World Rabbit Science

World Rabbit Sci. 2017, 25: 251-260
doi:10.4995/wrs.2017.6813

DRIED BREWERS GRAINS IN GROWING RABBITS: NUTRITIONAL VALUE AND EFFECTS ON PERFORMANCE

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Abstract: Two assays were carried out to determine i) the nutritional value of dried brewers' grains and ii) the effects of inclusion of this ingredient in growing rabbit diets on animal performance and economic performance of the breeding unit. In the digestibility assay, a total of 28 male rabbits were distributed in 2 groups differing in the diet offered to animals: a reference diet (35.51% neutral detergent fibre and 16.50% crude protein [CP]) and a test diet (60% of reference diet and 40% of dried brewers grains). The dried brewers' grain contained 37.9% of CP and 3371 kcal digestible energy/kg dry matter. In the performance study, 80 weaned rabbits (40 males and 40 females) were allotted at 40 d of age to 5 groups differing in the inclusion levels of dried brewers' grains (0, 7, 14, 21 and 28%) from 40 d to 90 d of age. Inclusion of dried brewers' grains did not affect the live weight at 90 d, the feed intake between 40 d and 90 d or the dressing percentage of rabbits (on average 223 g, 96 g/d and 51.3%, respectively). There was no effect of diet on the meat quality parameters (69.5% water holding capacity, 25.6% cooking loss, 3.4 kg/cm^2 Warner-Bratzler shear force and pH 5.70) and inclusion levels above 14% reduced the feed cost (–18%; *P*<0.001), while inclusion above 21% improved net income (+32%; *P*<0.001). In conclusion, these results suggest that the use of dried brewers' grains in diets for growing rabbits could improve the economic performance of the production system without impairing the animals' performance.

Key Words: alternative feedstuff, barley, rabbit production.

INTRODUCTION

The feeding of rabbits during fattening period is characterised by high efficiency of ingested nutrients, resulting in high deposition of muscle tissue. The characteristics of the digestive physiology of rabbits allow the use of considerable amounts of fibrous feedstuffs in diets, enabling us to introduce some agro-industrial by-products (De Blas *et al*., 2015; Guermah *et al*., 2016). This practice can lower feed costs by replacing commonly-used energy or protein sources such as corn and soybean meal, adding value to by-product feedstuffs and reducing the environmental impact caused by their improper disposal.

During use of barley and other cereals for beer production a large amount of residue is disposable, including wet brewers' grains, composed of the solid and less soluble fraction of barley; in addition, residue could contain wheat, maize or rice residues used in brewing (Mussato and Roberto, 2006). This residue contains a moisture level close to 80%, so it may be used in a dehydrated form. It contains about 26% crude protein (Gilaverte *et al.,* 2011) and 24% acid detergent fibre (NRC, 2007), and can be used as an interesting alternative feedstuff in rabbit diets.

Although Lounaouci-Ouyaed *et al.* (2008) found that the inclusion of dried brewers' grains in rabbit diets reduced performance, Etchu *et al.* (2012) observed that this feedstuff can replace the palm kernel cake in rabbit diets up to 25% without affecting the animals' performance. Thus, dried brewers' grains can be an alternative feedstuff to

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https://doi.org/10.4995/wrs.2017.6813

alfalfa hay and wheat bran, fibre sources commonly used in rabbit diets and which present a high cost value in the diet (Vieira, 2009). Furthermore, due to its high protein content and amino acid composition, it was observed that the inclusion of dried brewers' grains also enables the substitution of soybean meal in diets for rabbits (Lounaouci-Ouyaed *et al.,* 2008).

Based on the above, the aim of this study was to determine the nutritional value of dried brewers' grains and evaluate the effect of increasing levels of this feedstuff in growing rabbit diets on performance, carcass traits, meat quality and economic viability of the production system.

MATERIAL AND METHODS

The experimental procedures followed the protocols approved by the Ethics Committee on Animal Research (CEPA 77/2015) of the Federal University of Ceara (FUC).

The wet brewers' residue was purchased from a beer production company and exposed to sun in plastic canvases to dry for 3 d. Throughout the process, the residue was mixed 4 times a day, then stored in plastic bags for later use in the digestibility and performance assays.

Digestibility measurement of dried brewers' grains

The digestibility assay was performed using 28 New Zealand White×California male rabbits, 50 d old and with an initial weight of 1400±0.1 kg. The animals were individually housed in cages with dimensions of 80×60×45 cm with metal feeder and nipple drinker. The mean temperature and relative humidity during the experimental period were 27.5°C and 83,2%, respectively. Two experimental diets were used: a reference diet and a test diet, consisting of 60% reference diet and 40% dried brewers' grains (Table 1). The reference diet was formulated according to the requirements for growing rabbits recommended by De Blas and Mateos (2010) and provided in pelletised form. The rabbits were distributed on a randomised block design, with 2 treatments and 14 replicates per treatment. The animals' weight was taken into account for the formation of blocks, consisting of light (1221±0.10 kg) and heavy animals (1513±0.12 kg).

The digestibility assay was performed using the total faecal collection method and lasted 14 d:10 d of adaptation to diets and cages, and 4 d for faeces collection (Perez *et al.,* 1995). The diets and water were fed *ad libitum* throughout the experimental period. During the collection period, the faeces of each animal were collected once a day in the morning, packed in plastic bags and stored at –10°C. At the end of the period, the faeces were sampled and placed in a forced air oven (55°C) for 72 h. Then, feeds and faeces samples were ground through a 1 mm screen and analysed for dry matter (DM), mineral matter (MM), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF) and acid detergent fibre (ADF), according to the methodologies described by AOAC (2005). The gross energy (GE) was determined in calorimetric bomb (IKA C200, Germany). The digestible nutrients of dried brewers' grains were determined according to the equation of Matterson *et al.* (1965): (1) $DN_{(ing)}=DN_{RD}+[(DN_{TD}–DN_{RD})/\text{ Inclusion level}]$, where $DN_{(ing)}$: ingested digestible nutrient; DN_{RD}: digestible nutrient reference diet; DN_{TD}: digestible nutrient test diet, and the digestible energy was estimated as described by Villamide (1996).

Performance trial

In the performance assay, a total of 80 New Zealand White×California weaned rabbits, 40 males and 40 females, at 40 d of age, were housed in galvanised wire cages of dimensions of 80×60×45 cm with metal feeder and nipple drinker and considering the cage with 2 rabbits of the same sex as the experimental unit. The animals were allotted in a randomised block design in a 5×2 factorial arrangement, considering 5 levels of dried brewers grain (0, 7, 14, 21 and 28%) and sex (male and female), with 4 replicates of 2 animals. The mean temperature and relative humidity during the experimental period were 28.3° C and 80.2%, respectively. The weight of the animals was considered for forming the blocks. The initial weight of the light block was 819±31 g for females and 818±42 g for males, and the heavy block was 928±60 g for females and 976±42 g for males.

The experimental diets were based on corn, soybean meal, wheat bran and alfalfa hay, according to the nutritional requirements of rabbits during the growing period, as recommended by De Blas and Mateos (2010), and provided in pelletised form (Table 1). The digestible energy (DE) value and nutritional composition of dried brewers' grains measured during the digestibility assay were used to formulate the diets so that they contained similar energy and protein content. The amino acid composition of dried brewers' grains was obtained by high performance liquid chromatography analysis (HPLC), with values of 0.893% for lysine, 0.554% for methionine, 0.968% for methionine+cystine, 0.934% for threonine and 0.248% for tryptophan, on a DM basis.

The assay lasted 50 d and mortality rate during the performance trial was 1%. The rabbits were weighed at the beginning and end of the experimental period (90 d old). Diet and water were offered *ad libitum* and the diet leftovers were weighed to assess the animals' performance in terms of feed intake, weight gain and feed conversion ratio.

Table 1: Percentage and chemical composition of the experimental diet.

		Digestibility assay	Performance assay diets				
Ingredients	Cost[1] (US$/kg)	Reference diet	0%	7%	14%	21%	28%
Corn	0.20	22.60	31.94	33.02	33.71	34.39	34.20
Alfalfa hay	0.66	44.24	22.33	18.61	14.74	10.87	7.86
Soybean meal	0.47	4.82	16.85	12.29	8.26	4.24	0.00
Wheat bran	0.79	24.00	10.91	10.91	10.91	10.91	10.91
Rice husk	0.03	0.00	7.52	7.52	7.52	7.52	7.52
Tifton hay	0.49	0.00	5.69	5.69	5.69	5.69	5.69
Dried brewers grains	0.19	0.00	0.00	7.00	14.00	21.00	28.00
Soybean oil	1.04	1.77	1.00	1.00	1.00	1.00	1.00
Limestone	0.07	0.69	0.79	0.79	0.79	0.80	0.91
Dicalcium phosphate	0.88	0.32	0.76	0.96	1.14	1.32	1.51
Salt	0.06	0.51	0.49	0.50	0.51	0.51	0.60
Vitamin and mineral mixture[2]	3.04	0.30	0.40	0.40	0.40	0.40	0.40
L-lysine HCL	4.47	0.50	0.17	0.22	0.28	0.34	0.41
DL- methionine	2.68	0.25	0.15	0.10	0.06	0.01	0.00
Inert	0.02	0.00	1.00	1.00	1.00	1.00	1.00
Total		100.00	100.00	100.00	100.00	100.00	100.00
Cost (US$/kg)		0.60	0.45	0.42	0.39	0.36	0.34
Nutritional composition							
Digestible energy[3] (kcal/kg)		2515	2521	2523	2563	2569	2513
Crude protein[3] (%)		16.65	17.42	17.42	18.03	17.75	17.46
Neutral detergent fibre[3] (%)		45.51	46.13	42.49	45.20	45.69	43.06
Acid detergent fibre[3] (%)		18.50	17.32	18.23	18.05	17.71	17.88
Starch[4] (%)		25.00	25.42	25.48	25.37	25.25	24.56
Total lysine[4] (%)		0.73	0.75	0.73	0.73	0.73	0.73
Total methionine+cystine[4] (%)		0.53	0.54	0.52	0.52	0.52	0.54
Calcium[4] (%)		0.79	0.80	0.80	0.80	0.80	0.85
Total phosphorus[4] (%)		0.50	0.50	0.50	0.50	0.50	0.50

[1] Cost calculated using the prices of the feedstuffs during the experimental period at Ceará (Brazil).

[2] Vitamin and mineral mixture - quantity per kg of product: vitamin A, 2 500 000 IU; vitamin D3, 500 000 IU; biotin, 50 mg; choline, 50 mg; niacin, 10000 mg; calcium pantothenate, 3000 mg; vitamin B12, 7 mg; vitamin B2, 1800 mg; vitamin E, 7500 mg; vitamin K3, 1000 mg; Fe, 40000 mg; Cu, 35000 mg; Mn, 20000 mg; Zn, 40000 mg; Co, 360 mg; I, 840 mg; Se, 120 mg.

[3] Analyzed value.

[4] Calculated value.

Digestibility measurement of experimental diets

After the 30 d of the performance assay, a trial was performed to determine the nutrient digestibility of the experimental diets for 4 d using the total faecal collection method (Perez *et al.,* 1995). The diets and water were offered *ad libitum* throughout the experimental period and the feed intake was determined. During the collection period, the faeces of each replicate were collected once a day in the morning, packed in plastic bags and stored at –10°C. At the end of the period, the faeces were sampled and placed in a forced air oven (55°C) for 72 h. Then, feeds and faeces samples were ground through a 1 mm screen and analysed for DM, MM, CP, EE, NDF, ADF, following the methodologies described by AOAC (2005). GE was determined in calorimetric bomb (IKA C200, Germany). The nutrient digestibility coefficients of the diets were determined according to the formula: (2) CD (%)=100×(NI-NE)/NI, where CD: coefficient of digestibility; NI: nutrient intake; NE: nutrient excreted.

Carcass traits

At 90 d of age the animals were subjected to fasting for 12 h and then weighed. All the animals were slaughtered and the carcass was weighed to determine the carcass yield. After evisceration, the pancreas, liver and the visceral fat were weighed. The stomach, small and large intestines were emptied and weighed. The relative weights of organs and visceral fat were calculated (% of slaughter weight). The carcasses were then kept under refrigeration (2°C) for 24 h.

The legs of the rabbits were separated and weighed, according to the method described by Blasco and Ouhayoun (1996). The right leg was used to determine the meat/bone ratio, according to the following formula: M/B=MW/BW, where M/B is the meat/bone ratio, MW is the meat weight (g), and BW is the bone weight (g), according to Rao *et al.* (1978).

Meat quality

After a 24-hour refrigeration period, meat from *Longissimus dorsi* of the right side of carcass was removed to determine the colour, pH and water holding capacity (WHC, %). Weight loss in cooking (WLC, %) and Warner-Bratzler shear force (WBSF, kg/cm^2) were determined on the *Longissimus dorsi* from the left side of carcass. The pH was measured using a digital pH meter (Hanna Instruments HI99163, Brazil), with direct insertion of the electrode into the loin muscle. Meat colour was evaluated using a chromameter (Chromameter CR 300 Minolta Ltd, Japan) according to the reflectance coordinates (L*, a* and b* value). The WHC was determined on a 2.0 g loin sample, considering the released water by filter paper press method. Cooking loss was determined on a whole *Longissimus dorsi*, which was thawed in vacuum-packed plastic bag and then cooked at 80°C by immersion in a water bath and calculated as percentage of weight loss. The meat from *Longissimus dorsi* after cooking loss analysis was used to determine the WBSF, being cut into pieces of 1.5 cm width of the apparatus Texture Analyser TA-XT2i coupled to the Warner-Bratzler device according to the methodology described by Liu *et al.* (2004).

Economic evaluation

Economic evaluation of the rearing units that would fed the rabbits according to the experimental treatments was determined considering the cost of diet, the animal performance and the carcass traits. The costs of experimental

Table 2: Chemical composition, coefficient of digestibility, digestible nutrients and energy of dried brewers' grains, on dry matter basis.

Nutrients and energy	Chemical composition	Coefficient of digestibility	Digestible nutrients or energy
Dry matter (%)	90.4	80.5	72.8
Mineral matter (%)	5.3	84.8	4.5
Proteins (%)	37.9	41.0	15.6
Ether extract (%)	8.1	59.6	4.8
Neutral detergent fibre (%)	51.7	90.1	46.6
Acid detergent fibre (%)	22.1	64.8	14.3
Energy (kcal/kg)	4803	70.2	3371

diets (US$/kg feed) were calculated based on the prices of the feedstuffs during the experimental period. The feeding cost (US$/rabbit) was determined from the total feed intake of animals and cost of diet in the corresponding period. The average cost of feed per kilogram of body weight (US$/kg rabbit), in turn, was calculated on the feed intake, daily weight gain and feeding cost.

The net income was obtained by the difference between the gross income, considering the average value of rabbit (US$ 1.54/kg), and the feeding cost for each treatment.

Statistical analysis

The statistical analysis was performed using the Statistical Analysis System software (SAS 2000), and the statistical model applied for the variance analysis was $Yijk=\mu+Li+Sj+LSij+eijk$, where μ=overall mean; Li=effect of the level of inclusion of dried brewers' grains (i=0, 7, 14, 21 and 28%); Sj=effect of sex (j=male or female); LSij=interaction between the level of inclusion i on sex j; and eijk=effect of the error.

The degrees of freedom referring to the levels of inclusion of dried brewers' grains, excluding the control diet (0% of inclusion) were broken down into polynomials, to establish the curve that best describes the behaviour of the data. Dunnett's test (5%) was used to compare the results obtained with each of the inclusion levels in relation to the diet without inclusion of the ingredient (0% of inclusion).

RESULTS AND DISCUSSION

Nutritional composition and digestible energy of dried brewers' grains

In our study, the crude protein content of dried brewers' grains was 37.9% (Table 2), which was higher than reported by Gilaverte *et al.* (2011; 26.1%). However, the amount of neutral detergent fibre (51.7%) was lower than the value obtained by Siddaramanna *et al.* (2009; 62.9%) and Gilaverte *et al.* (2011; 62.1%). These differences could be explained by the composition of the brewery residue in terms of differences in the barley used in brewing and other

Table 3: Nutrient digestibility coefficients and digestible energy of the experimental diet, based on the dry matter.

	Coefficients of digestibility and digestible energy						
Inclusion level (%)	DM (%)	Protein (%)	MM (%)	EE (%)	NDF (%)	ADF (%)	DE (kcal/kg)
0	68.4	84.3	50.4	88.4	60.4	27.8	2774
7	66.6	82.0	47.5	94.7*	59.6	27.5	2667
14	68.9	84.4	53.6	90.8	59.1	29.9	2821
21	67.4	80.8*	50.1	89.8	57.5	29.8	2874
28	63.9	80.1*	47.4	88.5	50.8*	28.5	2746
Sex							
Male	66.6	82.7	49.8	89.9	55.2	24.5	2757
Female	67.5	81.9	49.9	90.8	57.2	26.6	2788
Mean	67.0	82.3	49.8	90.4	56.2	25.5	2772
SD	4.62	3.40	6.70	3.13	6.83	11.20	191.31
ANOVA (*P*-value)							
Level	0.2085	0.0381	0.4601	<0.0001	0.0140	0.0562	0.3185
Sex	0.5634	0.4668	0.9673	0.2482	0.3454	0.5222	0.6263
Level×Sex	0.4955	0.9761	0.2543	0.9229	0.3525	0.3822	0.5480
Regression for Level							
Linear	0.1118	0.0538	0.6699	<0.0001	0.0010	0.7765	0.2542
Quadratic	0.0206	0.0531	0.0609	<0.0001	0.0009	0.6773	0.0159

DM: dry matter; MM: mineral matter; EE: ether extract; NDF: neutral detergent fibre; ADF: acid detergent fibre, DE: digestible energy. SD: Standard deviation; ANOVA: analysis of variance. *Differs from control (0%) by Dunnett test ($P<0.05$).

raw materials used, as well as variations in the process and type of additives used in the mashing process (Mussato and Roberto, 2006).

The CP in dried brewers' grains is higher than the other ingredients used in rabbit diet formulation as alfalfa hay (17%), but lower than CP in soybean meal (45%). Dried brewers' grains have the potential for replacing both, considering the participation and high cost of these in the diet (Ferreira *et al.,* 2008). The low digestibility of dried brewers' grains protein may be related to the high fibre content of this feedstuff, resulting in lower digestible protein than soybean meal (15.6 *vs.* 38.3%; Fazano *et al.,* 1989).

The digestibility coefficients of NDF and ADF were high (90.1 and 64.8%, respectively). This result may be explained by the low ADF content in dried brewer grain (22.1%) when compared to other fibre sources such as alfalfa hay (33.1% ADF). In this study, the gross energy value of the dried brewers' grains was 4803 kcal/kg, while the DE content was 3371 kcal/kg, a value close to that found in pigs by Albuquerque *et al.* (2011; 3371 kcal DE/kg).

Digestibility of experimental diets

There was no effect (P>0.05) of sex on digestibility of all the variables evaluated (Table 3). Level of inclusion of dried brewers' grains had no effect on digestibility of DM of diets, but inclusion of dried brewers' grains has a quadratic regression and showed a quadratic effect on DM digestibility ($Y=61.868+0.9024X-0.0297X^2$; $R^2=0.2350$), indicating better utilisation of nutrients by rabbits with up to 15.19% inclusion of the dried brewers' grains (Table 3).

The digestibility of crude protein was lower (P<0.05) in diets containing 21 and 28% of dried brewers' grains than in other diets. The NDF digestibility was lower in diet containing 28% of dried brewers' grains than in other diets. This result suggests that the fibre characteristics of the ingredient could interfere in dietary digestibility. In turn, the digestibility of EE was higher (P<0.05) in the diet containing 7% of dried brewers' grains than in other diets.

Table 4: Performance of growing rabbits fed different levels of dried brewers grains.

	Evaluated parameters				
Inclusion level (%)	Initial body weight (kg)	Final body weight (kg)	Feed intake (g/d)	Body weight gain (g/d)	Feed conversion ratio
No. of observations	8	8	8	8	8
0	0.84	2.24	94.3	28.0	3.38
7	0.82	2.25	96.3	28.7	3.39
14	0.84	2.24	96.6	28.2	3.45
21	0.83	2.23	95.7	27.8	3.45
28	0.84	2.22	94.4	27.7	3.44
Sex					
Male	0.85	2.30[a]	95.9	28.8[a]	3.34[a]
Female	0.85	2.20[b]	93.4	26.9[b]	3.49[b]
Mean	0.85	2.25	94.7	27.9	6.83
SD	0.06	0.16	6.04	2.53	0.22
ANOVA (P-value)					
Level	-	0.7970	0.6147	0.7973	0.7066
Sex	-	0.0490	0.3177	0.0325	0.0357
Level×Sex	-	0.2213	0.6634	0.1991	0.1535
Regression for Level					
Linear	-	0.5236	0.4625	0.3471	0.6488
Quadratic	-	0.5285	0.4726	0.5485	0.8361

SD: standard deviation; ANOVA: analysis of variance. Means followed by different letters in the column differ (P<0.05) by F test. No.: number of rabbits studied per treatment, considering the mortality rate.

Inclusion of dried brewers' grains in the diet had no effect on the digestible energy content of the diet. However, the level of inclusion of dried brewers' grains had a quadratic effect on digestible energy content of the rations ($Y=2351.9+54.502X-1.4392X^2$; $R^2=0.2484$), with a better inclusion level at 19%. This result could be explained by a high level of non-starch polysaccharides, such as beta-glucans, in the diet containing 28% of the dried brewers' grains (Conte *et al.,* 2003).

The digestibility coefficients of EE ($Y=95.146-0.2597X$; $R^2=0.4841$) and NDF ($Y=63.800-0.4015X$; $R^2=0.3064$) decreased when the level of inclusion of dried brewers' grains in the diet increased ($P<0.05$). Rabbits do not have the enzymatic capacity to digest non-starch polysaccharides and these, when present, may decrease the digestibility of some nutrients (Nascimento *et al.,* 2005).

Performance and carcass traits

The use of increasing levels of dried brewers grain did not influence ($P>0.05$) the feed intake, weight gain and feed conversion ratio of rabbits during the period from 40-90 d of age. These results demonstrate the feasibility of the replacement of soybean meal by dried brewers' grain up to 28% in the diet (Table 4).

The male rabbits had greater weight gain (+7.3%; $P<0.05$), higher final weight (+4.6%; $P<0.05$) and better feed conversion ratio (+4.3%; $P<0.05$) than females.

For carcass traits, the relative liver weight was lower in the animals receiving a diet containing 14, 21 and 28% of dried brewers' grains (–16, –20 and –17%; $P<0.05$) than in animals fed the control diet (Table 5). Other carcass traits were not affected by dietary inclusion of dried brewers grain. This result suggests that this feedstuff may affect the hepatic metabolism. The results corroborate those reported by Papadomichelakis *et al.* (2012), who found that dietary fibre is correlated with hepatic fatty acid, glycogen and cholesterol, all being determinant components of rabbit liver.

Table 5: Influence of dried brewers' grains level in rabbit diets on carcass traits and relative weight of digestive tract organs.

Inclusion level (%)	WC (kg)	CY (%)	M/B	Liver (%)	Pancreas (%)	Stomach (%)	SI (%)	LI (%)	VF (%)
No. of observations	8	8	15	8	8	8	8	8	8
0	1.18	52.17	7.43	3.26	0.33	1.03	1.82	2.37	1.39
7	1.20	51.26	7.30	3.05	0.29	1.02	1.85	2.25	1.65
14	1.17	51.15	7.29	2.72*	0.31	1.03	1.83	2.30	1.55
21	1.16	51.35	7.23	2.60*	0.32	1.08	1.95	2.48	1.66
28	1.14	51.42	7.21	2.70*	0.34	1.05	1.85	2.40	1.69
Sex									
Male	1.18	51.09	7.30	2.96	0.32	1.04	1.88	2.28[a]	1.48[a]
Female	1.15	51.93	7.21	2.78	0.32	1.05	1.85	2.43[b]	1.69[b]
Mean	1.16	51.51	7.25	2.87	0.32	1.04	1.86	2.35	1.58
SD	0.09	2.07	0.35	0.45	0.07	0.09	0.20	0.19	0.25
ANOVA (*P*-value)									
Level	0.1316	0.1673	0.1720	0.0088	0.8499	0.7219	0.6861	0.2052	0.1353
Sex	0.2341	0.0771	0.3629	0.1802	0.8680	0.7634	0.4767	0.0283	0.0152
Level×Sex	0.2565	0.5325	0.2120	0.5342	0.2224	0.9510	0.9597	0.6137	0.4093
Regression for Level									
Linear	<0.0001	0.1885	0.2800	0.0760	0.0001	0.0684	0.1127	0.1267	0.2432
Quadratic	<0.0001	0.3466	0.2400	0.1130	0.0005	0.1177	0.1977	0.1844	0.3353

WC: Carcass weight; CY: Carcass yield; M/B: Meat/bone ratio; SI: Small intestine; LI: Large intestine; VF: Visceral fat; SD: Standard deviation; ANOVA: Analysis of variance. Means followed by different letters in the column are significantly different ($P<0.05$) by F. *Differs from control (0%) by Dunnett test ($P<0.05$). No.: number of rabbits studied per treatment, considering the mortality rate.

Table 6: Influence of dried brewers' grains level in rabbit diets on meat quality.

	Evaluated parameters						
Inclusion level (%)	WHC	CL	WBSF	pH	L*	a*	b*
No. of observations	15	15	15	15	15	15	15
0	68.48	28.02	3.87	5.78	61.64	12.70	10.64
7	68.34	24.67	3.48	5.67	63.24	12.89	10.53
14	69.94	25.36	3.47	5.72	63.40	12.76	10.42
21	69.44	26.00	3.25	5.70	63.54	12.84	10.66
28	70.50	26.29	3.37	5.73	61.99	12.92	10.91
Sex							
Male	69.15	26.30	3.51	5.73	62.42	12.92	10.57
Female	68.37	25.85	3.47	5.71	63.06	12.73	10.69
Mean	68.76	26.07	3.49	5.72	62.74	12.82	10.63
SD	3.44	4.12	0.66	0.15	1.92	0.70	1.21
ANOVA (*P*-value)							
Level	0.0512	0.6016	0.3968	0.7707	0.1048	0.9751	0.9354
Sex	0.4194	0.7693	0.9671	0.6957	0.3289	0.4048	0.8592
Level×Sex	0.1446	0.6316	0.1963	0.9834	0.0601	0.7422	0.2108
Regression for Level							
Linear	0.0612	0.4893	0.1235	0.5458	0.4195	0.9349	0.1039
Quadratic	0.1382	0.6995	0.2401	0.7532	0.3194	0.9554	0.2004

WHC: Water holding capacity; CL: Cooking loss; WBSF: Warner Bratzler Shear Force; SD: Standard deviation; ANOVA: analysis of variance. Means followed by different letters in the column differ ($P<0.05$) by F test. No.: number of rabbits studied per treatment, considering the mortality rate.

There was no effect ($P>0.05$) of dried brewers' grains inclusion on other carcass traits such as carcass weight (117 g), carcass yield (51.30%), or the relative weights of the stomach (1.05%), intestines (4.23%) and visceral fat (1.64%). However, regression analysis evidenced a linear effect of dried brewers' grains inclusion in the diet on carcass weight (Y=1.2762–0.0024X; R^2=0.6209; $P<0.001$) and relative weight of pancreas (Y=0.3214+0.0020X; R^2=0.4612; $P<0.001$).

This latter result may be due to the presence of non-starch polysaccharides present in the dried brewers grain, corroborating with Partridge and Wyatt (1995) who also observed a hypertrophy of this organ, due to the presence of fibre, which increases the viscosity of the digesta and decreases the transit time of the chyme. In this sense, the presence of this feedstuff in the small intestine induces the pancreas to secrete more enzyme, so this organ is continuously stimulated to release more secretions, resulting in pancreatic hypertrophy.

The relative weight of the large intestine (+6.58%; $P<0.05$) and visceral fat deposition (+14.19%; $P<0.05$) were higher in females than in male rabbits.

Inclusion of dried brewers' grains in rabbit diets had no effect on meat quality, the meat/bone ratio, water holding capacity, cooking loss, Warner Bratzler shear force, pH and colour components ($P>0.05$; Table 6).

The economic analysis indicates that inclusion of dried brewers' grains in rabbit diets can be interesting (Table 7). Indeed, the feeding cost (Y=6.8367–0.0664X; R^2=0.6831), the cost of feed per kilogram of body weight (Y=4.8562–0.0434X; R^2=0.5654) and the cost index (Y=141.87–1.2682X; R^2=0.5654) were reduced when the level of incorporation of dried brewers grain increased, so economic efficiency index increased (Y=68.954+0.8748X; R^2=0.6132). The inclusion levels of dried brewers' grains had a quadratic effect on net income (Y=5.0856+0.0296X+0.0006X^2; R^2=0.5262), and the best estimated level was 25%. The net income was significantly higher when the diet contained 21 or 28% of dried brewers grain compared to other diets. Mufwa *et al.* (2011), evaluating increasing levels of

Table 7: Influence of dried brewers' grains level in rabbit diets on economic evaluation.

	Evaluated parameters				
Inclusion level (%)	Feeding cost (US$/rabbit)	CFBW[1] (US$/kg rabbit)	Cost index (%)	Economic efficiency index (%)	Net income (US$/kg rabbit)
0	2.06	1.51	130.54	76.89	1.42
7	1.97	1.42	122.74	81.96	1.56
14	1.85*	1.37*	118.79*	84.58	1.62
21	1.60*	1.21*	104.28*	96.08*	1.78*
28	1.57*	1.16*	100.00*	100.00*	1.88*
Sex					
Male	1.84	1.30b	95.22b	100.00a	1.73a
Female	1.78	1.38a	100.00a	95.81b	1.60b
Mean	1.81	1.34	97.61	97.90	1.66
SD	0.74	0.51	15.00	9.67	0.82
ANOVA (*P*-value)					
Level	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sex	0.1891	0.0331	0.0331	0.0338	0.0157
Level×Sex	0.6933	0.1687	0.1687	0.0982	0.3117
Regression for Level					
Linear	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Quadratic	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[1]Cost of feed per kilogram of body weight; SD: Standard deviation; ANOVA: Analysis of variance; Means followed by different letters in the column differ ($P<0.05$) by F test. *Differs from control (0%) by Dunnett test ($P<0.05$).

dried brewers' grains in rabbit diets, also observed a reduction in feeding cost and cost per kilogram of weight gain, concluding that this feedstuff can be included up to 40%.

CONCLUSION

Dried brewers' grains could be included in diet for growing rabbits up to 28% without affecting performance, carcass traits and meat quality of rabbits. The use of this feedstuff could help reduce the inclusion of alfalfa hay and soybean meal in diets for fattening rabbits, while increasing economic indexes and cutting the cost of feed.

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