 7 cages per treatment). Addition of DDGS was mostly compensated for by reducing contents of sorghum, soy flour and monocalcium phosphate (Table 1), based on the control diet (0% DDGS)[15].

Table 1: Diet composition and nutrient contribution as fed basis

Ingredients	DDGS Treatments (%)			
	0	10	20	30
Alfalfa meal	50.38	49.05	53.88	55.28
Sorghum grain	30.00	26.94	17.20	10.40
Soybeanmeal	13.70	9.60	4.60	0.00
DDGS	0.00	10.00	20.00	30.00
Molasses	3.00	3.00	3.00	3.00
Monocalcium phosphate	0.68	0.54	0.46	0.36
Salt	0.50	0.50	0.50	0.50
Vit+trace min premix[1]	0.20	0.20	0.20	0.20
DL-Methionine	0.14	0.14	0.14	0.14
L-Lysine	0.00	0.00	0.02	0.12
Soya oil	1.40	0.00	0.00	0.00
Analyzed contribution:				
Crude protein, %	17.05	16.73	16.94	17.42
Crude fat, %	3.23	2.82	3.57	4.99
NDF, %	18.89	22.30	24.82	27.94
ADF, %	15.32	17.85	18.87	20.95
Gross energy, kcal/kg	3006	3106	3239	3286
Calculated composition:				
Crude fiber, %	17.43	17.57	19.46	20.36
Digest energy, kcal/kg	2814	2714	2635	2583
Total phosphorous, %	0.45	0.45	0.45	0.45
Calcium, %	0.88	0.85	0.90	0.91
Lysine, %	0.77	0.71	0.65	0.65
Methonine + Cysteine, %	0.60	0.60	0.60	0.60

[1] Vit + trace mineral premix provided (per kilo premix): Vit. A: 12,000,000 UI; Vit. D_3: 1,500,000 UI; Vit. E: 60,000 UI; Vit. K_3: 2 g; thiamin (B_1): 2 g; riboflavin: 6 g; pyridoxin (B_6): 3.5 g; B_{12}: 20 mg; biotin: 150 mg; folic acid: 520 mg; niacin: 60 g; pantothenic acid: 15 g; and choline chloride: 500 g. Minerals: manganese 40 g; zinc: 100 g; iron: 90 g; copper: 10 g, iodine: 480 mg; selenium: 240 mg.

At the end of the finishing trial (96 days), at an average commercial weight of 1.955 ± 86 g, twenty rabbits were randomly selected (five per treatment) and slaughtered without previous fasting. The animals were slaughtered with a single blow to the base of the skull, on the upper portion of the neck, in the occipital region, and death confirmed by circulation ceasing(21). These animals were used to provide meat for the sensory tests.

Weight was measured of the anterior and posterior limbs, rib section and loin. Each portion was then boned and weight measured for total meat and bone, and loin fat. These figures were used to calculate the carcass meat:bone ratio following an established methodology(22).

The *Longissimus dorsi* muscle (LD) to the 5th lumbar vertebra was extracted to evaluate meat color and tenderness. Carcasses were butchered according to a common methodology(23). After 24 h refrigeration, meat color was quantified with a colorimeter

(CR-400, Konica, Minolta, Japan) by measuring the color parameters used in the CIELAB color space[24]: luminosity (L^*); index (a^*), greens (negative values) to reds (positive values); and index (b^*) blues (negative values) to yellows (positive values). Meat tenderness was evaluated with a texturometer (TA-XT Plus, Texture Analyzer, Stable Micro Systems, Godalming, UK), equipped with a triangular cut Warner-Bratzler blade[25] to measure shear force.

Meat sensory evaluation was done by using affective analysis with the participation of potential or current consumers, who express their preferences among several products offered for evaluation[26]. The panel of 46 evaluators (age range = 17 to 56 yr) were prepared following a method developed for pork[27]. In an effort to offer a meat product at least somewhat familiar to the panelists, for each independent treatment the meat samples were prepared as meatballs (fried) without added spices, except salt. Each panelist was offered four samples (one from each treatment) on a tray along with a glass of water. Samples were randomly identified with a code. The organoleptic characteristics of aroma, color, flavor and texture were measured with a 1-to-5 sensory scale[28]. For aroma the scale corresponded to very disagreeable (1), disagreeable (2), neither agreeable nor disagreeable (3), agreeable (4), and very agreeable (5). The color scale was very strong (1), strong (2), neither pale nor strong (3), pale (4), and very pale (5). The five flavor values were strongly dislike (1), dislike (2) neither like nor dislike (3), like (4) and like very much (5). For texture they corresponded to very firm (1), firm (2), neither soft nor firm (3), soft (4), and very soft (5).

Statistical analysis of the variables for cold carcass weight, carcass quality and meat quality (expressed as a percentage cold carcass weight) was done with the StatSoft program[29]. The theoretical assumptions of the analysis of variance were tested with the Levene variance homogeneity analysis[30], and the Shapiro-Wilk error normality test[31]. The data met these assumptions and therefore required no transformation. An analysis of variance was then run following a completely randomized design with four treatments and five replicates per treatment. Differences between treatments were identified with a Duncan Test[33] using a $P<0.05$ significance level. Analyses were done with the INFOSTAT ver. 2012 statistical package[32].

Meat sensory evaluation results were examined with a non-parametric statistics (χ^2) analysis of response frequency to identify differences between treatments for each indicator. This analysis was run with the SPSS ver. 24 package.

Results and discussion

No differences (*P*>0.05) were observed for any of the carcass weight and edible cut variables (Table 2). Inclusion of up to 30% DDGS in the diet of growing rabbits had no effect on carcass characteristics. Even though the question arises if this absence of effect on carcass composition may be due to the number of replicates employed (n= 5 per treatment). The present results agree with those of previous studies involving inclusion levels of up to 20% DDGS(19,20), and up to 28% DDGS(34) in diets for rabbits without alterations in carcass yield.

Table 2: Carcass weight and commercial cut proportion in rabbits fed diets containing different levels of DDGS

Indicators	DDGS (%)				SE (±)	*P*
	0	10	20	30		
Cold carcass weight, g	1057.1	957.7	1004.8	956.9	35.31	0.1851
Posterior limbs, %	34.15	31.84	31.66	31.18	1.47	0.5070
Loin, %	26.39	32.41	31.89	29.40	1.84	0.1213
Ribs, %	21.15	19.37	20.86	23.00	1.34	0.3294
Anterior limbs, %	18.31	16.39	15.59	16.42	0.72	0.0913

As in the present study up to 30% DDGS inclusion in the diet caused no negative effects in carcass composition, this highlights the benefit of DDGS inclusion in diets for growing rabbits since up to 65 % of sorghum grain and 100 % of soybean were replaced in the diet. In a previous study(34), DDGS was used in diets for growing rabbits to replace 65 % alfalfa hay and 100 % soybean meal in the reference diet. In contrast, the goal of our research group is to evaluate the use of more fodder and agro-industrial byproducts in livestock diets without negatively affecting, or ideally improving, productive performance. This coincides with a study in which up to 65 % of grains and 95 % of soybean meal were substituted with up to 30 % DDGS in diets for growing rabbits with good results in growth indicators(14).

The studied DDGS inclusion levels did not affect (*P*>0.05) the carcass meat, bone or fat proportions (Table 3). The meat proportion averaged 65 ± 1.24 %, which corresponded to 2.2 times the bone proportion. Fat content was less than 2.5 % in all treatments. These results are similar to those of a study in which no differences were observed in the rabbit leg meat:bone ratio and in visceral fat content in response to DDGS inclusion levels ranging from 0 to 28 % in diets for growing rabbits(34).

Table 3: Carcass meat, bone and fat proportions and the meat:bone ratio in rabbits fed diets containing different levels of DDGS

Indicators	DDGS (%)				SE (±)	*P*
	0	10	20	30		
Meat, %	65.52	64.95	65.72	64.35	1.24	0.8615
Bone, %	28.46	30.36	30.98	29.95	1.29	0.5704
Loin fat, %	2.30	1.59	1.04	2.28	0.36	0.0743
Meat:Bone	2.32	2.15	2.15	2.18	0.13	0.7319

In the sensory evaluation differences (P<0.05) were observed in response frequency for each of the five categories in each evaluated rabbit meat parameter: aroma, color, flavor and texture (Table 4). However, panelist opinions did not differ between treatments (P>0.367).

Table 4: Sensory evaluation of meat from rabbits fed diets containing different levels of *DDGS (n= 46 panelists)*

	DDGS (%)							
Responses	0		10		20		30	
	No.[1]	%	No.	%	No.	%	No.	%
Aroma:								
Very agreeable	14	30.4^{ab}	13	28.3^{a}	9	19.6^{b}	10	21.7^{b}
Agreeable	24	52.2^{a}	22	47.8^{a}	27	58.7^{a}	26	56.5^{a}
Neither agreeable nor disagreeable	8	17.4^{b}	10	21.7^{a}	10	21.7^{b}	10	21.7^{b}
Disagreeable	0	0.0^{c}	1	2.2^{b}	0	0.0^{c}	0	0.0^{c}
Very disagreeable	0	0.0^{c}	0	0.0^{c}	0	0.0^{c}	0	0.0^{c}
Color:								
Very pale	6	13.0^{b}	3	6.5^{b}	5	10.9^{b}	6	13.0^{b}
Pale	18	39.1^{a}	18	39.1^{a}	17	37.0^{a}	16	34.8^{a}
Neither pale nor strong	18	39.1^{a}	18	39.1^{a}	16	34.8^{a}	17	37.0^{a}
Strong	4	8.7^{b}	7	15.2^{b}	8	17.4^{b}	5	10.9^{b}
Very strong	0	0.0^{c}	0	0.0^{c}	0	0.0^{c}	2	4.3^{b}
Flavor:								
Like very much	7	15.2^{b}	11	23.9^{ab}	8	17.4^{b}	10	21.7^{b}
Like	21	45.7^{a}	25	54.3^{a}	26	56.5^{a}	22	47.8^{a}
Neither like nor dislike	13	28.3^{ab}	6	13.0^{b}	11	23.9^{b}	10	21.7^{b}
Dislike	4	8.7^{b}	3	6.5^{b}	0	0.0^{c}	2	4.3^{c}
Dislike very much	1	2.2^{b}	1	2.2^{b}	1	2.2^{c}	2	4.3^{c}

Texture:								
Very soft	6	13.0^{b}	6	13.0^{ab}	2	4.3^{b}	4	8.7^{b}
Soft	20	43.5^{a}	15	32.6^{a}	22	47.8^{a}	18	39.1^{a}
Neither soft nor firm	11	23.9^{a}	7	15.2^{ab}	8	17.4^{ab}	11	23.9^{ab}
Firm	9	19.6^{b}	16	34.8^{a}	14	30.4^{a}	9	19.6^{ab}
Very firm	0	0.0^{c}	2	4.3^{b}	0	0.0^{c}	4	8.7^{b}

^{a,b,c} Different letter superscripts in the same column indicate differences in panelist response frequencies (*P*<0.05).

[1] Number of panelists.

Between 35 (75 %) and 38 (82 %) of the 46 panelists (*P*=0.687) stated that the aroma of the rabbit meat was agreeable to very agreeable, with no differences between treatments. In contrast between 8 (17 %) and 10 (21 %) felt the aroma to be neutral (neither agreeable nor disagreeable), with no differences between treatments (*P*=0.957).

Meat color was perceived as neutral (i.e. neither pale nor strong) by 16 to 18 of the evaluators in each treatment (*P*=0.984). Fewer (*P*<0.05; Table 4) felt it to be very pale (3 to 6 panelists for treatment; *P*=0.753), or strong (4 to 8 responses per treatment; *P*=0.644).

From 21 (45 %) to 26 (56 %) of the panelists said they liked the flavor of the rabbit meat, while 8 (17 %) to 11 (24 %) said they very much liked the meat from the treatments with 10 to 30 % DDGS (*P*=0.774). As far as the meat from the control treatment, 21 (45 %) said they liked it, and seven said they very much liked it, with no differences between treatments (*P*=0.774; Table 4). Very few (<11%) panelists stated they did not like the meat, with no differences among treatments (*P*=0.717). Most of the panelists expressed their approval of the rabbit meat both with and without DDGS. This represents a potential market niche worth exploring in more detail, especially since consumption of rabbit meat is notcommon in the region where the sensory evaluation was done.

Between 45 and 56 % of the panelists perceived the meat to be soft or very soft, with no differences among treatments (P>0.05). From 15 to 24 % (Table 4) were of the opinion that it was medium texture (neither soft nor firm), again with no differences (*P*=0.711). The meat was stated to be of firm texture by 19 to 35 % of the panelists with no differences among treatments (*P*=0.367). Less than 9 % described its texture as very firm, with no differences (*P*=0.414).

Overall, the panelists expressed varying opinions of their degree of acceptance of the rabbit meat in the different evaluated sensory quality categories. The sensory analysis method applied here is known as an affective test[26]. The main objective of this kind of test is for a group of consumers or potential consumers to express their personal responses when evaluating a product using a given set of response options. In the present case it was focused on characterizing the sensory perceptions of a panel of potential rabbit meat consumers regarding meat from rabbits fed diets containing different levels of DDGS.

The panel consisted of a broad sample of 46 untrained panelists. Another possibility would have been to use eight to ten trained evaluators to evaluate meat quality. These follow specific methodologies and use specialized equipment. However, in a study including sensory evaluation of rabbit meat, trained evaluators were unable to detect differences (P>0.900) between meat samples[35].

No previous studies exist of sensory analysis of meat from rabbits fed diets containing DDGS. However, the present results agree with a study done using pigs fed diets containing DDGS in which no negative effects were found on the sensory attributes of pork from these pigs[36].

Color is an important quality factor in meats. In the present results the L^* and a^* chromatic coordinates of *Longissimus dorsi* muscle did not differ between treatments (P>0.05) (Table 5). But there were differences (P<0.05) in the b^* coordinate between the treatments containing DDGS levels (10, 20 and 30 %) and the control. This indicates that the *Longissimus dorsi* from rabbits in the DDGS treatments exhibited a more intense yellow color. This may be due to the carotenoid pigments in the DDGS, the source of the yellow color of corn grains, which would have occurred in higher concentrations in the DDGS treatments than in the control[37]. These results agree in general with those from a study of the color of the carcass and *Longissimus dorsi* muscle of rabbits fed diets containing DGGS from different sources (barley, wheat, corn) at three concentrations (0, 20 and 40 %)[20]. Carcass color did not differ among treatments, which was also true of the *Longissimus dorsi* except for a higher a^* value (reds) in the treatment with 20 % DDGS from wheat. Luminosity values (L^*) did not differ between the treatments in the present study, indicating the analyzed rabbit meats had similar levels of clarity. The levels observed here (L^* = 59.42 to 62.23) are within the ranges reported in the literature for rabbit meat, which are generally high (L^*>50)[38]. They also indicate that the analyzed rabbit meat should be considered pale, since L^* values greater than 52 in rabbit meat are indicative of pale meat[39]. The sensory evaluation (Table 4) generally supports these results in that panelists largely perceived the rabbit meat to be pale or neither pale nor strong in color.

Numerical values for shear force were higher in the meat from rabbits fed diets containing higher DDGS proportions (Table 5), although the differences were not significant (P>0.05). The present shear force values are slightly higher than reported values (2.9 to 3.5 kg/cm^2)[22], indicating the meat evaluated here was firmer. This discrepancy may be due to slaughter age since the animals in the present study were slaughtered at 96 d of age while those in the previous study were slaughtered at 63 d of age[22]. Older animals are known to produce firmer meat than younger animals mainly due to the increase in connective tissue and its characteristics[40]. The texture evaluation results coincided with those of the sensory evaluation, and in both cases differences in meat texture among treatments were not significant. No previous studies have included texture analyses of meat from rabbits fed diets containing DDGS. Studies of pork from finishing pigs fed diets containing up to 20 % DDGS found no negative effects on meat quality determined by shear force in cooked loin chops[41]. In another study inclusion of 10 or 20 % DDGS in the diets of growing-finishing pigs had no effect on the shear force nor the overall palatability of bacon and pork chops[42]. This agree in general with the present results.

Table 5: Chromatic coordinate (*L*, a** and *b**) and shear force values for *Longissimus dorsi* muscle from rabbits fed diets containing different levels of DDGS

	DDGS (%)					
Indicators	**0**	**10**	**20**	**30**	**SE (±)**	***P***
*L**	60.37	60.51	59.42	62.23	1.44	0.5904
*a**	8.79	8.58	6.75	8.22	0.82	0.3237
*b**	9.68[a]	11.77[b]	12.17[b]	12.22[b]	0.56	0.0157
Shear force, kg/cm^2	3.25	3.50	3.65	3.88	0.35	0.637

[a,b] Different letter superscripts in the same row indicate significant difference (P<0.05).

Conclusions and implications

Inclusion of up to 30 % DDGS in rabbit diets had no effect on carcass or meat characteristics. This widely available agricultural byproduct is an interesting alternative for replacing costlier ingredients such as soybean and sorghum in diets for growing rabbits. Sensory evaluation showed the rabbit meat from the DDGS treatments to have favorable organoleptic characteristics for human consumption, although further promotion would be needed for consumers in the study area to accept its taste.

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