



Evaluation of Dehydrated Orange Pulp and Sugar Beet Pulp as Alternatives to Yellow Corn as Energy Sources in Rabbit Diets

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Abstract

IN a completely randomized experiment, 63 unsexed weaned New Zealand White rabbits (6 weeks old, 817.2 ± 21.6 g) were used to evaluate the effects of replacing yellow corn (YC) with dehydrated orange pulp (OP) or sugar beet pulp (SBP) in their diets. The rabbits were divided into seven groups (9 rabbits each), each fed one of seven diets: a control diet with YC, or diets where 25%, 50%, and 75% of YC was replaced by 7.5%, 15%, and 22.5% of OP or SBP, respectively. The experiment lasted 56 days.

Results showed significant improvements ($P < 0.01$) in digestibility of dry matter, organic matter, crude protein, ether extract, crude fiber, and nitrogen-free extract, as well as in total digestible nutrients and digestible crude protein, in rabbits fed diets supplemented with OP or SBP. No significant changes were observed in growth performance parameters including body weight, weight gain, feed intake, feed conversion ratio, and relative growth rate. Blood analysis revealed increased levels ($P < 0.05$ or 0.01) of albumin, globulin, alkaline phosphatase, and calcium, while uric acid, creatinine, ALT, AST, and LDL significantly decreased. Other blood parameters remained unchanged, and all values were within normal physiological ranges. Carcass traits and organ weights showed no significant differences.

This study demonstrated that dehydrated orange pulp (OP) and sugar beet pulp (SBP) can serve as effective alternative energy sources, successfully substituting up to 75% of yellow corn (YC) in rabbit diets without negative impacts, while enhancing nutrient utilization, supporting health status.

Keywords: Orange pulp, Sugar beet pulp, Nutrient digestibility, Yellow Corn, Blood metabolites, Health, Carcass quality, Rabbits.

Introduction

Egypt suffers from a severe shortage of animal and poultry concentrated feeds, estimated at about 3.5 million tons of total digestible nutrients (TDN). This shortage is considered a major obstacle to the development of livestock in Egypt. The shortage of yellow corn, the main ingredient in concentrated feed, represents a large part of the feed shortage problem. Egypt needs 12 million tons of corn annually; while only 7 to 8 million tons are available from local production and value of the annually corn imports accounts about 262.43 million dollars/ annually [1]. Egypt produces huge amounts of agricultural industrial co-products such as fruit-derived waste and sugar

industry residues without full utilization from these wastes. Many researchers reported about the high nutritional value of these by-products and can be used as partial or total replacers for some traditional feeds. Utilizing these waste materials in livestock and poultry diets could help mitigate feed shortages in Egypt, reduce feeding expenses, and simultaneously contribute to environmental protection.

Orange (*Citrus sinensis*) pulp is the remaining part after extraction the juice from the orange fruit. [2] clarified that citrus pulp is composed of approximately 60- 65 % peel, 30- 35 % internal tissues and round 10 % seeds. As a result of its elevated levels of moisture and sugars, orange pulp

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rapidly deteriorated and may cause environmental pollution. Dried citrus pulp has been utilized as a non-conventional source of energy and protein in the diets of farm animals [3-7]. Orange pulp contains high concentrations of ascorbic acid and bioactive compounds compared to its juice [8, 9]. The bioactive compounds in orange peel are alkaloids, flavonoids, phenols, terpenes, resins, steroids, and essential oils plays a vital role in promoting growth and modulating biological activities and act as anti-stress, appetizers, immune-stimulators and antimicrobial [10-14].

Sugar beet (*Beta vulgaris* L.) pulp is the fibrous, energy dense by-product obtained after extracting sugar from the beetroot through a water-based process. According to reports, processing one ton of sugar beet produces approximately 150 kg of sugar and around 500 kg of wet pulp, which corresponds to about 210 kg when pressed or 50 kg in dehydrated form [15, 16]. Sugar beet pulp was used in rations of poultry, rabbits, goats, sheep, calves and dairy cattle [17-24].

The previous studies on the impact of dietary replacement of yellow corn by dehydrated orange pulp (OP) or sugar beet pulp (SBP) on rabbit performance were different and in discrepancy; for this reason, the current study was planned to determine the optimal replacement ratios that achieve the best nutrient utilization and growth characteristics and blood metabolites and health status of growing rabbits. Carcass traits of growing rabbits were also determined.

Material and Methods

Materials

Preparing of dehydrated orange and sugar beet pulps:

Fresh orange pulp (OP) was obtained from fruit juices pressing factories in Zagazig, Egypt. The orange pulp was washed before drying and left for drying at 30 ± 2 °C away from the sun. The dehydrated pulp was used to formulate the experimental diets after there. The dehydrated sugar beet pulp (SBP) was sourced from the Dakahlia Sugar Company, located in Belka, Dakahlia Governorate, Egypt.

Rabbits and the experimental design:

A feeding trial was conducted over an 8-week period using sixty-three weaned New Zealand White rabbits, aged 6 weeks, with an average initial body weight of 817.2 ± 21.6 g were used in a feeding trial for 8 weeks. The experimental period initiated in July 2023 and terminated in September 2023 (56 days). This study aimed to evaluate the impact of partial substitution of yellow corn by increasing levels of dehydrated OP or SBP on productive growth traits, nutritional utilization and haematological and biochemical blood parameters of rabbits. Carcass traits were also determined.

The animals were divided into seven experimental groups of 9 rabbits each (3 replicates for each). The animals were accommodated in flat deck wire cages ($50 \times 55 \times 40$ cm) fitted with galvanized feed troughs and automated drinkers. Each rabbits group was fed on one of seven rations, the 1st ration was a basal ration contained yellow corn as a main source of energy, while in the 2nd, 3rd and 4th diet, 25, 50 and 75 % of yellow corn grains in the basal diet were replaced, respectively by ground dehydrated orange pulp (OP) and in the 5th, 6th and 7th diet, 25, 50 and 75 % of yellow corn grains were replaced, respectively by ground dehydrated Sugar beet pulp (SBP).

The experimental diets

The experimental diets were formulated and processed into pellets at a commercial feed manufacturing facility in Damietta Governorate, Egypt. The experimental diets were formulated (Table 1) to be isonitrogenous and isocaloric and meet the standardized nutrient demands for growing rabbits according to [25, 26]. The diets were offered to rabbit's *ad libitum* and clean tap water was accessible all the times. The rabbits were housed in a well ventilated room under the same managerial and hygienic conditions.

Methods

Digestibility of nutrients and the nutritional value of the experimental diets

Following eight weeks of dietary treatment, at 14 weeks of age, four rabbits from each group were selected randomly for the digestibility trial and individually housed in metabolic cages ($40 \times 50 \times 50$ cm) designed to separately collect feces and urine.

Each metabolic cage was fitted with a nipple-equipped automatic drinker and a manual feeder. The digestibility trial spanned 8 days, comprising a 3-day preliminary phase for adaptation followed by a 5-day collection phase to record daily feed intake as well as fecal and urinary outputs.

Fecal samples were collected daily at approximately 09:00 hr each morning before offering the daily feed, and then 10% of the total faeces output were dried at 60°C for 24 hr., and stored in polyethylene bags until the end of the experiment. All feces collected from each animal were pooled, and representative samples were ground for subsequent chemical analysis.

The apparent nutrient digestion coefficients were calculated using the total collection method, as outlined by [28]. The apparent nutrient digestion coefficients of the diets were determined according to the standard formula:

The apparent nutrient digestion coefficient = $(NI - NE) \times 100 / NI$, Where:

NI = Nutrient intake and NE = Nutrient excreted in faeces.

ME (Kcal / Kg diet DM) of the experimental diet was estimated using the following equation as described by [27]:

$$\text{ME (Kcal / Kg diet DM)} = (0.588 + 0.164 X) \times 239$$

Where; X=Dry matter (DM) digestion coefficient of the experimental diet

The percentages of total digestible nutrients (TDN) and digestible crude protein (DCP) were determined based on the method outlined by [29] as follow:

TDN: TDN = % digestible CP + % digestible CF + % digestible NFE + (% digestible EE x 2.25).

DCP: DCP = Digestibility Coefficient of CP x Crude Protein content of feed

Growth characteristics:

At the beginning of the trial, all rabbits were weighed before allotting them to their feeding treatments and during the experiment; rabbits were weighed weekly to determine the weekly body weight and daily body gain. The experimental diets were provided ad libitum each morning at approximately 9:00 AM.

To assess daily feed intake, both the amount of feed offered and the refusals were recorded daily. Feed conversion ratio (FCR) was calculated as the ratio of total feed consumed to total body weight gain. Mortality and growth performance were also evaluated. The relative growth rate of rabbits was determined following the method described by [30], using the following equation:

$$\text{Relative growth rate} = (W_2 - W_1) \times 100 / \frac{1}{2} (W_2 + W_1)$$

Where: W1= the initial body weight (gm), W2 = the final body weight (g).

Feed conversion ratio (FCR) was calculated as follow:

Feed consumed (gm) during certain period / Body weight gain (gm) for the same period.

Chemical analysis:

The chemical composition of the experimental diets and fecal samples was analyzed at the Research Centre of Water, Soil and food (International Accredited Centre, has ISO 17025), Faculty of Technology and Development, Zagazig University, Zagazig, Egypt.

Chemical analyses were conducted following the guidelines of the International Standard Methods (ISO). Moisture content was determined according to [31], total nitrogen and crude protein according to

[32], crude ash according to [33], Crude fat content was determined using the method outlined by [34], and crude fiber was according to the method described in [35]. Calcium content in the experimental diets was measured using an atomic absorption spectrophotometer (Perkin Elmar 2380, Serial No.13186, USA) following the standard analytical procedure. [36]. Phosphorus content was analyzed using a spectrophotometer (Manufacturer Labomed, Inc., USA, Model Spetro22, S.N 221101) according to [37].

Blood metabolites analysis:

At the end of digestibility trial (at 14 weeks of age), three rabbits from each treatment group were fasted for 12 hr., then weighed and subsequently slaughtered. Blood samples were collected from each rabbit into two clean, dried and non-heparinized tubes. Following centrifugation of blood samples at 3000 rpm for 15 minutes, the separated serum was preserved at -20°C in 5 ml polyethylene tubes until analysis for albumin (Alb), globulin (Glob), uric acid (UA), creatinine, alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), low-density lipoprotein (LDL), total protein (TP), total cholesterol (TC), high-density lipoprotein (HDL), very-low density lipoprotein (VLDL), triglycerides (TG), calcium (Ca) and phosphorus (P).

Blood metabolites were analyzed at one of the accredited medicinal analytical Labs.

Carcass traits:

Following blood collection and complete bleeding, the slaughtered rabbits were skinned and eviscerated. The hot carcass weight, including the head, was measured and recorded using the following formula: Carcass percentage (%) = Empty body weight with head x100/ Preslaughter weight. Edible offals; liver, heart, and kidneys were weighed for giblets percentage and dressing percentage as the following formulas:

$$\text{Giblets percentage (\%)} = \text{Giblets weight} \times 100 / \text{Preslaughter weight}$$

$$\text{Dressing percentage (\%)} = (\text{carcass weight} + \text{Giblets weight}) \times 100 / \text{Preslaughter weight}$$

Statistical analysis:

The experimental data were analyzed using analysis of variance (one way ANOVA) under a completely randomized design, following the method described by [38], and employing the Linear Model software developed by [39].

The statistical models that were used to investigate the effect of partial total substitution of yellow corn by sugar beet pulp or orange pulp on rabbit's growth performance parameters is as follow:

$$Y_{ijk} = \mu + T_i + e_{ijk}, \text{ Where;}$$

Y_{ijk} = any observation, μ = the overall mean, T_i = the effect of treatment ($i = 1, \dots$ and 7)

e_{ijk} = the experimental error.

The differences among treatment means were compared using Duncan's Multiple Range Test [40]. Percentage data were subjected to arcsine square root transformation to normalize the variance prior to statistical analysis.

Results

Apparent nutrients digestibility coefficients and feeding values of the experimental diets:

Table (2) show effect of dietary inclusion of increasing levels of dehydrated OP and SBP as substitutes for the YC on apparent digestibility coefficients of nutrients and nutritive values ($\bar{X} \pm SE$) of the experimental diets fed to growing NZW rabbits.

It is well known that nutrients digestibility is considered one of the basic measurements to determine the nutritive value of the experimental diets. Data in Table (2) revealed significant ($P < 0.05$ or 0.01) improvement in all nutrients digestibility coefficients of ingested diets, including; DM, OM, CP, EE, CF and NFE and feeding values as TDN and DCP by inclusion increasing levels of either dehydrated OP or SBP in the diet up to 22.5 % in replacement of YC up to 75 % when compared with those fed the control diet (free from OP and SBP). However, the improvement in nutrients digestion coefficients and feeding values were the best with rabbit groups fed 22.5 % dehydrated OP in substitution of 75 % of YC.

Effect of dietary inclusion of dehydrated OP and SBP on:

Growth characteristics

Table (3) show effect of dietary inclusion of increasing levels of dehydrated OP and SBP as substitutes for the YC on growth characteristics ($\bar{X} \pm SE$) of growing NZW rabbits.

The data in Table (3) show that body weight (BW) of rabbits at 14 weeks of age, weekly live body weight (WBW) and daily live body weight gain (DWG) at 6-10, 10-14 and 6-14 weeks of age had insignificant differences between rabbits fed increasing levels of dehydrated OP or SBP in the diet and those fed the control one (free from OP or SBP). Live body weight (LBW) at 14 weeks of age ranged between 2017.2-2052 gm and DWG ranged between 21.5- 22.1 gm for rabbits fed the treated diets compared to 2011gm and 21.1 gm, respectively for the control group. No significant differences in daily feed intake (DFI) were observed among the dietary treatment groups; it recorded from 6-14 weeks of age between 83.6 – 85.2 gm in the groups fed OP or SBP diets and 85.1 gm for

the control rabbits. Feed conversion ratio (FCR) values and relative growth rate (%) had similar trend of BWG and DFI, where they were not statistically differed between the dietary groups, which recorded from 6-14 weeks of age between 3.8 – 4.0 (gm feed / gm gain) and relative growth rate between 84.4 – 86.4 % for rabbits fed OP or SBP diets versus 4.0 and 84.5 %, respectively for rabbits fed the control diet. Mortality rate in experimental groups recorded zero % from 6-14 weeks of age.

Blood metabolites

Data in Table (4) indicate that incorporation of dehydrated OP or SBP in the diet at increasing levels up to 22.5 % in replacement of 75 % of YC, significantly increased ($P < 0.05$ or 0.01) levels of albumin (Alb), globulin (Glob), alkaline phosphatase (ALP) and calcium (Ca) in the blood serum of growing rabbits, while significantly decreased ($P < 0.05$ or 0.01) levels of uric acid (UA), creatinine, alanine aminotransferase (ALT), aspartate aminotransferase (AST) and low- density lipoprotein (LDL) compared to rabbits fed the control diet. Levels of total protein (TP), AL/ Glob ratio, ALT/ AST ratio, total cholesterol (TC), high density lipoprotein (HDL), very- low density lipoprotein (VLDL), triglycerides (TG) and phosphorus (P) had non- significant differences by the dietary treatments.

Carcass traits:

As shown in Table (5), carcass traits did not differ significantly ($P > 0.05$) among rabbits fed diets containing increasing levels (7.5, 15, and 22.5%) of dehydrated orange pulp (OP) or sugar beet pulp (SBP), replacing 25, 50, and 75% of yellow corn grain (YC), compared to those receiving the control diet. Carcass as % recorded in the dietary groups from 65.3 – 67.8 versus 65.7 for control rabbits and dressing % from 69.8- 72.3 versus 69.8 for control rabbits. Liver, heart and kidney as weight and % were not significantly differed by the dietary treatments.

Discussion

The enhanced nutrient digestibility observed in rabbits fed diets containing orange pulp (OP) may be attributed to its high fiber content, which slows down the passage rate and prolongs digesta retention time within the gastrointestinal tract, thereby promoting greater feed breakdown and improved nutrient utilization. According to [41], dietary fiber inclusion can also support digestive health and reduce the risk of diarrhea in animals. [42] attributed the improvement in nutrient digestibility following the addition of OP to the diet to the presence of essential oils in OP, which contain numerous bioactive compounds. These compounds act as enhancer for digestive enzymes, thereby increasing the nutrients digestibility.

The obtained results of the effect of dietary inclusion of dehydrated OP on nutrients digestibility in rabbits agree in somewhat with those reported by [43] who showed that inclusion of dried orange pulp (OP) in rabbits diet at level 19 % instead of barley grains either alone (OP diet) or plus 1 % natural zeolite (OPZ diet) significantly ($P < 0.05$) increased the digestibility coefficients of dry matter (DM), crude fiber (CF) and nitrogen free extract (NFE), with exception that digestion coefficients of organic matter (OM) and crude protein (CP) recorded insignificant ($P > 0.05$) differences with rabbits fed the OP diet compared to those fed the control diet. Nutritive value as total digestible nutrients (TDN) and digestible energy (DE) values, significantly ($P < 0.05$) increased with diets containing dried OP, zeolite, or both compared to the control diet. Digestible crude protein (DCP) was significantly ($P < 0.05$) the highest with the OPZ diet, but it was statistically similar among OP, Z, and control diets.

The obtained results of nutrients digestibility (ND) were in contrary of those reported by [44] who found insignificant differences in ND among the rabbits fed increasing levels of dried OP (1.5, 3.0 and 6 %) in the diet in substitution of 1.5, 3.0 and 6 %, respectively of barley grains (BG) and those fed the control diet (free from OP), with the exception of EE, the digestibility coefficient recorded the highest ($P \leq 0.05$) values in rabbits fed OP diets. The NFE digestibility was lowest in the group where 30% of barley grain (BG) was replaced with orange pulp (OP), compared to the control and other substitution levels; however, this reduction was not statistically significant. Similarly, metabolizable energy (ME), total digestible nutrients (TDN), and digestible crude protein (DCP) showed no significant differences among the control group and those fed diets with 7.5%, 15%, and 30% BG replacement by OP. The authors concluded that dietary inclusion of dried orange pulp up to 6 % in replacement up to 30 % of barley grains had no negative effects on nutrients digestibility coefficients.

The enhancement in nutrients digestibility of SBP diets in the current study is in line with the findings of [17] who showed that inclusion of dried SBP in replacement of YC up to 75% (equivalent to 27 % SBP) significant ($P < 0.05$ or 0.01) improved the digestibility coefficients of DM, CP, and NFE. Additionally, they noted a significant increase ($P < 0.01$) in the digestibility of organic matter (OM), whereas the digestibility of crude fiber (CF) declined significantly ($P < 0.01$) as the level of YC substitution with dried SBP increased to 100% (equivalent to 36% SBP). Values of total digestible nutrients (TDN) and digestible energy (DE) showed a significant increase ($P < 0.01$) with the progressive replacement of YC by SBP at levels of 25%, 50%, and 75%, compared to the control group. Also [45] noted that incorporating 20%

dried sugar beet pulp (SBP) into the diet enhanced the digestibility of dry matter, organic matter, gross energy, and all fiber fractions (NDF, ADF, and ADL), while reducing crude protein digestibility in comparison to the control diet. Meanwhile, the effect was more or less important depending on the origin of SBP ($P < 0.05$), especially on the digestibility of all fibrous fractions, being the highest digestibility when SBP is collected in summer.

On the other hand, [46] included dried SBP in the diet as a fibrous feed at 0 % (control), 25 and 50% of the whole diet. The authors indicated that the digestibility coefficients of dry matter (DM), organic matter (OM), crude protein (CP), and crude fiber (CF) were significantly reduced ($P \leq 0.01$) in diets containing 25% or 50% sugar beet pulp (SBP), with the reduction being more pronounced in the diet containing 50% SBP. However, EE digestibility values were ($P \leq 0.01$) higher with diets contained SBP, while NFE digestibility did not differed among groups. Nitrogen utilization and the nutritional value of the experimental diets, expressed as total digestible nutrients (TDN) and digestible crude protein (DCP) percentages, declined significantly ($P \leq 0.01$) with the increase in sugar beet pulp (SBP) replacement level up to 50%.

The variations between our results and those reported by other investigators for nutrients digestibility can be attributed to the variations in the diet ingredients and composition of SBP (contain molasses or not), number and type of the rabbits strain used in the experiment.

The statistically similar results of growth performance indices achieved by feeding rabbits increasing levels of dehydrated OP or SBP in the diet in comparison with feeding the yellow corn (YC) based diet can be attributed to that orange pulp (OP) and sugar beet pulp (SBP) contain high digestible energy and other nutritive components which can be comparable to YC. [47, 48] clarified that sugar beet pulp (SBP) is considered an energy concentrate feed, due to its content of highly digestible fibre, pectin and sugar and SBP contains approximately 50% of neutral detergent fibre (NDF). Also, [49] showed that sugar beet pulp consists of about 80% carbohydrates (on dry matter basis) and glucose is the main constituent of the monosaccharides besides other carbohydrate components such as; cellulose, arabinose sucrose and uronic acid (both from pectin). These components constitute about 60-70% of the dry matter of sugar beet pulp. Besides carbohydrates, SBP contains about 7.0-13.2% of protein and low levels of minerals, lignin and lipids. The lignin content of sugar beet pulp is low, account 1.8-3.4%. Concerning orange pulp (OP), [50] claimed that citrus pulp contains high energy percentage due to its highly fermentable

carbohydrates. Citrus pulp contains about 82 % total digestible nutrients (TDN). [5] found that dried orange pulp (OP) contained higher levels of crude protein (CP), ether extract (EE), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, and digestible crude protein (DCP) compared to yellow corn (YC).

The statistically similar results of final body weight, average daily weight gains, daily feed intake and feed conversion ratio between rabbits fed diets containing orange pulp (OP) or sugar beet pulp (SBP) and those on the control diet indicates that substituting up to 75% of yellow corn (YC) with 22.5% dehydrated OP or SBP has no detrimental impact on rabbit growth performance. The current results are in agreement with those reported by [51] who recorded insignificant ($P > 0.05$) differences in the final live body weight, total feed consumption, and feed conversion ratio of rabbits fed increasing levels (8, 16, 24 and 32 %) of dried sweet orange pulp (SOP) in the diet up to 32 % in replacement up to 100 % of maize. However, growth performance was optimum by feeding 24 % SOP diet in replacement of 75 % of maize. Similarly, [52] found that replacing maize with sweet orange peel meal (SOPM) in rabbit diets at levels up to 40% resulted in no significant differences ($P > 0.05$) in final live weight (g) or daily body weight gain (g/day).

In the contrary with our results, [53] showed that rabbits groups which were fed 10 and 20 % dried orange pulp (DOP) in replacement of maize had equal final body weight (1770gm), but higher ($P < 0.05$) than those fed the control diet (1770gm) or 30 % DOP diet (1500gm). Feed intake significantly ($P < 0.05$) decreased with 30 % DOP in the diet, but feed conversion ratio (FCR) was improved, where, recorded 2.7 versus 2.91, 3.11 and 3.58 for groups fed the control, 10 and 20 % DOP diets, respectively. The authors interpreted the decrease in feed intake with 30 % DOP to the astringent taste of the essential oils present in DCP which reduced feed intake with increasing level of DOP in the diet. In another study, [54] showed that inclusion of dehydrated OP in the diet of rabbits at levels, 0, 10, 20 and 30 % in replacement of the same percentages of commercial feed concentrate recorded higher weight gain ($p < 0.05$) with 20% substitution, along with a better feed conversion ratio. The authors stated that dehydrated orange pulp can replace up to 30% of the commercial feed concentrate without any adverse effects on growth performance traits of growing rabbits. [3] substituted wheat offal with dried citrus pulp (DCP) in the diet of growing rabbits at levels 0, 10, 20 and 30% (weight/weight) respectively. The results revealed significant ($P < 0.01$) differences in the final live body weight, total weight gain, average weight gain, metabolic weight gain and growth rate with rabbits fed

DCP diets. The growth rate was decreased with increasing level of DCP in the diets. The lowest feed conversion ratio was obtained with 0% level of DCP inclusion (control) and 10% dietary inclusion of DCP improved growth performance of rabbits.

Concerning the effect of feeding sugar beet pulp (SBP), [17] found in contrary with our results that feeding rabbits diets containing 9, 18, 27 and 36% dehydrated SBP in replacement of 25, 50, 75 and 100% of yellow corn grains (YC) in the control diet resulted in significant ($p < 0.01$) increase in the live body weight at 14 weeks of age, live body weight gain (BWG) and feed conversion ratio (FC) and insignificant increase in daily feed intake (FI) from 6-14 weeks of age with increasing SBP level in the diets up to 27% (equal replacement of 75 % of YC).

In another study, [46] reported that both total weight gain and average daily gain significantly declined ($P \leq 0.01$) as the inclusion level of sugar beet pulp (SBP) in the diet increased up to 50%. However, the feed conversion ratio improved significantly ($P \leq 0.05$) in groups receiving SBP-based diets, with the most favorable value observed at the 25% SBP inclusion level.

The variations between our results of growth performance indices and those reported by other investigators may be due to the variation in the number and type of rabbits strain used in the experiment, method of processing of citrus pulp and sugar beet pulp and the ingredients and chemical composition of the experimental diets.

Results of the current study and the results of the previous researchers indicate that dehydrated orange pulp and sugar beet pulp are considered good and low-cost energy feed source and can substitute up to 75 % of maize without any negative effects on growth performance traits of growing rabbits.

Determination of blood metabolites is very important to assess the effect of feeding the experimental diet on health status of an animal.

In the current study, the increase levels of Alb and Glob in the blood serum of rabbits fed OP and SBP diets compared to those fed the control diet indicate to the increase immune capacity of rabbits by the dietary treatments, because antibodies are made from Alb and Glob which transport proteins to steroid and thyroid hormones and play an important role in the natural immunity against infection. Serum AST and ALT are indicators of liver function and health. Decreased AST and ALT concentration in serum of rabbits fed OP or SBP diets compared to the control rabbits indicate to the normal liver function. Also, decreased levels of creatinine and uric acid demonstrate the normal kidney function. Alkaline phosphatase (ALP) is essential for bone development, as it promotes the

incorporation of calcium and phosphate into the bone matrix. More than 80% of serum alkaline phosphatase (ALP) is derived from hepatic and bone sources, while the intestine contributes only a small proportion. Alkaline phosphatase (ALP) levels in the blood can be elevated due to various conditions, including liver diseases and bone disorders. While ALP is found in many tissues, higher concentrations are particularly associated with the liver, bile ducts, and bones. Elevated ALP can indicate to liver disease like biliary obstruction, cirrhosis, hepatitis, or liver cancer [55, 56]. In this study, rabbits receiving diets containing orange pulp (OP) and sugar beet pulp (SBP) exhibited elevated serum ALP levels compared to those in the control group. However, ALP concentrations stayed within the established reference range for clinically healthy rabbits, according to [57, 58]. The improvement in the biochemical blood indices of rabbits fed OP diets which reflected on the better liver and kidney functions can be attributed to the bioactive compounds in orange pulp (OP) as reported by many researchers who reported that orange peels contain essential oils, flavonoids, steroids, terpenoids, alkanes, Vet. C. These compounds possess beneficial pharmacological properties which act as antioxidants, antimicrobial, anticancer, antiinflammation and have immune stimulating activity [12, 14, 59-63]. The significant decrease ($P < 0.05$) in LDL level with non-significant differences in the levels of TC, HDL, VLDL and TG demonstrate good cholesterol levels in the blood and normal health status of heart of rabbits fed OP or SBP diets. [64] demonstrated that cholesterol is transported through the bloodstream by protein carriers known as lipoproteins. Three main types of lipoproteins-low-density lipoproteins (LDL), very-low-density lipoproteins (VLDL), and high-density lipoproteins (HDL)-are responsible for carrying cholesterol and triglycerides in the blood. The combination of high levels of triglycerides (TG) with low HDL and/or high LDL and VLDL cholesterol levels can cause health problems in heart and body arteries. The beneficial effect of feeding SBP diets on liver and kidney functions and blood biochemistry can be attributed to that SBP contain flavonoids, and polyphenols, especially phenolic acids which act as antioxidants and high content of arabinans that could be used as a raw material for the production of arabinose or its derivative, L-arabitol, both of which possess notable health-promoting properties such as a low glycemic index and prebiotic effects [65].

In the current study, the dietary inclusion of dehydrated OP and SBP increased serum Ca concentration ($P < 0.05$), because dehydrated OP and SBP are good sources of Ca [66]. No significant differences were detected in serum phosphorous levels of rabbits fed treated diets and those fed the control

diet. The results of the present study concerning blood metabolites differed from those mentioned by [43] who found non-significant effect of feeding a diet containing 19 % dried orange pulp (OP) on plasma concentrations of total protein, albumin, globulin, AST, ALT, and total lipids. However, the dietary treatment significantly ($P < 0.05$) lowered concentrations of cholesterol, LDL, and triglycerides, and increased level of HDL compared with those fed the control diet. [2] recorded also insignificant differences in levels of blood serum AST, TP, Glob, Glu, TC and P, while levels of Ca, Alb, Alb : Glob ratio and ALP were significantly ($P < 0.05$) increased by dietary inclusion of different levels of dried OP (7, 14 and 21 %) compared to those fed the control diet (free from OP).

Concerning the effect of feeding sugar beet pulp (SBP) meal on blood biochemistry, [67] found that feeding either 20 or 40 % dried SBP in the diet of rabbits had no significant effect on blood serum levels of TP, Alb, Glob, ALT, creatinine, Urea- N, and triglycerides. However, the albumin/globulin (Alb/Glob) ratio and aspartate aminotransferase (AST) levels showed a significant increase ($P < 0.05$ or 0.01), while level of total cholesterol was significantly decreased ($P < 0.01$) by the dietary treatments compared with those fed the control diet. [68] demonstrated that levels of blood serum TP, Alb, Glob, Glucose, AST, ATP and ASP / ATP ratio were not affected significantly by dietary inclusion of dried SBP up to 25 % instead of 100 % of berseem hay and about 67.7 % of maize with exception that triglycerides was significantly increased ($P < 0.05$) by the dietary treatment compared with rabbits fed the control diet.

The insignificant differences in carcass, dressing and internal organs (liver, kidneys and heart) as weight or percentage % among rabbit groups fed dehydrated OP or SBP were in agreement with results of growth performance (Table 3) which indicated that the dietary treatments had no significant impact on the body weight or weight gain of the rabbits. This result demonstrate that dietary inclusion of increasing levels of either dehydrated orange pulp (OP) or sugar beet pulp (SBP) up to 22.5 % to replace up to 75 % of yellow corn grains had no adverse effects on carcass traits of growing rabbits. The insignificant differences obtained for carcass traits of the rabbits among groups demonstrate that the incorporation of increasing levels of dehydrated orange pulp or sugar beet pulp into rabbit diet as a replacement for maize up to 75 % did not interfere with the utilization and conversion of feed nutrients into meat and other associated meat tissue constituents. Moreover, the lack of significant differences ($p > 0.05$) in kidney, heart, and liver weights implies that increasing dietary levels of

orange pulp or sugar beet pulp did not adversely affect the physiological functions of these organs in rabbits.

The obtained results are similar with those reported by [54] who showed no significant effects on carcass quality of growing rabbits (carcass yield, thighs, shoulders, rib and loin %) fed increasing levels (10, 20 and 30 %) of orange pulp (peels+ membranes + seeds) up to 30 % instead of commercial feed concentrate. Also, [2] revealed that rabbits fed in the diet increasing citrus pulp level (7, 14 and 21 %) up to 21 % exhibited insignificant differences in hot carcass weight, dressing yield % and internal organs % of live weight compared with those fed the control diet. Similarly, [44] indicated that substituting barley with up to 30% dried orange pulp did not result in significant alterations in carcass characteristics of growing rabbits when compared to those on the control diet. In another study, [51] found that rabbits fed diets containing 24% and 32% sweet orange pulp meal (SOPM) had significantly ($P<0.05$) higher dressing percentages than those fed diets without SOPM. Additionally, thigh weights were significantly ($P<0.05$) greater in rabbits receiving SOPM at 16%, 24%, and 32% levels, replacing 25%, 50%, 75%, and 100% of maize, respectively, compared to those fed a 32% maize-based diet. However, no significant differences ($P<0.05$) were observed across the groups regarding slaughter weight, carcass yield, or carcass length.

In another study on the effect of feeding SBP on carcass quality of rabbits, [17] reported that carcass traits (carcass, dressing and giblets as weight and %) were not significantly affected by dietary inclusion of increasing level of dehydrated SBP up to 36 % in replacement of 100 % of YCG. Also, [69] clarified that carcass weight (%), edible organs (%) and liver weight % insignificantly influenced by dietary inclusion of increasing level of dehydrated SBP up to 25 % in the diet in replacement of 100 % of berseem hay. However, kidney and heart percentages were significantly reduced ($P < 0.05$) by the dietary treatments. Furthermore, the highest ($P < 0.05$) carcass yield was observed in rabbits fed diets containing 25% and 50% SBP, compared to those fed the control diet or higher SBP levels (75% and 100%).

Conclusion

Dehydrated orange pulp and sugar beet pulp represent cost-effective and efficient alternative energy sources that can be incorporated into the diets of growing rabbits at levels up to 22.5% as substitutes for yellow corn.

It is recommended to substitute 75 % of the yellow corn grains in the growing rabbit diet by 22.5 % of dehydrated orange pulp or sugar beet pulp for decreasing the cost of feeding and improve nutrient utilization and health status of growing fattening rabbits.

Author contributions

Hassan M. El-Kelawy, Mostafa I. Abd El- Rahim, Hassan I. Ibrahim, Nermin A. Basha, Yaser S. Rizk, Mona A. Ragab and Ramadan M. Abo El-Haded were involved in conceptualization, data curation, formal analysis, investigation, methodology, resources, validation, visualization, roles/writing of the original draft, writing review and editing.

Conflict of interest:

We the authors declare that they have no conflict of interest.

We also confirm that the paper is original and is not being considered for peer-reviewed publication elsewhere and imply that we have approved the paper for release and are in agreement with its content.

Data availability

All the data generated or analyzed during this study are included in this published article.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

TABLE 1. Components and chemical composition of the experimental diets formulated with varying inclusion levels of dehydrated orange pulp (OP) and sugar beet pulp (SBP)

Ingredients (%)	The experimental diets						
	Control	7.5 % OP	15 % OP	22.5 % OP	7.5 % SBP	15 % SBP	22.5 % SBP
Yellow corn grains	30	22.5	15	7.5	22.5	15	7.5
Dehydrated OP or SBP	—	7.5	15	22.5	7.5	15	22.5
Soybean meal (44% CP)	17	17	17	17	17	17	17
Alfalfa hay	26	26	26	26	26	26	26
Wheat bran	15	15	15	15	15	15	15
Barley grains	10	10	10	10	10	10	10
Dicalcium phosphate	1	1	1	1	1	1	1
Premix	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Table salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5
DL-methionine	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Anti- fungal powder	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chemical composition (%)							
Moisture	10.01	8.10	8.79	8.42	8.31	7.51	7.67
DM	89.99	91.90	91.21	91.58	91.69	92.49	92.33
ME (kcal / kg)**	2307	2419	2581	2694	2439	2529	2591
OM	84.41	84.88	84.66	85.68	84.24	84.66	83.81
CP	15.90	15.30	15.00	14.80	15.30	14.70	14.40
EE	2.87	1.49	1.99	1.91	1.67	1.73	1.72
CF	8.07	9.38	9.47	10.30	9.37	10.06	10.71
Ash	5.58	7.02	6.55	5.90	7.45	7.83	8.52
NFE	57.57	58.71	58.20	58.67	57.90	58.17	56.98
Calcium (Ca)	0.65	0.70	0.75	0.79	0.66	0.68	0.69
Phosphorus (P)	0.61	0.60	0.59	0.58	0.60	0.60	0.59

* Each 3 kilograms of premix contains: Vit. A 12000000 IU, Vit. D₃ 1500000 IU, Vit. E 50 gm, Vit. K₃ 2 gm, Vit. B₁ 2 gm, Vit. B₂ 6 gm, Vit. B₁₂ 0.01 gm, Chol.Chlod 1200 gm, Biotin 0.2 gm, Niacin 50 gm, Pantothenic acid 20 gm, Folic acid 5 gm, Magnesium 400 gm, Copper 5 gm, Iodine 0.75 gm, Selenium 0.1 gm, Iron 75 gm, Manganese 30 gm, Zinc 70 gm. **It was determined according to [27].

TABLE 2. Effect of dietary inclusion of increasing levels of dehydrated OP and SBP as substitutes for the YC on apparent nutrients digestibility coefficients and nutritive values ($\bar{X} \pm SE$)* of the experimental diets.7

Nutrient	Dietary groups							Sig
	Control	7.5 %OP	15%OP	22.5%OP	7.5%SBP	15%SBP	22.5%SPB	
Nutrients digestion coefficients (%)								
DM	55.27 ^e ±0.13	58.13 ^{de} ±1.99	62.26 ^{ade} ±0.96	65.15 ^a ±1.02	58.64 ^{cde} ±0.69	60.95 ^{bcd} ±0.78	62.54 ^{ab} ±1.72	**
OM	57.18 ^c ±0.11	62.85 ^b ±1.55	64.22 ^b ±0.79	67.45 ^a ±0.85	62.84 ^b ±0.53	64.23 ^b ±0.6	64.14 ^b ±1.35	**
CP	60.88 ^e ±0.40	65.30 ^b ±1.62	66.72 ^b ±0.7	71.30 ^a ±0.9	65.56 ^b ±0.49	66.54 ^b ±0.50	67.21 ^b ±1.17	**
EE	68.44 ^e ±0.3	71.72 ^d ±0.9	69.62 ^e ±0.7	79.80 ^a ±0.5	77.57 ^b ±0.3	74.35 ^b ±0.3	77.53 ^b ±0.4	**
CF	41.40 ^b ±0.3	45.03 ^b ±3.4	43.77 ^b ±1.7	52.34 ^a ±2.1	42.66 ^b ±0.6	44.68 ^c ±1.4	45.73 ^b ±2.4	**
NFE	60.00 ^d ±0.2	64.93 ^{bc} ±1.2	69.04 ^{ab} ±0.7	70.01 ^a ±0.7	68.49 ^{ab} ±0.6	66.66 ^{bc} ±0.6	68.96 ^{ab} ±1.2	**
Nutritive values of the experimental diets								
DCP	9.68 ^b ±0.1	9.99 ^{ab} ±0.3	10.00 ^b ±0.1	10.55 ^a ±0.2	10.03 ^{ab} ±0.1	9.78 ^b ±0.1	9.68 ^b ±0.2	*
TDN	50.09 ^d ±0.1	54.73 ^{bc} ±1.3	57.46 ^{bc} ±0.6	60.44 ^a ±0.7	56.60 ^{bc} ±0.4	55.94 ^{bc} ±0.5	56.87 ^{bc} ±1.2	**

SE = Standard Error of Means. ** a, b, c = Means in the same row with different superscript significantly differ ($P < 0.01$).

* Means in the same row with different superscript significantly differ ($P < 0.05$).

TABLE 3. Effect of dietary inclusion of increasing levels of dehydrated OP and SBP as substitutes for the YC on growth performance traits ($\bar{X} \pm \text{SE}$) of growing NZW rabbits

Parameters	The dietary groups							Sig
	Control	7.5% OP	15% OP	22.5% OP	7.5% SBP	15% SBP	22.5% SBI	
Live body weight (gm) at :								
6 weeks	816.7±3.5	814.4±16.7	817.8±19.3	820.0±23.7	816.1±8.7	815.0±45.1	820.6±34.1	NS
10 weeks	1495.0±19.3	1471.1±14.4	1494.4±30.2	1467.8±17.3	1462.8±30.7	1546.1±2.0	1522.8±39.5	NS
14 weeks	2011.1±34.5	2052.2±46.4	2024.4±36.8	2017.2±27.9	2051.7±51.7	2017.8±18.5	2033.9±31.3	NS
Weekly body weight gain (gm) from:								
6-10 weeks	678.3±22.6	656.7±26.4	676.7±26.1	647.8±9.2	646.7±35.8	731.1±45.3	702.2±23.6	NS
10-14 weeks	516.1±48.7	581.1±44.5	530.0 ±6.7	549.4±44.9	588.9±36.7	471.7±17.3	511.1±50.7	NS
6-14 weeks	1194.4±33.2	1237.8±63.0	1206.7±32.2	1197.2±49.7	1235.6±60.1	1202.8±61.4	1213.3±29.9	NS
Daily body weight gain (gm) from:								
6-10 weeks	24.3±0.8	23.5±0.9	24.2±0.9	23.2±0.3	23.1±1.3	26.1±1.6	25.1±0.8	NS
10-14 weeks	18.4±1.7	20.8±1.6	18.9±0.2	19.6±1.6	21.0±1.3	16.9±0.6	18.3±1.81	NS
6-14 weeks	21.3±0.6	22.1±1.1	21.5±0.6	21.4±0.9	22.1±1.1	21.5±1.1	21.7±0.5	NS
Daily feed intake (gm) from:								
6-10 weeks	68.6±0.3	68.4±0.6	69.9±0.6	69.4±0.21	66.6±1.7	70.1±0.4	68.3±0.3	NS
10-14 weeks	101.5±1.9	98.8±0.3	100.2±1.3	100.9±1.8	99.6±1.8	100.7±0.7	102.1±1.0	NS
6-14 weeks	85.1±0.9	83.6±0.2	85.1±0.3	85.1±0.8	83.1±1.3	85.4±0.3	85.2±0.5	NS
Feed conversion ratio (gm feed / gm gain) From:								
6-10 weeks	2.8±0.1	2.9±0.1	2.9±0.1	3.0±0.0	2.9±0.1	2.9±0.1	3.0±0.0	NS
10-14 weeks	5.6±0.6	4.8±0.4	5.3±0.1	5.2±0.4	4.8±0.4	5.3±0.1	5.2±0.4	NS
6-14 weeks	4.0±0.2	3.8±0.2	4.0±0.1	4.0±0.2	3.8±0.2	4.0±0.1	4.0±0.1	NS
Relative growth rate (%)								
6-10 weeks	58.68 ±5.54	52.56±3.82	58.52±5.55	56.63±2.6	56.76±4.32	61.93±5.45	59.93±4.62	NS
10-14 weeks	29.44±2.55	32.99±2.05	30.12±3.21	31.53±3.05	33.51±1.9	26.47±2.12	28.74±2.59	NS
6-14 weeks	84.48±6.31	86.36±4.65	84.91±6.73	84.39±4.58	86.17±4.16	84.92±4.84	85.01±5.59	NS
Mortality % from:								
6-14 weeks	Zero	Zero	Zero	Zero	Zero	Zero	Zero	NS
SE = Standard error of means. NS= Not significant. The growth experiment lasted 56 days.								

SE = Standard error of means. NS= Not significant. The growth experiment lasted 56 days.

TABLE 4. Effect dietary inclusion of increasing levels of dehydrated OP and SBP as substitutes for the YC on some blood metabolites ($\bar{X} \pm \text{SE}$).

Items	Dietary groups							Sig.
	Control	7.5%OP	15%OP	22.5%OP	7.5%SBP	15%SBP	22.5%SPB	
TP (g / dl)	5.96±0.16	7.42±0.13	7.27±0.20	6.08±0.06	6.81±0.31	6.72±0.14	7.13±0.13	NS
Alb (g / dl)	3.35 ^b ±0.11	4.16 ^a ±0.15	4.11 ^a ±0.16	3.76 ^{ab} ±0.22	3.91 ^a ±0.09	3.82 ^a ±0.12	4.02 ^a ±0.12	*
Glob (g/ dl)	2.61 ^b ±0.03	3.26 ^a ±0.21	3.16 ^a ±0.04	2.82 ^{ab} ±0.12	2.90 ^a ±0.26	2.90 ^a ±0.03	3.11 ^a ±0.13	**
Alb/Glob	1.27±0.03	1.29±0.12	1.30±0.04	1.62±0.66	1.35±0.11	1.32±0.04	1.30±0.08	NS
ALT (U/L)	55.02 ^a ±1.08	42.67 ^c ±0.61	45.17 ^c ±1.12	48.56 ^b ±1.21	47.08 ^{bc} ±1.38	48.22 ^{bc} ±1.63	46.36 ^{bc} ±1.06	**
AST (U/L)	38.49 ^a ±1.24	28.52 ^c ±0.29	29.14 ^c ±0.9	34.43 ^b ±0.54	30.81 ^{bc} ±2.15	31.98 ^{bc} ±2.07	30.57 ^{bc} ±0.87	**
ALT/AST	1.43±0.07	1.5±0.01	1.55±0.05	1.41±0.02	1.54±0.07	1.52±0.12	1.52±0.03	NS
ALP (U/L)	55.77 ^f ±0.96	87.66 ^a ±1.77	84.9 ^{ab} ±0.77	61.06 ^e ±1.37	74.54 ^c ±0.61	68.19 ^d ±1.65	81.11 ^b ±1.24	**
UA (mg/dl)	1.81 ^a ±0.10	1.04 ^e ±0.04	1.26 ^d ±0.04	1.72 ^a ±0.02	1.45 ^{bc} ±0.03	1.56 ^b ±0.02	1.35±0.03	*
Ca (mmol/L)	1.85 ^{cd} ±0.13	2.51 ^{ab} ±0.18	1.46 ^d ±0.20	2.25 ^{bc} ±0.06	2.06 ^{bc} ±0.08	2.24 ^{bc} ±0.16	2.73 ^a ±0.13	**
P (mmol/L)	1.10±0.02	1.40±0.09	1.13±0.06	1.18±0.04	1.14±0.08	1.16±0.07	1.17±0.04	NS
Cre (mg/dl)	1.45 ^a ±0.05	0.92 ^c ±0.05	0.99 ^c ±0.15	1.28 ^{ab} ±0.09	1.09 ^{bc} ±0.1	1.12 ^{bc} ±0.08	1.09 ^{bc} ±0.02	**
TC	94.66±1.1	80.99±0.98	84.83±4.17	90.61±2.17	88.95±1.6	89.4±1.63	88.67±1.42	NS
HDL	45.87±0.79	53.69±0.79	51.23±0.98	46.55±2.46	48.28±2.52	48.02±2.07	49.8±2.77	NS
LDL	30.83 ^a ±0.24	12.5 ^c ±0.58	18.41 ^{bc} ±3.73	27.55 ^a ±2.17	24.85 ^{ab} ±1.58	25.43 ^{ab} ±3.11	23.49 ^{ab} ±4.10	**
VLDL	17.95±0.45	14.79±0.16	15.19±0.29	16.51±0.28	15.82±0.34	15.95±1.02	15.39±0.10	NS
TG	89.76±2.28	73.97±0.82	75.94±1.47	82.57±1.39	79.08±1.67	79.77±5.07	76.95±0.52	NS

SE = Standard Error of Means. *a, b, c = Means in the same row with different superscript significantly differ ($P < 0.05$). **= significantly differ ($P < 0.01$). NS= Not significant.

TP: total protein; Alb: Albumin; Glob: globulin; UA: uric acid; ALT: alanine aminotransferase; AST: aspartate aminotransferase; ALP: alkaline phosphatase; Cre: Creatinine; TC: total cholesterol; Ca: calcium; P: phosphorus; LDL: low density lipoprotein; VLDL: very-low density lipoprotein; TG: triglycerides.

TABLE 5. Effect of dietary inclusion of increasing levels of dehydrated OP and SBP as substitutes for the YC on carcass traits of growing rabbits ($\bar{X} \pm SE$).

Items	Dietary groups							Sig
	Control	7.5% OP	15% OP	22.5% OP	7.5%SBP	15% SBP	22.5% SPB	
Pre slaughter weight (g)	2160 $\pm$ 42.5	2141.7 $\pm$ 58.1	2065 $\pm$ 21.8	2130.7 $\pm$ 64.7	2113.3 $\pm$ 41.0	2170 $\pm$ 52.2	2166.7 $\pm$ 44.4	NS
Carcass weight (g)	1418.3 $\pm$ 25.9	1410.0 $\pm$ 42.5	1348.3 $\pm$ 22.4	1405.0 $\pm$ 50	1433.3 $\pm$ 30.9	1471.7 $\pm$ 53.6	1453.3 $\pm$ 23.5	NS
Carcass percent (%)	65.7 $\pm$ 0.4	65.8 $\pm$ 0.4	65.3 $\pm$ 0.5	66.0 $\pm$ 0.5	67.8 $\pm$ 1.5	67.8 $\pm$ 1.4	67.1 $\pm$ 0.4	NS
Liver weight (g)	69.2 $\pm$ 6.47	66.42 $\pm$ 2.68	80 $\pm$ 7.66	64.15 $\pm$ 7.07	79 $\pm$ 6.56	69.77 $\pm$ 6.97	66.47 $\pm$ 3.36	NS
Liver percent (%)	3.21 $\pm$ 0.32	3.12 $\pm$ 0.23	3.88 $\pm$ 0.38	3.01 $\pm$ 0.31	3.75 $\pm$ 0.37	3.2 $\pm$ 0.25	3.08 $\pm$ 0.21	NS
Heart weight (g)	12.42 $\pm$ 1.73	9 $\pm$ 0.14	10.6 $\pm$ 1.08	9.88 $\pm$ 1.06	10.38 $\pm$ 0.76	10.42 $\pm$ 0.96	8.62 $\pm$ 0.25	NS
Heart percent (%)	0.57 $\pm$ 0.07	0.42 $\pm$ 0.02	0.51 $\pm$ 0.05	0.46 $\pm$ 0.03	0.49 $\pm$ 0.04	0.48 $\pm$ 0.05	0.4 $\pm$ 0.004	NS
Kidney weight (g)	6.75 $\pm$ 0.92	4.58 $\pm$ 0.22	6.07 $\pm$ 0.78	4.30 $\pm$ 0.12	5.62 $\pm$ 0.69	6.48 $\pm$ 0.53	4.92 $\pm$ 0.3	NS
Kidney percent (%)	0.31 $\pm$ 0.05	0.21 $\pm$ 0.01	0.29 $\pm$ 0.03	0.20 $\pm$ 0.01	0.27 $\pm$ 0.031	0.3 $\pm$ 0.03	0.23 $\pm$ 0.01	NS
Giblets weight (g)	88.33 $\pm$ 8.33	80 $\pm$ 2.89	96.67 $\pm$ 8.33	78.33 $\pm$ 7.26	95 $\pm$ 7.64	86.67 $\pm$ 6.01	80 $\pm$ 2.89	NS
Giblets percent (%)	4.10 $\pm$ 0.41	3.75 $\pm$ 0.26	4.68 $\pm$ 0.4	3.68 $\pm$ 0.28	4.51 $\pm$ 0.43	3.99 $\pm$ 0.19	3.7 $\pm$ 0.2	NS
Dressing weight (g)	1506.7 $\pm$ 23.3	1490.0 $\pm$ 41.4	1445.0 $\pm$ 21.8	1483.3 $\pm$ 55.9	1528.3 $\pm$ 9.3	1558.3 $\pm$ 39.3	1533.3 $\pm$ 20.9	NS
Dressing percent (%)	69.8 $\pm$ 0.3	69.6 $\pm$ 0.4	70.0 $\pm$ 0.3	69.6 $\pm$ 0.8	72.3 $\pm$ 1.8	71.8 $\pm$ 1.5	70.8 $\pm$ 0.5	NS

NS= Not significant; SE= Standard Error of Means; OP = Orange pulp; SBP= Sugar beet pulp; YCG= Yellow corn grains; Giblets weight= weights of liver + kidney + heart. Carcass % = Empty weight with head / Preslaughter weight X 100; Dressing percentage % = Carcass weight + Giblets weight / Preslaughter weight X 100; Giblets % = Giblets weight / Preslaughter weight X 100; Liver %= Liver weight / Preslaughter weight X 100.

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تقييم لب البرتقال وتفل بنجر السكر المجفف كمصادر طاقة بديلة للذرة الصفراء في علائق الأرانب

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الملخص

هدفت الدراسة الحالية إلى تقييم تأثير إدخال مستويات متزايدة من لب البرتقال وتفل البنجر المجفف بدلاً من حبوب الذرة الصفراء في الغذاء كمصدر للطاقة على هضم العناصر الغذائية وخصائص النمو ونواتج تمثيل الدم في الأرانب النامية. استخدم لهذه الدراسة عدد 63 أرنب نيوزيلندي أبيض مغطوم بمتوسط وزن 817.2 + 21.6 جرام ، قُسمت الأرانب إلى سبع مجموعات تجريبية، كل مجموعة تضم 9 أرانب (3 مكررات لكل مجموعة). غُذيت كل مجموعة على واحد من سبعة أغذية، الغذاء الأول (الكنترول) عبارة عن غذاء قاعدي (كنترول) يحتوي على حبوب الذرة الصفراء بنسبة 30 % كمصدر رئيسي للطاقة ، بينما في الغذاء الثاني والثالث والرابع تم استبدال 25% ، 50% ، 75% من حبوب الذرة الصفراء في الغذاء القاعدي (الكنترول) بنسب 7.5 ، 15 ، 22.5 % على التوالي بلب البرتقال المجفف (OP) ، وفي الغذاء الخامس والسادس والسابع تم استبدال 25% ، 50% ، 75% من حبوب الذرة الصفراء في الغذاء القاعدي، على التوالي، بتفل بنجر السكر المجفف (SBP) بنفس نسب لب البرتقال.

أسفرت نتائج البحث عن عدم تأثير متوسط وزن الجسم الحي وعائد وزن الجسم ، وكمية العلف المستهلكة، ومعدل التحويل الغذائي ومعدل النمو النسبي من عمر 6 إلى 14 أسبوعاً معنوياً ($P > 0.05$) باستبدال مستويات متزايدة من حبوب الذرة في الغذاء بلب البرتقال أو تفل بنجر السكر المجفف حتى 75% وهذا يعادل 22.5 % لكل منهما.

حدث تحسين معنوي ($P \leq 0.01$) في جميع معاملات هضم العناصر الغذائية ، في المادة الجافة (DM) والمادة العضوية (OM) والبروتين الخام (CP) ومستخلص الإثير (EE) والألياف الخام (CF) والمستخلص الخالي من الأزوت (NFE) وكذلك القيمة الغذائية في صورة DCP ، TDN .

حدث تحسين معنوي في المكونات البيوكيميائية للدم ، حيث ارتفعت مستويات الألبومين (Alb) والجلوبيولين (Glob) والفوسفاتيز القلوي (ALP) والكالسيوم (Ca) في مصل دم الأرانب النامية بصورة معنوية ($P \leq 0.01$ or 0.05) ، بينما انخفضت مستويات حمض اليوريك (UA) والكرياتينين والأنين أمينوترانسفيراز (ALT) وأسبارتات أمينوترانسفيراز (AST) والبروتين الدهني منخفض الكثافة (LDL) معنوياً ($P \leq 0.01$ or 0.05) من خلال إدخال مستويات متزايدة من لب البرتقال أو تفل بنجر السكر في الغذاء مقارنة بالأرانب التي تغذت على غذاء الكنترول. ظهور اختلافات غير معنوية في مستويات البروتين الكلي (TP) ونسبة Alb / Glob ونسبة ALT / AST والكوليسترول الكلي (TC) والبروتين الدهني عالي الكثافة (HDL) والبروتين الدهني منخفض الكثافة جداً (VLDL) والدهون الثلاثية (TG) والفوسفور (P) بالمعاملات الغذائية. برغم وجود فروق معنوية في بعض المؤشرات البيوكيميائية في مصل دم الأرانب التي تغذت على الأغذية المضاف إليها مستويات متزايدة من لب البرتقال أو تفل بنجر السكر مقارنة بتلك التي تغذت على غذاء الكنترول، إلا أن جميع القيم المقدرة كانت في حدود المستوي الفسيولوجي الطبيعي للأرانب السليمة صحياً.

نستنتج من الدراسة إلى أنه يمكن استخدام لب البرتقال وتفل بنجر السكر المجفف كمصادر جيدة وإقتصادية للطاقة ووينصح بإدخالها في غذاء الأرانب النامية بنسبة حتى 22.5 % لكي تستبدل حتى 75 % من حبوب الذرة الصفراء لخفض تكلفة التغذية وتحسين الاستفادة الغذائية والحالة الصحية للأرانب.

الكلمات الدالة: لب البرتقال، تفل بنجر السكر، هضم العناصر الغذائية، الذرة الصفراء، الدم، الصحة، جودة الذبيحة، الأرانب.