International Journal of Current Research in
Biosciences and Plant Biology
Volume 4 • Number 11 (November-2017) • ISSN: 2349-8080 (Online)
Journal homepage: www.ijcrbp.com

EXCELLENT PUBLISHERS

Original Research Article **doi:** https://doi.org/10.20546/ijcrbp.2017.411.008

Possible Utilization of Corn Steep Liquor (CSL) in Rabbits' Diet

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Abstract

An experiment was conducted on newly weaned rabbits for eight weeks by fattening them on diets supplemented with corn steep liquor (CSL) replaced 0, 10, 20, and 30% of crude protein and energy of barley and soybean meal of the diets. The obtained results refer to increased feed intake (thus, worst the feed conversion and economic efficiency); serum cholesterol, triglycerides, and low density lipoproteins (referring to somewhat negative effect on liver function, where the serum alanine aminotransferase activity was decreased too); as well as hemoglobin concentration and red blood cells count (as good indicators). Otherwise, there were no significant effects on growth performance, water intake, edible parts, digestibility, and muscular composition. So, it could be concluded that dietary inclusion of CSL (up to 30%) for rabbits is possible without adverse effects on performance and health state.

Article Info

Accepted: 02 November 2017
Available Online: 06 November 2017

Keywords

Corn steep liquor
Digestibility
Economic efficiency
Rabbit
Slaughter animals

Introduction

Searching for novel economic animal food sources to overcome the Egyptian gap in animal nutrition, many attempts were carried out to evaluate new agro-industrial by-products (Abdelhamid, 1988) such as rice straw and maize stover (El-Shinnawy et al., 1986 and Abdelhamid et al., 1989a, b, 1991 and 1994), poor quality barley straw (Gabret al., 1989), pea by-products (Abdelhamid and El-Ayoty, 1988), dried sugar beet pulp (Abdelhamid, 1992), whole sunflower seeds (Abdelhamid et al., 2011a; 2012, 2013a, b) and sieving wastes of Egyptian clover's seeds (Abdelhamid and Saleh, 2015 and Abdelhamid et al., 2016). Different field crops and wastes such as grass silages (Abdelhamid and Topps, 1991), and new sources of fodder (clitoria and phillipesara, Abdelhamid and Gabr, 1993as well asteosinte and kochia, Shehata et al., 2001 and Ahmed et al., 2001) were evaluated too. Agricultural by-products (Abdelhamid et al., 2009a, b) as banana waste (Abdelhamid et al., 2009c, d) and aquatic and salt plants as water hyacinth (Abdelhamid and Gabr, 1991a,b; Abdelhamid et al., 2006 and 2007) were studied also. Besides animal wastes as poultry litter (Gabr et al., 1991a, b) as unconventional feedstuffs (Abdelhamid et al., 1992 and 2001; Abdelhamid, 2004) or unconventional silage making using plant and animal wastes (Abdelhamid et al., 2001). Feed additives as chamomile flowers (Abdelhamid et al., 2004a and b) and other medical herbs (Abdelhamid et al., 2011b) and biologically treated diets (Abdel-Khalek et al., 2012) were fed to different animal species. Also, many other feed additives were used in animal nutrition including propylene glycol (McClanahan et al., 1998 and Nielsen and Ingvartsen, 2004) and calcium propionate (Abdel-Latif et al., 2016; Gabr et al., 2017). Therefore we attempt herein to evaluate the possibility of using corn steep liquor (CSL) in rabbits' diet.

Materials and methods

Thirty six male and female "Balady" local rabbits strain, directly after weaning (ca. 28 days old), were purchased from the local market then divided into four groups; each (of eight males plus one female rabbits) was divided into three subgroups, each of three rabbits of initial live bodyweight of 602 – 611 grams. The experimental groups were:

1) The first one was considered as a control group, its rabbits were fed a commercial fattening diet (17% CP).
2) The second group's rabbits were fed the commercial diet with 10% replacement of the total dietary CP (17%) from barley and soybean meal with CSL.
3) The third group's rabbits were fed the commercial diet with 20% replacement of the total dietary CP (17%) from barley and soybean meal with CSL.
4) The fourth group's rabbits were fed the commercial diet with 30% replacement of the total dietary CP (17%) from barley and soybean meal with CSL.

The CSL is obtained from Starch and Glucose Factory, Cairo, Mostorod. It is a by-product of wet milling process of maize-starch industry. It is a dark yellow flowing liquid with molasses. It contains high levels of soluble protein, glucose and minerals that make it useful to compensate the poor value of low quality forages by increasing the energy and protein levels without more fiber intake. The CSL is a thick liquid contains ca. 57% moisture and 43% dry matter (DM). It contains 33.5% CP on DM basis. It was preserved via concentration to 88% DM and to be similar to the other dietary ingredients. The CSL could be also mixed with corn milling process (corn bran) to avoid further drying into a moist friable mass. The product is gravitationally and microbial stable and is a non-agglomerating mixture having no obvious undesirable wet characteristics. Consequently, the product may be readily transported via conventional transfer systems from its storage location to place of consumption. Since, all animal feeds, whether fluid feeds or non-pelleted solid feeds are prone to component separation especially during distribution and, in the case of high moisture products as are the present products, during storage, this being caused at least in part because of the influence of gravity. In fluid feeds suspended solids tend to precipitate out and in solid feeds liquid components may separate from solid components and various solid components (Linton and Hussar, 1989).

The partial replacement of CSL instead of soybean meal and barley based on crude protein and energy contents. So, four experimental diets were formulated to be iso-caloric and iso-nitrogenous. After concentrating the CSL, all ingredients were mixed then pelleted into 12 mm length and 4 mm diameter of the pellets using chicken and rabbit's feed pelleting Chinese machine with a capacity of 200 Kg / h imported by Kitman Company for Agricultural Tools. The following Table No. 1 presents the chemical composition of CSL as produced (43% DM) and after its concentrating to 88% DM.

Table 1. Chemical composition (%) of the CSL as purchased (43% DM) and after concentrating(88% DM)

CSL-State	CP	Fat	Starch	NFE	Sugar	ME*
43% DM	33.5	1.00	17.4	1.00	3.30	15.4
88% DM	68.6	1.80	31.3	1.84	5.93	27.7

* MJ/Kg DM according to Feed Guide Energy Products, Copyright © 2011 James, Australia Pty Ltd.

Tables 2 and 3 show the formulation and calculated chemical composition of the experimental diets. All rabbits were housed in wire batteries provided with feeders and drinkers under the same environmental conditions concerning air temperature and relative humidity, using thermometer and hygrometer.

At the latest five days of the experimental period (eight weeks, after one week for adaptation), feed intake and feces excreted for individual three males /treatment were quantitatively weighed. Collective feed and feces samples were taken for chemical analysis and digestibility calculation. At the end of the feeding experiment and digestibility trial, three male rabbits/treatment were fasted for 12 hours, slaughtered, blood samples collected for complete blood picture, skinned, and portioned to calculate edible parts as well as sampled for chemical analysis of rabbits' meat.

Table 2. The formulation[1] of 100 Kg of each experimental diet.

Ingredients (CP %)	Control	10% CSL	20% CSL	30% CSL
Alfalfa hay (18)	32	32.00	32.00	32.00
Barley (11)	30	29.73	29.46	29.19
Wheat bran (15)	25	25.00	25.00	25.00
Soybean meal (44)	10	9.700	9.400	9.100
CSL (29.4)	-	0.570	1.140	1.710
Ca-diphosphate	1.5	1.500	1.500	1.500
Lime stone	1.0	1.000	1.000	1.000
Common salt	0.5	0.500	0.500	0.500
Total CP	17.2	17.2	17.2	17.2
Cost of one Kg diet in LE*	4.55	4.51	4.48	4.44

1: According to NRC (1977). *According to the local prices (LE) during 2017, where 1 Kg of soybean meal equal 9.7, barley 5.25, alfalfa hay 3.0, wheat bran 4.0, CSL 0.9, Ca-diphosphate 12.0, and common salt equal 1.0 LE.

Table 3. Calculated chemical composition of the experimental diets (according to NRC, 1977).

Composition	Control	10% CSL	20% CSL	30% CSL
Digestible energy, Kcal/Kg	2747	2747	2748	2749
Crude protein, %	17.0 2	17.02	17.03	17.03
Crude fat, %	2.63	2.64	2.65	2.66
Crude fiber, %	12.84	12.80	12.76	12.72
Calcium, %	1.26	1.26	1.26	1.26
Available phosphorus	0.565	0.564	0.563	0.562

Digestibility trials: At the collection period of the digestibility trial, 3 male rabbits/treatment group were individually housed in the same batteries, daily feed consumption and feces excreted were weighed, samples were taken and kept in a refrigerator at – 4 ºC till the chemical analysis was undertaken.

Slaughter test: Three rabbits/group were fasted for 12 h then weighed, sacrificed, blood samples collected, de-skinned, different parts separated and weighed, and trunk meat samples collected.

Chemical analysis: Dry matter, crude protein, ether extract, and ash of feeds, feces and meat samples were analyzed using FOSS NIRS ™ DA 1650, Denmark.

Hematological parameters: Hematological parameters including count of red blood cells (RBC's) and white blood cells (WBC's), packed cell volume (PCV%), and hemoglobin concentration were counted or measured in fresh whole blood drawn into heparinized test tubes using fully digital hematology counter (Laboratories, USA).

Blood serum analysis: Other collected samples were allowed to clot and centrifuged at 3500 rpm for 20 minutes to separate blood serum. Serum was carefully decanted into labeled tubes using serological pipettes and stored at -20 ºC until analysis. Where total protein and albumin concentrations were determined using commercial kits according to the Douman et al. (1971). Globulin was calculated by difference. Using commercial kits purchased from bio-Merieux, Laboratory Reagents and Products, France, creatinine was estimated in serum by the method of Joffe reaction described by Giorgio (1974) with standard creatinine purchased from Boehringer Mannheim Gmb H-W Germany. Activities of serum transaminases AST and ALT were determined according to Reitman and Frankel (1957) using a colorimetric method via commercial kits. Blood serum was tested also for uric acid, cholesterol, triglycerides, and high density lipoprotein (HDL) concentrations using commercial kits. The low density lipoprotein (LDL, the bad cholesterol) concentration was calculated by subtracting the high density lipoprotein (HDL, the good cholesterol) concentration and triglycerides concentration (divided by 5) from the total cholesterol concentration [LDL = total cholesterol – HDL – (triglycerides / 5)].

Statistical analysis: The obtained numerical data were statistically analyzed using standard error (SE), coefficient of variance (CV %= 100 [S / mean (Ẍ)]), and statistical analysis system software (SAS, 2006) for windows. One way analysis of variance and (Duncan, 1955) multiple range tests were used to compare between the parameters of the different nutritional group. The differences were significant at 0.05 levels.

Results

Feed and water consumption: The daily feed consumption of the experimented rabbits ranged between 88.89± 6.41and 133.3 ± 0.64 g/h/d with increasing trend by age going on (from the 1st to the 8th week of the feeding trial) and with significant ($p \leq 0.05$) increases in the case of dietary inclusion of CSL, particularly at 30 and 20% of the diet (Table 4).

Table 4. Feed consumption as means (of 9 rabbits) ± standards errors of the 4 treatment groups (gram/head/day) throughout the experimental period (8 weeks).

Weeks	Treatment groups			
	G1	G2	G3	G4
W1	88.89^{b} ± 6.41	94.44^{b} ± 3.21	93.33^{b} ± 3.39	113.7^{a} ± 1.61
W2	105.6^{b} ± 3.21	113.7^{ab} ± 1.61	114.8^{a} ± 3.70	115.2^{a} ± 0.98
W3	105.6^{b} ± 3.21	114.0^{ab} ± 1.61	118.5^{a} ± 1.85	111.5^{ab} ± 5.14
W4	100.0^{a} ± 0.00	103.0^{a} ± 2.96	103.5^{a} ± 2.25	101.7^{a} ± 6.55
W5	123.0^{a} ± 4.27	119.3^{a} ± 0.21	123.0^{a} ± 1.96	123.3^{a} ± 4.44
W6	92.6^{bc} ± 7.52	105.9^{ab} ± 3.53	117.4^{a} ± 1.96	121.5^{a} ± 1.33
W7	106.7^{b} ± 3.39	114.1^{b} ± 2.43	123.7^{a} ± 2.07	128.5^{a} ± 1.96
W8	122.2^{b} ± 3.57	130.0^{ab} ± 3.33	133.3^{a} ± 1.11	133.3^{a} ± 0.64

a - c: Means in the same row superscripted with different letters differ significantly at $p \leq 0.05$.W (1…8) Feeding Weeks, G1- Control (zero Corn Steep Liquor), G2- 10% Corn Steep Liquor, G3- 20% Corn Steep Liquor, and G4-30% Corn Steep Liquor.

Daily water intake (ml/head/day) take the same trend of the daily feed consumption, since it take the range from 38.90± 1.67 to 141.6± 0.81 with increasing trend by age going on (from the 1st to the 8th week of the feeding trial) and with significant ($p \leq 0.05$) increases in the case of dietary inclusion of CSL, particularly during the 2nd and 3rd weeks of feeding trial (Table 5).

Table 5. Drinking water consumption as means (of 9 rabbits) ± standards errors of the 4 treatment groups (ml/head/day) throughout the experimental period (8 weeks).

Weeks	Treatment groups			
	G1	G2	G3	G4
W1	38.90^{a} ± 1.67	53.70^{a} ± 7.41	59.26^{a} ± 3.35	51.85^{a} ± 9.26
W2	55.56^{b} ± 1.67	73.33^{a} ± 1.11	75.00^{a} ± 1.85	79.63^{a} ± 1.85
W3	96.22^{b} ± 1.85	104.8^{ab} ± 2.59	112.2^{a} ± 2.32	98.15^{b} ± 3.70
W4	122.2^{a} ± 6.42	107.8^{b} ± 1.11	115.9^{ab} ± 3.87	103.0^{b} ± 2.96
W5	136.7^{a} ± 1.29	114.3^{b} ± 1.45	136.8^{a} ± 6.30	134.9^{a} ± 0.52
W6	120.0^{a} ± 2.31	98.26^{b} ± 1.91	130.5^{a} ± 4.91	129.3^{a} ± 3.31
W7	127.2^{a} ± 0.84	114.0^{ab} ± 3.51	132.8^{a} ± 5.62	136.2^{a} ± 0.33
W8	131.8^{a} ± 1.14	122.3^{ab} ± 3.37	138.2^{a} ± 5.74	141.6^{a} ± 0.81

a,b: means in the same row superscripted with different letters differ significantly at $p \leq 0.05$.W (1…8) Feeding Weeks, G1- Control (zero Corn Steep Liquor), G2- 10% Corn Steep Liquor, G3- 20% Corn Steep Liquor, and G4-30% Corn Steep Liquor.

Growth performance: Although the significant ($p \leq 0.05$) increases in feed intake by the dietary inclusion of CSL; yet, there were no significant ($p \geq 0.05$) differences among treatments in live bodyweight (Table 6) throughout the experimental intervals (8 weeks).

Nutrients digestibility: Table 7 presents means ± standard errors of digestibility coefficiency of different nutrients by the experimented rabbits at the end of the fattening period. There were no significant ($p \geq 0.05$) differences among treatments in the dry and organic matters digestibility. Yet, there were significant ($p \leq 0.05$) differences in the crude protein digestibility (since G2 was the best) and ether extract digestibility (since G4 was the worst whereas G1 was the best).

Table 6. Live bodyweight in grams as means (of 9 rabbits) ± standards errors of the 4 treatment groups throughout the experimental period (8 weeks).

Weeks	Treatment groups			
	G1	**G2**	**G3**	**G4**
W0	607.8 ± 48.07	601.0 ± 24.45	606.1 ± 41.63	602.8 ± 47.88
W1	686.1 ± 49.53	743.3 ± 33.01	742.2 ± 42.85	725.0 ± 48.52
W2	981.2 ± 68.19	956.1 ± 52.53	1040.0 ± 49.41	999.4 ± 47.93
W3	1277.2 ± 76.84	1273.3 ± 58.05	1351.7 ± 53.02	1282.8 ± 48.29
W4	1497.2 ± 66.38	1440.0 ± 54.81	1492.8 ± 49.78	1493.3 ± 53.18
W5	1702.8 ± 70.25	1613.3 ± 56.37	1674.7 ± 55.24	1751.1 ± 49.22
W6	1875.9 ± 70.17	1737.2 ± 59.72	1804.7 ± 58.61	1868.3 ± 45.26
W7	2033. 9 ± 58.93	1862.2 ± 59.64	1922.8 ± 63.95	2011.1 ± 41.90
W8	2124.4 ± 52.68	2007.8 ± 65.36	2062.2 ± 67.08	2147.8 ± 59.07

W (1…8) Weeks Feeding, G1- Control (zero Corn Steep Liquor), G2- 10% Corn Steep Liquor, G3- 20% Corn Steep Liquor, G4-30% Corn Steep Liquor

Table 7. Means ± standard errors of digestibility coefficiency of different nutrients (%, dry matter basis).

Nutrient digestibility	Treatment groups			
	G1	**G2**	**G3**	**G4**
Dry matter	81.0 ± 3.46	70.2 ± 5.72	78.4 ± 4.83	69.0 ± 5.11
Organic matter	81.7 ± 3.29	73.8 ± 4.33	83.2 ±3.73	74.7 ± 4.18
Crude protein	80.1^{b} ± 3.54	91.4^{a} ± 1.52	82.0^{abc} ±4.04	73.8^{bc} ± 4.27
Ether extract	84.9^{a} ± 1.30	70.8^{ab} ± 4.83	59.6^{ab} ± 9.74	53.9^{b} ± 7.61

G1- Control (zero Corn Steep Liquor), G2- 10% Corn Steep Liquor, G3- 20% Corn Steep Liquor, G 4 -30% Corn Steep Liquor.a-c: Means in the same row superscripted with similar letter significantly ($p \leq 0.05$) differ.

Feed utilization: Feed conversion ratio and economic efficiency of feeding rabbits with CSL-including diets during the fattening period of 8 weeks (Table 8) showed that the best diet was the control one, since CSL-inclusion increased the feed intake (Tables 4 and 8) and did not improve body weight (Tables 6) nor body weight gain (Table 8).

Slaughter test: Absolute weights (g) of different edible parts of the experimental rabbits after the fattening period (8 weeks) as means (of 3 rabbits) ± standards errors of the 4 treatment groups are given in Table 9. This Table reflects no significant ($p \geq 0.05$) differences among treatments at the end of the experiment. However, the chemical analysis of the carcass meat revealed no remarkable differences among different treatments; since the dry matter contents were 71.1, 71.4, 73.1, and 71.7% and crude protein contents were 80.6 ± 0.23, 79.8 ± 1.55, 70.2 ± 1.59, and 81.5 ± 0.26% for G1, G2, G3, and G4, respectively.

Table 8. Economic efficiency of feeding rabbits with CSL-including diets during the fattening period as means (of 9 rabbits) ± standards errors of the 4 treatment groups.

Treatment groups	Daily body weight gain throughout the whole experimental period, g/h	Total body weight gain, g/h	Total feed consumption throughout the whole experimental period, g/h	Feed conversion ratio	Price* of the experimental diets, LE/Kg	Cost of feed /Kg live body weight gain, LE
G1	27.08	1516	5912	3.90	4.55	17.74
G2	25.12	1407	6261	4.45	4.51	20.07
G3	26.00	1456	6493	4.46	4.48	19.98
G4	27.59	1545	6641	4.30	4.44	19.08

G1- Control (zero Corn Steep Liquor), G2- 10% Corn Steep Liquor, G3- 20% Corn Steep Liquor, G4-30% Corn Steep Liquor.
*According to the local prices (LE) during 2017, where 1 Kg of soybean meal equal 9.7, barley 5.25, alfalfa hay 3.0, wheat bran 4.0, CSL 0.9, Ca-diphosphate 12.0, and common salt equal 1.0 LE.

Table 9. Absolute weights (g) of different edible parts of the experimental rabbits after the fattening period (8 weeks) as means (of 3 rabbits) ± standards errors of the 4 treatment groups.

Organs	Treatment groups			
	G1	G2	G3	G4
LBW	2098.3 ± 49.69	2051.7 ± 16.91	2126.7 ± 40.55	2160.0 ± 51.31
CW	1383.3 ± 34.68	1336.7 ± 41.46	1375.0 ± 36.06	1416.7 ± 46.03
HW	123.3 ± 4.41	126.7 ± 6.66	123.0 ± 1.66	126.7 ± 4.41
KW	13.33 ± 1.66	15.00 ± 0.00	10.00 ± 0.00	15.00 ± 0.00
TW	5.00 ± 0.00	6.67 ± 1.66	5.00 ± 0.00	5.00 ± 0.00
Total edible parts*	1524.9	1485.1	1513.0	1563.4

G1: Control (zero Corn Steep Liquor, G2: 10% Corn Steep Liquor, G3: 20% Corn Steep Liquor, G 4: 30% Corn Steep Liquor, LBW: Live Body Weight, CW: Carcass Weights, HW: Heart Weight, KW: Kidney Weight, TW: Tests Weight, *: CW+HW+KW+TW.

Table 10. Relative weights (% of the live body weight) of different edible parts of the experimental rabbits after the fattening period (8 weeks) as means (of 3 rabbits) ± standards errors of the 4 treatment groups.

Organs	Treatment groups			
	G1	G2	G3	G4
CRW	65.9	65.2	64.7	65.6
HRW	5.88	6.18	5.78	5.87
KRW	0.64	0.73	0.47	0.69
TRW	0.24	0.33	0.24	0.23
Total edible parts*	72.7	72.4	71.1	72.4

1- Control (zero Corn Steep Liquor, G2- 10% Corn Steep Liquor, G3- 20% Corn Steep Liquor, G 4 -30% Corn Steep Liquor.CRW –Carcass relative weights, HRW -Heart relative weight, KRW –Kidney relative weight, TRW -Tests relative weight, *: CRW+HRW+KRW+TRW.

Blood biochemical parameters: Table 10 presents means ± standard errors and variation coefficient of some biochemical parameters determined in rabbits' blood sera of different dietary treatments. The significant ($p \leq 0.05$) effects were calculated among treatments only for ALT activity, and concentrations of creatinine, uric acid, cholesterol, triglyceride, and LDL. The best values were obtained by the first treatment (10% replacement) concerning ALT, creatinine, uric acid, cholesterol, and LDL.

The higher replacement percentages (20 and 30%) reduced ALT activity, and increased the concentrations of creatinine, cholesterol, and LDL. That means that the replacement in rabbits' diets must be not exceeding 10% to maintain the public health [liver function (via lowering the activity of ALT and increasing the concentration of cholesterol and triglyceride) and heart and blood vessels (through thrombosis via increasing LDL levels)] of the treated rabbits. Yet, the obtained values lying within the normal ranges of the biochemical measurements for rabbits' sera.

Blood hematological parameters: Table 11 presents means ± standard errors and variation coefficient of some hematological parameters determined in rabbits' blood of different dietary treatments. The significant effects were calculated among treatments only for granulocytes count and percentage, lymphocytes percentage, hemoglobin concentration, red blood cells' count, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, red cells distribution width-standard deviation, platelets count, and platelet crit.

The higher replacement percentages (20 and/or 30%) elevated significantly ($p \leq 0.05$) the granulocytes count and %, lymphocytes % (referring to higher immunity), hemoglobin level, red blood cells count, hematocrit %, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and platelets count. That means that the replacement at its high rates (20 and / or 30%) may improve most of the tested hematological parameters, reflecting an improvement in the public health of the treated rabbits. Yet, the obtained values lying within the normal ranges of the hematological parameters for rabbits.

Table 10. Effect of the dietary treatments on the blood biochemical parameters* of the tested rabbits at the end of the experiment (means ± standard errors and variation coefficient (V%) between brackets).

Parameters	Control	T1	T2	T3
Total protein, g/dl	6.65 ± 0.09 (2.26)	6.75 ± 0.14 (3.70)	6.85 ± 0.09 (2.19)	6.85 ± 0.26 (6.57)
Albumin, g/dl	2.70 ± 0.06 (3.70)	2.80 ± 0.06 (3.57)	2.90 ± 0.06 (3.45)	2.85 ± 0.14 (8.77)
Globulin, g/dl	3.95 ± 0.03 (1.27)	3.95 ± 0.09 (3.80)	3.95 ± 0.03 (1.27)	4.00 ± 0.12 (5.00)
Glucose, mg/dl	108 ± 6.93 (11.1)	111 ± 3.46 (5.41)	117 ± 3.46 (5.13)	110 ± 2.60 (4.11)
AST, u/l	48.3 ± 3.00 (10.8)	64.3 ± 7.10 (19.1)	53.0 ± 9.02 (29.5)	46.9 ± 3.49 (12.9)
ALT, u/l	$75.8^{a} \pm 6.90$ (15.8)	$69.5^{a} \pm 3.64$ (9.06)	$49.1^{b} \pm 4.10$ (14.5)	$55.1^{ab} \pm 3.66$ (11.5)
Creatinine, mg/dl	$1.50^{a} \pm 0.00$ (0.00)	$1.35^{b} \pm 0.03$ (3.70)	$1.55^{a} \pm 0.03$ (3.23)	$1.50^{ab} \pm 0.06$ (6.67)
Uric acid, mg/dl	$0.95^{a} \pm 0.09$ (15.8)	$0.70^{b} \pm 0.00$ (0.00)	$0.95^{a} \pm 0.03$ (5.26)	$0.95^{a} \pm 0.03$ (5.26)
Cholesterol, mg/dl	$59.1^{b} \pm 0.06$ (0.17)	$63.4^{b} \pm 1.93$ (5.29)	$85.2^{a} \pm 2.14$ (4.34)	$77.9^{ab} \pm 10.6$ (23.6)
Triglycerides, mg/dl	$59.1^{b} \pm 2.63$ (7.71)	$90.9^{a} \pm 5.25$ (10.0)	$68.1^{ab} \pm 7.94$ (20.0)	$72.5^{ab} \pm 10.7$ (25.5)
HDL, mg/dl	40.7 ± 2.14 (9.09)	37.8 ± 0.35 (1.59)	42.3 ± 2.19 (8.98)	46.2 ± 8.86 (33.3)
LDL, mg/dl	$6.60^{c} \pm 2.71$ (71.2)	$7.35^{c} \pm 0.55$ (12.9)	$29.3^{a} \pm 2.74$ (16.2)	$17.3^{b} \pm 0.38$ (3.77)

*: Each value is the mean of 3 rabbits. a-c: Means in the same row superscripted with different letters differ significantly ($p \leq 0.05$). AST: Aspartate aminotransferase. ALT: Alanine aminotransferase. HDL: High density lipoprotein. LDL: Low density lipoprotein.

Table 11. Effect of the dietary treatments on the blood hematological parameters* of the tested rabbits at the end of the experiment (means ± standard errors and variation coefficient (V %) between brackets).

Parameters	Control	T1	T2	T3
WBCs, 10^3/ul	7.10 ± 0.23 (5.63)	9.45 ± 1.70 (31.2)	5.90 ± 1.33 (39.0)	7.65 ± 0.55 (12.4)
Lymph., 10^3/ul	3.35 ± 0.66 (34.3)	4.45 ± 0.95 (37.1)	3.40 ± 0.75 (38.2)	2.95 ± 0.09 (5.08)
Mid., 10^3/ul	0.78 ± 0.01 (3.16)	1.35 ± 0.38 (48.1)	0.55 ± 0.14 (45.5)	0.90 ± 0.12 (22.2)
Gran., 10^3/ul	2.98^{ab}± 0.42 (24.4)	3.65^{a}± 0.38 (17.8)	1.95^{b}± 0.43 (38.5)	3.80^{a}± 0.35 (15.8)
Lymph., %	46.0^{b}± 8.11 (30.6)	46.0^{b}± 1.85 (6.96)	58.2^{a}± 0.14 (0.43)	38.8^{c}± 1.56 (6.96)
Mid., %	11.1 ± 0.61 (9.50)	13.3 ± 1.59 (20.8)	9.85 ± 0.32 (5.58)	11.9 ± 0.40 (5.88)
Gran., %	43.0^{ab}± 7.50 (30.2)	40.8^{ab}± 3.44 (14.6)	32.0^{b}±0.17 (0.94)	49.3^{a}± 1.16 (4.06)
Hb, g/dl	10.8^{b}± 0.23 (3.70)	11.1^{b}± 0.17 (2.70)	11.3^{b}± 0.03 (0.44)	11.9^{a}± 0.09 (1.27)
RBCs, 10^6/ul	5.73^{b}± 0.04 (1.22)	6.16^{a}± 0.15 (4.30)	6.03^{a}± 0.03 (0.74)	6.05^{a}± 0.01 (0.33)
Hct, %	36.0^{b}± 0.66 (3.20)	37.5^{ab}± 0.95 (4.41)	36.8^{ab}± 0.06 (0.27)	38.6^{a}± 0.09 (0.39)
MCV, fl	62.8^{ab}±0.72 (1.99)	60.9^{b}± 0.06 (0.16)	61.1^{b}± 0.17 (0.49)	63.8^{a}± 0.03 (0.08)
MCH, pg	18.9^{abc}±0.26 (2.39)	18.0^{c}± 0.17 (1.67)	18.7^{b}± 0.14 (1.35)	19.6^{a}± 0.12 (1.02)
MCHC, %	30.1^{c}± 0.09 (0.50)	29.7^{bc}± 0.32 (1.86)	30.6^{ab}± 0.14 (0.82)	30.8^{a}± 0.14 (0.82)
RDW-CV, %	14.7 ± 0.03 (0.34)	14.7 ± 0.20 (2.39)	14.5 ± 0.52 (6.21)	15.0 ± 0.43 (5.02)
RDW-SD, fl	31.3^{c}± 0.75 (4.15)	30.5^{c}± 0.26 (1.48)	32.2^{b}± 0.23 (1.24)	37.5^{a}± 0.23 (1.07)
Plt, 10^3/ul	275^{b}± 12.1 (7.64)	223^{b}± 25.4 (25.4)	292^{ab}± 37.8 (22.4)	354^{a}± 2.89 (1.41)
MPV, fl	6.85 ± 0.43 (10.9)	7.15 ± 0.78 (18.9)	6.05 ± 0.26 (7.44)	5.90 ± 0.23 (6.78)
PDW	16.7 ± 0.49 (5.11)	16.9 ± 0.49 (5.04)	16.1 ± 0.32 (3.43)	15.9 ± 0.14 (1.58)
PCT, %	0.19^{b}± 0.00 (3.39)	0.15^{c}± 0.00 (0.65)	0.17^{b}± 0.02 (15.2)	0.21^{ab}± 0.01 (8.31)

*: Each value is the mean of 3 rabbits. a-b:Means in the same row superscripted with different letters differed significantly ($p \le 0.01$).WBC: White blood cells. Lymph: Lymphocytes. Mid: Monocytes. Gran: Granulocytes. Hb: Hemoglobin. RBC: Red blood cells. Hct: Hematocrit. MCV: Mean corpuscular volume. MCH: Mean corpuscular hemoglobin. MCHC: Mean corpuscular hemoglobin concentration. RDW-CV: Red cells distribution width-standard deviation. RDW-SD: Red cells distribution width-standard deviation. Plt: Platelets. MPV: Mean platelet volume. PDW: Platelet distribution width. PCT: Platelet crit.

Discussion

Most of the obtained results herein lying within the normal ranges mentioned for different rabbits' strains by different researchers such as Abdelhamid et al. (2016) for mean daily body weight gain, feed and water daily consumption, feed conversion ratio, digestibility, slaughter test, muscles composition, and blood analysis. Said (2016) concerning feed and water consumption, body weight, feed conversion ratio, edible parts, digestibility, and blood picture. Similar results were registered also by Abdel-Khalek et al. (2012), Sadek

(2011), Selim et al. (2012), Abu El-Hamd et al. (2013), El-Medany et al. (2013), Ragab et al. (2013) and Abdelhamid and Saleh (2015)concerning rabbits' performance, digestibility, slaughter test, muscular composition, and blood picture.

However, CSL was used as unconventional animal feed source of energy and / or protein for feeding finishing steers (Trenkle, 2002), lambs (Mirza and Mushtaq, 2006; Freitas et al., 2015; Azizi-Shotorkhoft et al., 2016), Labeo rohita fingerlings and carp (Chovatiya et al., 2010), chicken (Rafhan Product Reference Guide, 2010; Ullah et al., 2017), lactating cows (Santos et al., 2012), crossbred calves (Siverson, 2013), Rahmani lambs (El-Emam et al., 2014), ewes (Hafez et al., 2015; Khalifa et al., 2015b) Zaraibi nanny goats (Khalifa et al., 2015a and Saba et al., 2015).

Although the significant effects on some biochemical and hematological parameters; yet, the obtained values lying within the normal ranges of the biochemical measurements for rabbits' sera and the hematological parameters for rabbits according to Merck (1976), who added that Hb concentration and RBCs count increase by actual polyglobulinemia followed by O_2–shortage or dehydration, whereas WBCs count increases by acidosis. However, Merck (1974) mentioned that serum ALT activity increases and quickly decreases by hepatic toxicity, serum uric acid level decreases by acute hepatic dystrophy, whereas serum triglyceride concentration increases by essential hyperlipidemia and hepatic cirrhosis. Moreover, Varley (1978) cited that hypercholesterolemia is found in nephritis. Gout is an inflammatory disease diagnosed by hyperuricaemia. The liver is the most important area for the production of cholesterol (Goldberg, 1999). Hypouricaemia (low serum urate) may arise insevere liver disease, increased excretion, rasburicase (Beckett et al., 2010 and Walker et al., 2013). Hypertriglyceridemia is a risk factor for cardiovascular disease. Deposition of lipids in arterial walls and the subsequent formation of an atheroma are keyfeatures of atherogenesis and coronary heart disease (Ahmed, 2011).

Conclusion

From the aforementioned results, it could be concluded that the dietary inclusion of CSL in rabbits' diets (up to 30 % of crude protein and energy of dietary barley and soybean meal) could be beneficial in case of barley and soybean meal shortage, unavailable or tend to be expensive. However, the control diet was better concerning feed conversion and economic efficiency (cost of feeding to produce one kilogram body weight gain). The CSL-inclusion improved to some extent the blood parameters and did not negatively affect the rabbit's performance.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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How to cite this article:
Abdelhamid, A. M., Behery, H. R., Hammoudah, S. R. M., 2017. Possible utilization of corn steep liquor (CSL) in rabbits' diet. Int. J. Curr. Res. Biosci. Plant Biol. 4(11), 57-69. **doi:** https://doi.org/10.20546/ijcrbp.2017.411.008