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# Dehydrated tomato pulp in rabbit feed: effects of incorporation rate on growth performance, carcass yield, meat quality and economic efficiency

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**ABSTRACT.** The economic value of animal production depends on the price of raw materials used in feed formulas and the level of incorporation of agro-industrial by-products of low-added value. The study aimed to determine the effects of incorporating dehydrated tomato pulp (DTP) at rates of 30, 40 and 60% instead of dehydrated alfalfa in the diet of fattening rabbits on growth and slaughter performances, meat quality and economic efficiency. One hundred and twenty local rabbits, called the 'white population,' weaned at 33 day of age, were randomly divided into 4 groups of 30 animals, identified and distributed in cages, 6 rabbits/cage, i.e. 5 replicates per group. There were no statistically significant differences among groups concerning growth performance for the whole study period (days 33–77). The liver weight of the 60% DTP group was positively influenced (on average +20 g) in comparison to the control, while the perirenal fat weight took values inversely proportional to the DTP incorporation rate for the experimental groups. The middle part (loin) was heavier in 30% DTP group (on average +68 g) in comparison to the control group. The partial substitution of dehydrated alfalfa by DTP improved the economic efficiency of the 60% DTP group (on average +0.38%). So, DTP might remain an alternative to the substitution of alfalfa at rates of 60% without negative effects on the growth performance, slaughter performance, carcasses characteristics and at the same time it may assure cost-effectiveness.

## Introduction

In rabbit farming, as for other monogastric livestock, feed represents a significant share of financial expenses, estimated at nearly 70% according to several authors (Guermah et al., 2016). In Algeria, raw materials that are added to rabbit feed formulas are mostly imported and dependent on fluctuations in foreign stock markets and the parity of the Algerian dinar (DZD), leading to a high cost of meat products.

As such, in rabbit farming, the share of ballast is generally brought by dehydrated alfalfa, very little and poorly produced in the national territory, mostly imported.

To minimize food dependence, the use of local agro-industrial by-products in domestic animal feed remains a possibility that has been studied by several authors, based on numerous experiments conducted on various species (Mennani et al., 2017, 2019; Ouzzir et al., 2020).

Dehydrated tomato pulp (DTP), a by-product of industrial tomato processing, remains a nonnegligible prospect for substitution of dehydrated alfalfa in rabbits for fattening and has been introduced at rates below 30% (Elazab et al., 2011; Peiretti et al., 2012; Sayed and Abdel-Azeem, 2012). In the latter study, contradictory results were presented, which allowed us to develop the subject of our research – much higher incorporation rates of DTP into rabbit feed.

Annually tomato-cultivated areas in the Algerian national territory comprise about 21 434 ha on average with an average annual production of 1 235 400 t/year (MADR, 2016). The industrial tomato processing industry generates about 19% of the whole by-products (Valerie and Tran, 2016), bringing 234 726 t/year. All these by-products are almost entirely disposed of in public landfills. These by-products consist of husks, seeds, stalks and leaves. Their chemical compositions vary depending on the technological process used; they are rich in protein (19.9% of dry matter (DM)), fat (16.1% of DM), neutral detergent fibre (NDF; 55.6% of DM), acid detergent fibre (ADF; 20.3% of DM) and acid detergent lignin (ADL; 25.2% of DM) (Arbouche et al., 2018), which is important for the digestive health of rabbits (Gidenne et al., 2015). Moreover, dehydrated tomato by-products contain more essential amino acids than dehydrated alfalfa (Elazab et al., 2011).

Our study is part of a research project aimed to incorporate agro-industrial by-products in rabbit feed for fattening, as well as apricot kernel cake and date waste (Mennani et al., 2017, 2019; Ouazzir et al., 2020). Dehydrated tomato pulp in our study was a substitute for dehydrated alfalfa in the amounts of 30, 40 and 60%, which will allow us to assess how the tested replacement percentages affect the growth performance of rabbits, their slaughter characteristics and the composition of meat.

# Material and methods

The present study was conducted after obtaining the approval no. 08/UG/19 of the Institutional Animal Ethics Committee, Laboratory of Agriculture Department, University of Ghardaia, Algeria.

## Animals, diets and experimental protocol

The study was conducted in 2020, at a professional breeding centre, located in the Wilaya of Sétif. One hundred and twenty rabbits of the local 'white population', weaned at 33 day of age, were randomly divided into 4 groups of 30 animals each. The rabbits, of equal sex ratio (1:1), with an average weight of 770.6 g in each group, were identified and distributed in cages, 6 rabbits/cage, i.e. 5 replicates per group.

The tomato pulps were supplied by a cannery located in the industrial zone of the Wilaya of Sétif. They were sun-dried for three days. Analyses of DM, crude protein (CP), crude fibre (CF), parietal compounds (NDF, ADF and ADL), ether extract (EE), crude ash (CA) were made according to AOAC International (2005). Gross energy was determined by adiabatic calorimetry and amino acids by high-performance liquid chromatography (HPLC) (Table 1) (Arbouche et al., 2018).

**Table 1**. Chemical composition of dehydrated tomato pulp (DTP)

| Indices | Amount |
|---|---|
| Dry matter (DM), % | 89.8 |
| Crude protein, % DM | 19.9 |
| Crude fibre, % DM | 35.3 |
| Ether extract, % DM | 16.1 |
| Crude ash, % DM | 4.88 |
| Nitrogen-free extract, % DM | 13.6 |
| NDF, % DM | 55.6 |
| ADF, % DM | 20.3 |
| ADL, % DM | 25.2 |
| Hemicellulose, % DM | 35.3 |
| Gross energy, kcal/kg DM | 4063 |
| Digestible energy rabbit*, kcal/kg DM | 2298 |
| Rabbit digestible protein*, g/kg DM | 130 |
| Lysine, g/100 g feed | 1.0 |
| Methionine, g/100 g feed | 0.36 |
| Cysteine, g/100 g feed | 0.31 |

NDF – neutral detergent fibre, ADF – acid detergent fibre, ADL – acid detergent lignin; * – estimated by the equation of Lebas (2016)

Four compound feeds were formulated using WUFFDA (Food Formulation Software for Feeding Rabbits, 2002, ver. 1.4): one control feed (0% of dehydrated alfalfa substituted with DTP) and three experimental feeds, in which 30, 40 and 60% of dehydrated alfalfa were substituted with DTP (Table 2). Animals were weighed individually at 33, 44, 58 and 77 day of age. The feed was distributed *ad libitum* and consumption was monitored for each cage with weighing of the refusals.

**Table 2.** The formula of feeds distributed according to the substitution rate of alfalfa by dehydrated tomato pulp (DTP)

| Indices | DTP incorporation, % of dehydrated alfalfa substitution | | | |
|---|---|---|---|---|
| | 0 | 30 | 40 | 60 |
| Ingredients, kg/100 kg of feed | | | | |
| maize | 20 | 20 | 20 | 20 |
| soyabean meal | 12.7 | 12.7 | 12.7 | 12.7 |
| wheat bran | 32 | 32 | 32 | 32 |
| wheat straw | 4.7 | 4.7 | 4.7 | 4.7 |
| dehydrated alfalfa | 29 | 20.3 | 17.4 | 11.6 |
| DTP | 0 | 8.7 | 11.6 | 17.4 |
| salt (NaCl) | 0.5 | 0.5 | 0.5 | 0.5 |
| MVS | 0.5 | 0.5 | 0.5 | 0.5 |
| calcium carbonate | 0.5 | 0.5 | 0.5 | 0.5 |
| L-lysine | 0.08 | 0.04 | 0.05 | 0.03 |
| DL-methionine | 0.02 | 0.06 | 0.05 | 0.07 |
| Calculated nutrient levels | | | | |
| crude fibre, % | 15.1 | 15.5 | 15.8 | 16.4 |
| NDF, % | 36.6 | 37.1 | 37.2 | 37.5 |
| ADF, % | 20.1 | 20.5 | 20.6 | 20.9 |
| ADL, % | 4.3 | 5.4 | 5.8 | 6.5 |
| hemicellulose, % | 16.6 | 16.6 | 16.6 | 16.6 |
| lysine, % | 0.83 | 0.84 | 0.86 | 0.88 |
| methionine, % | 0.29 | 0.27 | 0.26 | 0.27 |
| total sulphur amines, % | 0.50 | 0.52 | 0.53 | 0.55 |
| DP*, % | 10.6 | 10.7 | 10.8 | 10.9 |
| DE*, kcal/kg | 2335 | 2374 | 2387 | 2412 |
| metabolizable energy, kcal/kg | 2187 | 2213 | 2222 | 2239 |
| cellulose vs ADF-ADL, % | 15.7 | 15.1 | 14.8 | 14.4 |
| calculated DP/DE, g/1000 kcal | 48.4 | 48.6 | 48.6 | 48.7 |

MVS – mineral and vitamin supplement composed of: mg/kg: calcium 150.7, sodium chloride 332 000, vitamin E 1 500, vitamin K 200, vitamin $B_1$ 100, vitamin $B_2$ 450, vitamin $B_3$ 780, vitamin $B_6$ 150, vitamin $B_{12}$ 1, PP 1 000, folic acid 50, biotin 1.5, choline chloride 35 000, iron 3 600, copper 2 250, zinc 7 500; IU/kg: vitamin A 800 000, vitamin $D_3$ 150 000; NDF – neutral detergent fibre, ADF – acid detergent fibre, ADL – acid detergent lignin, DP – digestible protein, DE – digestible energy; * – estimated by the equation of Lebas (2016)

## Growth performances

Average daily gain (ADG; g/day), daily feed intake (DFI; g/day) and feed conversion ratio (FCR; g feed/g weight) were calculated for selected periods (days 33–44, 44–58 and 58–77) and the whole 44-day experimental trial (days 33–77). Water was available *ad libitum* through automatic pipette-type drinkers.

## Slaughtering and carcass parameters, and meat quality

Slaughter parameters, carcass characteristics and meat quality were determined on 10 animals, taken randomly from each group, at day 77 of age, according to the methods proposed by Dalle Zotte et al. (2009).

Slaughtering and carcass parameters were: live weight at slaughter (LWS; g); hot carcass weight (HCW; g); cold carcass weight after 24 h in cold storage (CCW; g); hot carcass yield (HCY = HCW / LWS × 100; %) and cold carcass yield (CCY = CCW / LWS × 100; %); liver weight (LW; g); liver weight to live weight ratio (LW / LWS × 100; %); perirenal fat weight (PFW; g); perirenal fat weight to live weight ratio (PFW / LWS × 100; %); perirenal fat weight to hot carcass weight ratio (PFW / HCW × 100; %); skin weight (SW; g); skin weight to live weight ratio (SW / LWS × 100; %); full digestive tract weight (FDTW; g); full digestive tract weight to live weight ratio (FDTW / LWS × 100; %); fore-end weight (FEW; g); hind-end weight (HEW; g); intermediate saddle weight (ISW; g); fore-end weight to hot carcass weight ratio (FEW / HCW × 100, %), hind-end weight to hot carcass weight ratio (HEW / HCW × 100, %) and intermediate saddle weight to hot carcass weight ratio (ISW / HCW × 100, %).

After slaughter and dissection of meat, the chemical composition of meat was determined. The samples of each animal were homogenized in a blender and then lyophilized to assess moisture, protein content, ether extract and ash (AOAC International, 2005) with three replicates. The $pH_{24h}$ was measured at 24 h post-mortem by inserting the electrode of a pH meter (HI 8424 Microcomputer; Hanna Instruments, Woonsocket, RI, USA) directly into the pectoral muscle (*longissimus lumborum*) (~2 cm deep).

## Statistical analysis

The data were prepared using Microsoft Excel (Microsoft, Redmont, WA, USA). Statistical analysis and comparison of the means between different diets (control and three experimental ones) were performed by unidirectional analysis of variance using the SPSS software version 21 (IBM Corp., Armonk, NY, USA). Student-Newman-Keuls and Duncan's tests were done if a significant difference at 5% standard error was found ($P < 0.05$).

## Economic efficiency

Economic efficiency was calculated from the equation by Asar et al. (2010):

economic efficiency (%) = (net income / total feed cost) × 100;

where:

net income = income from total weight gain − total feed cost;

income from total weight gain = average weight gain (kg/subject) × price of 1 kg of LWS;

total feed cost = average feed intake (kg/subject) × price of 1 kg of feed.

The cost of each kg of feed for the control and experimental diets was calculated based on the price of ingredients on the local market at the time of the experiment (the year 2020). Ancillary costs were not considered.

For the experimental batch, the total feed cost also included the cost of purchasing DTP (Table 3). All prices are presented in Algerian dinar (DZD; 1 DZD = 0.0062 EUR)

**Table 3.** Data used for dehydrated tomato pulp (DTP) cost estimation

| Indices | Cost, DZD/t |
|---|---|
| Parameters value | |
| purchase | 5 |
| transport cost | 100 |
| truck unloading | 35 |
| treatment | |
| energy cost (drying) | 10 |
| time required for drying | 2 t/h |
| total labour cost | 10 |
| cost of depreciation of equipment | 100 |
| Total | 250 |

DZD – Algerian dinar

The cost of production of DTP was calculated according to the direct cost method, which consists of allocating the direct fixed expenses specific to the production of DTP. The common expenses were not negligible but they were reported on the whole of the products of the company because they are difficult to evaluate in our case which relates to only one by-product.

The basic salary in Algeria (SMIG) is 18 000 DZD/month. If we accept 35 000 DZD (gross salary + employer's contributions) as the average salary per month, the salary for 1 h would be about 200 DZD.

The cost of energy was calculated by estimating the energy consumption of the equipment used for the production of DTP, knowing in the framework of professionals, each kWh is charged at 4.472 DZD/kWh (Sonelgaz, 2019).

The depreciation of the equipment was estimated according to the purchase prices of the equipment (e.g., dryer) that exists on the market and according to the average capacity of the companies carrying out the drying of the tomato pulps.

# Results

## Growth performances

Only the weight at 44 day of age was positively influenced ($P$ < 0.05) by the different substitution rates of dehydrated alfalfa with DTP (Table 4), with a mean difference of +67 g. At all other time points (days 58 and 77 of age), there was no difference among groups concerning weight gain ($P$ > 0.05).

**Table 4.** Changes in daily feed intake (DFI (g/day)), weight growth (g), average daily gain (ADG (g/day) and feed conversion ratio (FCR (g feed/g weight)) during fattening of rabbits according to the percentage of dehydrated tomato pulp (DTP) incorporation

| Indices | DTP incorporation, % of dehydrated alfalfa substitution | | | | SEM | $P$-value |
|---|---|---|---|---|---|---|
| | 0 | 30 | 40 | 60 | | |
| $DFI_{33–44d}$ | 88.0$^{a}$ | 86.3$^{b}$ | 86.0$^{b}$ | 86.7$^{b}$ | 0.058 | 0.01 |
| $DFI_{44–58d}$ | 96.1$^{b}$ | 97.8$^{a}$ | 99.2$^{a}$ | 98.3$^{a}$ | 0.077 | 0.02 |
| $DFI_{58–77d}$ | 116 | 115 | 117 | 118 | 0.185 | 0.09 |
| $DFI_{33–77d}$ | 99.7 | 99.7 | 101 | 101 | 0.067 | 0.08 |
| Weight, at day | | | | | | |
| 33 | 770 | 777 | 764 | 764 | 10.2 | 0.46 |
| 44 | 1117$^{b}$ | 1177$^{a}$ | 1189$^{a}$ | 1187$^{a}$ | 12.8 | 0.02 |
| 58 | 1510 | 1499 | 1529 | 1508 | 15.1 | 0.889 |
| 77 | 2006 | 2002 | 2012 | 2011 | 18.0 | 0.13 |
| $ADG_{33–44d}$ | 31.5$^{b}$ | 36.4$^{a}$ | 38.6$^{a}$ | 38.4$^{a}$ | 0.372 | 0.001 |
| $ADG_{44–58d}$ | 28.1$^{a}$ | 23$^{b}$ | 24.3$^{b}$ | 22.9$^{b}$ | 0.353 | 0.02 |
| $ADG_{58–77d}$ | 26.1 | 26.5 | 25.4 | 26.5 | 0.330 | 0.665 |
| $ADG_{33–77d}$ | 28.1 | 27.8 | 28.4 | 28.3 | 0.294 | 0.532 |
| $FCR_{33–44d}$ | 2.8$^{a}$ | 2.3$^{b}$ | 2.3$^{b}$ | 2.2$^{b}$ | 0.049 | 0.01 |
| $FCR_{44–58d}$ | 3.4$^{b}$ | 4.3$^{a}$ | 4.1$^{a}$ | 4.3$^{a}$ | 0.071 | 0.02 |
| $FCR_{58–77d}$ | 4.4 | 4.4 | 4.6 | 4.5 | 0.710 | 0.83 |
| $FCR_{33–77d}$ | 3.5 | 3.6 | 3.6 | 3.6 | 0.049 | 0.44 |

$^{a-b}$ – values with different superscripts within the same row are significantly different at $P$ < 0.05; SEM – standard error of the mean

The $ADG_{33–44d}$ values of all three experimental groups were similar and significantly higher on average by +6.3 g/day in comparison to the control group; while the $ADG_{44–58d}$ values for experimental groups were decreased (on average −4.7 g/day) in comparison to the control group. The $ADG_{58–77d}$ and $ADG_{33–77d}$ of all the groups were similar.

The $FCR_{33–44d}$ of the control group was the highest ($P$ < 0.05) in comparison to experimental groups, which recorded a similar mean value of 2.26, creating a difference with the control group of −0.5 g/g. The experimental groups (30, 40 and 60% DTP) recorded significantly higher values in $FCR_{44-58d}$ with a difference of +0.83 g/g in comparison to the control group. The same changes were stated for $DFI_{33–44d}$ and $DFI_{44–58d}$ in the experimental groups with lower values in the first phase (−1.7 g/day in comparison to the control group) and higher values in the second one (+2.33 g/day in comparison to the control group). For all other rearing phases (days 58–77 and 33–77), the FCR and DFI values were identical among all groups.

**Table 5.** Evolution of slaughter parameters, carcass characteristics, and chemical composition of meat of fattening rabbits according to the percentage of dehydrated tomato pulp (DTP) incorporation

| Indices | DTP incorporation, % of dehydrated alfalfa substitution | | | | SEM | *P*-value |
|---|---|---|---|---|---|---|
| | 0 | 30 | 40 | 60 | | |
| Slaughtering parameters | | | | | | |
| live weight at slaughter (LWS), g | 2028 | 2051 | 2056 | 2000 | 11.8 | 0.38 |
| hot carcass weight (HCW), g | 1320 | 1303 | 1260 | 1246 | 12.2 | 0.22 |
| cold carcass weight (CCW), g | 1273 | 1270 | 1220 | 1215 | 12.9 | 0.43 |
| HCW/LWS yield, % | 65.1 | 63.5 | 61.2 | 62.3 | 0.594 | 0.17 |
| CCW/LWS yield, % | 62.8 | 61.9 | 59.3 | 60.7 | 0.518 | 0.15 |
| Carcass characteristics | | | | | | |
| liver weight (LW), g | $70.0^{b}$ | $81.6^{ab}$ | $83.3^{ab}$ | $90.0^{a}$ | 6.98 | 0.04 |
| LW/LWS yield, % | $3.4^{b}$ | $4.0^{ab}$ | $4.0^{ab}$ | $4.5^{a}$ | 0.348 | 0.046 |
| perirenal fat weight (PFW), g | $31.7^{a}$ | $26.7^{b}$ | $18.3^{c}$ | $13.3^{d}$ | 0.726 | 0.001 |
| PFW/LWS yield, % | $1.6^{a}$ | $1.3^{b}$ | $0.9^{c}$ | $0.7^{c}$ | 0.036 | 0.001 |
| PFW/HCW yield, % | $2.4^{a}$ | $2.0^{b}$ | $1.4^{c}$ | $1.0^{d}$ | 0.051 | 0.001 |
| skin weight (SW), g | 273 | 273 | 271 | 270 | 2.82 | 0.83 |
| SW/LWS yield, % | 13.5 | 13.3 | 13.2 | 13.5 | 0.110 | 0.81 |
| full digestive tract weight (FDTW), g | $323^{b}$ | $445^{a}$ | $462^{a}$ | $455^{a}$ | 5.89 | 0.01 |
| FDTW/LWS yield, % | $15.9^{b}$ | $21.7^{a}$ | $22.4^{a}$ | $22.7^{a}$ | 0.243 | 0.01 |
| fore-end weight (FEW), g | $223^{b}$ | $252^{a}$ | $240^{ab}$ | $248^{ab}$ | 5.56 | 0.03 |
| hind-end weight (HEW), g | $368^{ab}$ | $398^{a}$ | $361^{b}$ | $359^{b}$ | 4.75 | 0.01 |
| intermediate saddle weight (ISW), g | $327^{b}$ | $395^{a}$ | $363^{ab}$ | $357^{ab}$ | 4.33 | 0.01 |
| FEW/HCW yield, % | $16.9^{b}$ | $19.3^{a}$ | $19.1^{a}$ | $19.9^{a}$ | 0.484 | 0.03 |
| HEW/HCW yield, % | $27.9^{ab}$ | $30.5^{a}$ | $28.7^{b}$ | $28.8^{b}$ | 0.435 | 0.02 |
| ISW/HCW yield, % | $24.7^{b}$ | $30.3^{a}$ | $28.9^{ab}$ | $28.6^{ab}$ | 0.389 | 0.03 |
| Chemical composition of the meat | | | | | | |
| $pH_{24h}$ | $6.0^{b}$ | $7.0^{a}$ | $6.9^{a}$ | $6.7^{a}$ | 0.035 | 0.001 |
| moisture, % DM | $61.7^{b}$ | $65.9^{a}$ | $65.8^{a}$ | $65.8^{a}$ | 0.230 | 0.001 |
| protein, % DM | $20.9^{b}$ | $23.9^{a}$ | $23.0^{a}$ | $23.5^{a}$ | 0.137 | 0.002 |
| fat, % DM | $7.8^{b}$ | $9.6^{a}$ | $8.9^{a}$ | $9.8^{a}$ | 0.084 | 0.003 |
| ash, % DM | 1.02 | 1.02 | 1.05 | 1.04 | 0.003 | 0.102 |

DM – dry matter; $^{a\text{-}b}$ – values with different superscripts within the same row are significantly different at $P < 0.05$; SEM – standard error of the mean

## Slaughter and carcass characteristics

The slaughter parameters of all experimental groups were not influenced by the rate of alfalfa substitution with DTP (Table 5).

The LW was positively influenced by the substitution of dehydrated alfalfa with DTP in the amount of 60%, with the difference in relation to the control group by an average of +20 g; however, no differences were stated between the three experimental groups in the case of LW and LW/LWS ratio (Table 5). On the other hand, the PFW took values inversely proportional to the DTP incorporation rate for the experimental groups, with a statistical difference of −5 g for the 60% DTP group in comparison to the 40% DTP group; of −13.4 g in comparison to the 30% group and of −18.4 g in comparison to the control. For the PFW/LWS and PFW/HCW ratios, a similar pattern was noted as for PFW.

The SW and its ratio to LWS (SW/LWS) were not influenced by the rate of substitution of dehydrated alfalfa with DTP (Table 5), but the FDTW was positively influenced ($P < 0.05$) with a difference of +131 g (on average) concerning the control; the same annotation was made for the ratios FDTW/LWS with a difference of +6.37% (on average) ($P < 0.05$). The FEW took an optimal value (+29 g in comparison to the control group) for the 30% DTP group; while the 40 and 60% DTP groups did not differ from either control group or 30% DTP group. For HEW, a significantly higher value was noted for the 30% DTP group in comparison to the 40 and 60% DTP groups; however, none of the experimental groups differed from the control group. The ISW recorded a significantly higher weight for the 30% DTP group in comparison to the control group ($P < 0.05$) (+68 g on average), while the 40 and 60% DTP groups did not differ from either control group or 30% DTP group. The successive ratios of these two last parameters (HEW and ISW) to the HCW recorded values in the same direction as the evolution of their weights.

### Meat quality

The partial incorporation of DTP in substitution of dehydrated alfalfa, influenced the $pH_{24h}$ of the meat by neutralization of the acidity and impregnated similar values for the three experimental groups, bringing the difference with the control on average by +0.9 points (Table 5). There was also an improvement in moisture, protein content and fat content (on average by +4.1, +2.57 and +1.63%, respectively) in all three examined groups in comparison to the control group. The ash content was not influenced by the incorporation of DTP.

### Economic efficiency

The partial substitution of dehydrated alfalfa by DTP in the diet of rabbits for fattening improved the economic efficiency, especially for the 60% DTP group, with a difference from the control group of +0.38% (Table 6). For the same group, there was also an improvement in the price per one kg of feed produced (−4.77 DZD) as well as in the total feed cost (18 DZD/kg). The net income per kilogram of meat produced tended to improve proportionally to the substitution rates of alfalfa by DTP with an optimal value of +22.6 DZD/kg for the 60% DTP group.

the same growth curve, and work carried out on rabbits of local populations and selected breeds have shown that sex does not affect live weight (Lakabi et al., 2004).

Partial incorporation of DTP did not induce a significant difference in live weights at 77 day of age for all groups of rabbits. This finding remains consistent with the results reported by Elazab et al. (2011), Peiretti et al. (2012) and Sayed and Abdel-Azeem (2012), who reported that no significant difference was recorded in live weights of rabbits fattened with feed containing up to 30% of DTP. In contrast, Sayed and Abdel-Azeem (2012) found that rabbits fed with 20% DTP recorded the highest values in body weight. The $ADG_{33–77d}$ was similar among groups, such a result corroborate with those of Peiretti et al. (2012); however, remain contrary to those of Sayed and Abdel-Azeem (2012) and Peiretti et al. (2013) which indicated a higher ADG for rabbits fed a diet containing 20% DTP. The growth rates obtained in the present study are similar to those reported by Lounaouci-Ouyed et al. (2011) (28.1 g/day) but lower than those of Kadi et al. (2017) (35 g/day), Benali et al. (2018) (34 g/day), Berchiche and Kadi (2002) (30 g/day) and Mennani et al. (2019) (32 g/day). These different authors worked on the same local strain, allowing us to define a range of growth between 28 and 35 g day and which remains linked to the nutritional balance of the recommended diets.

**Table 6.** Economic efficiency of partial substitution of alfalfa by dehydrated tomato pulp (DTP) in rabbits for fattening

| Parameters | DTP incorporation, % of dehydrated alfalfa substitution | | | |
|---|---|---|---|---|
| | 0 | 30 | 40 | 60 |
| Live weight at day 33, g | 770 | 777 | 764 | 764 |
| Live weight at day 77, g | 2006 | 2002 | 2012 | 2011 |
| Total weight gain, kg | 1.24 | 1.23 | 1.25 | 1.25 |
| Selling price, DZD/kg live weight | 400 | 400 | 400 | 400 |
| Income from total weight gain, DZD | 494 | 490 | 499 | 498 |
| Total feed intake per rabbit, kg | 4.5 | 4.51 | 4.6 | 4.6 |
| Price of one kg of feed, DZD | 37.4 | 35.0 | 34.2 | 32.6 |
| Total feed cost, DZD/kg | 168 | 157 | 157 | 150 |
| Economic efficiency, % | 1.94 | 2.10 | 2.17 | 2.32 |
| Net income per kg of meat produced, DZD/kg | 326 | 332 | 341 | 348 |

DZD – Algerian dinar (1 DZD = 0.0062 EUR)

## Discussion

The overall mortality rate remained low (≤6%), it was due to the transfer after weaning and the adaptation of the subjects to their new rearing conditions as stated by De Blas (2013) and remained within the range of the standards advanced by Kadi et al. (2012).

The sex of the rabbits did not gain particular attention because Ouhayoun et al. (1983) observed that up to 20 week of age, males and females follow

In the present study, the $DFI_{33–77d}$ were similar for all groups, although the content of ADL was higher in the experimental groups (4.3 vs 6.5%), which should increase the average DFI according to Gidenne et al. (2015), who related the voluntary intake of rabbits with the concentration of ADL in the feed. Sawal et al. (1996) also report that incorporation of 10–20% DTP into rabbit diets increased DFI, as well as Sayed and Abdel-Azeem (2012) found that DFI of rabbits was significantly affected by the level of DTP incorporation in diets. The $FCR_{33–77d}$ was the same for all groups, which is consistent with the results put forward by Sayed and Abdel-Azeem (2012) and Peiretti et al. (2012) with diets up to 30% DTP incorporation. However, Sawal et al. (1996) found a decrease in FCR proportional to increasing DTP incorporation in diets.

For the experimental groups, liver weight and its ratio to live weight (LW/LWS) increased significantly in line with the findings by Kavamoto et al. (1970) but remain in contradiction with those found by Peiretti et al. (2013) and Sayed and Abdel-Azeem (2012) who did not find any improvement in the carcass characteristics of the rabbits fed diet with DTP addition up to 30%. Perirenal fat weight and its ratio decreased proportionally to the rate of incorporation of DTP (30, 40 and 60%) in the rations of the experimental groups, which was not reported by Elazab et al. (2011), Peiretti et al. (2013) and Grioui et al. (2021) who found no changes in carcass characteristics of rabbits fed with DTP incorporation rates below 30%. The weight of the full digestive tract of all the experimental groups recorded a similar and significantly higher value than that of the control as pointed out by Grioui et al. (2021) for incorporation rates of 10 and 20% of DTP. This would be due to a higher concentration of ADL in the experimental groups (+1.1, +1.5 and +2.2% for 30, 40 and 60% groups, respectively) as well as to the level of carotenoids, including lycopene, contained in the dehydrated tomato husks, which remain poorly assimilated if not cooked. However, for incorporation rates of 3 and 6% DTP, Peiretti et al. (2013) did not find an increase in full digestive tract weight. For DTP incorporation rates of less than 30%, Elazab et al. (2011) recorded no significant difference in the weights of the front, back and middle part of the rabbits; however in the present trial, with the incorporation rates of 30, 40 and 60%, an improvement in the weights of these three parameters of the carcass was found.

The value of 6.9 recorded for the $pH_{24h}$ of the *longissimus lumborum* muscle of the experimental groups had an influence, on the one hand, on the conservation of the meat because the proteolytic microorganisms quickly develop bad odours there (Dalle Zotte, 2014) and, on the other hand on its quality through the tenderness of the cooked meat which is linked to the degradation of glycogen and the release of lactate after slaughter, however, a $pH_{24h}$ lower than 6 (around 5), would lead to too firm meat because the water retention capacity would be decreased (Wang et al., 2016). Substitution rates higher than 30% in DTP in the rations of fattening rabbits result in an improvement of the protein and fat content of the meat, in contrast to incorporation rates lower than 30%, which did not lead to any changes in the chemical composition of the meat (Peiretti et al. (2013) and Elazab et al. (2011)).

The net income per kg of meat in the 60% group was significantly improved because the cost price of locally produced DTP remains low compared to dehydrated alfalfa which is mostly imported to Algier.

## Conclusions

Like dehydrated alfalfa, dehydrated tomato pulp (DTP) can be considered as a source of protein and fibre for the rabbit. Substitution of 60% of dehydrated alfalfa with DTP does not interfere with growth performance, slaughter parameters and carcass characteristics. However, it reduces the external fatness of the carcass and reduces the cost price of the consumed feed. To improve the feed efficiency, it would be interesting to consider the use of this agro-industrial by-product after cooking.

## Conflict of interest

The authors declare that there is no conflict of interest.

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