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# Effects of Replacing Barley with Processed Corn on the Growth Performance, Microbial Protein Synthesis and Profitability of Fattening Lambs

Research Article

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## ABSTRACT

Barley as a native cereal is the main source of carbohydrates in fattening sheep. Substituting barley with other sources of carbohydrates, such as corn, could decrease digestive disorders. The objective of this study was to assess profitability, growth performance, and microbial protein production in fattening lambs by replacing barley with different processed corn. To achieve this, a completely randomized design including seven rations with five lambs as replicates were used. The treatments reared in individual cages during an 84-day time frame allowed us to determine body weight, dry matter intake (DMI), feed conversion ratio (FCR), gross profit, and microbial protein production. The results showed that the 40% barley ration had minimum means of final body weight, DMI, daily weight gain (P<0.05), FCR, and gross profit (P<0.10) versus the other rations. Also, the rates of allantoin, uric acid, xanthine, hypoxanthine, and microbial protein in a 100% pelleted corn diet were the highest with a significant difference compared to other treatments. Furthermore, the results of economic models indicated that initial weight and feed cost had negative effects, as opposed to that of daily body weight gain and DMI, which yielded positive effects on the gross profit. In addition, a greater initial weight could decrease partial production elasticity, but utilization of the corn-based rations resulted in more growth rate overall. Of course, the 40% pelleting corn could create a more accelerated growth rate compared to the other processed corn.

KEY WORDS barley, body weight, corn, lambs, profitability, regression analysis.

## INTRODUCTION

Barley as a native cereal is the main source of carbohydrates in fattening sheep. However, since barley starch has a higher rate of degradation than corn starch (Ghoorchi *et al.* 2013), it may cause problems in the rumen (Horadagoda *et al.* 2008) and leads to digestive problems such as acidosis (Galyean and Rivera, 2003). Although extensive processing (pelleting, flaking to extensively gelatinize starch) could remedy this issue and result in better digestibility, typical grain processing methods used for ruminants are selected to economically enhance digestibility and acceptability without negative impacts on ruminal pH and causing digestive dysfunction. Milling with a roller mill or grinder simply to reduce particle size yields dry rolled or dry ground grain is the simplest approach to enhance digestibility (Owens, 2005). Heat can be applied before rolling; yielding steam rolled or "flacked" grain (Owens, 2005). Haddad and Nasr (2007) studied the effects of partial replacement of barley grain for corn in high concentrate rations on the growth performance of growing lambs and reported positive associative effects of partial replacement of barley with corn. Yahaghi *et al.* (2012) evaluated the effects of partial substitution of barley with corn or sorghum (slowly fermenting grains) on performance in finishing lambs. The results of their study affirmed the advantages of feeding a mixture of grains with differing fermentation rates. The results of Ziani and Khaled (2015) showed substitution of barley with corn has no significant effect on growth performance and final body weight, but a significant difference was found concerning the cost of the given ration.

Microbial biomass produced in the rumen represents an important supply of good quality protein that can promote animal performance (Storm and Ørskov, 1983; Clark *et al.* 1992). Different options have been studied to maximize microbial protein synthesis in the rumen and increase animal productivity. Sources of carbohydrates such as corn and barley differed in starch rapidly degraded fraction and indigestion rate (Herrera-Saldana *et al.* 1990). Furthermore, the processing is known to influence the rate and site of grain digestion. Indeed, damaging the pericarp of the kernel improved the starch degradation rate by increasing the surface area available to microorganisms and enzymes (McAllister *et al.* 1990). Nitrogen availability can be modified by the reatment of protein sources (Chalupa, 1975). Heating dietary protein creates amino-sugar complexes that are resistant to microbial degradation (Stern *et al.* 1994), which then could be digested in the lower gut.

Any change in the ration composition has economic effects in addition to the nutritional effects. Ignoring or changing ration compositions without considering these financial and economic effects could result in negative consequences. Different ration compositions could simultaneously have different cost and revenue effects and eventually lead to different profitability consequences. Cevger (2003) investigated determinants of profit in lamb fattening by using a regression model and found that initial weight and feed cost had a negative impact and body weight gain had a positive impact on profitability. Ramsey *et al.* (2005) used a regression approach to identify factors affecting beef cow producers' profit and conclude dthat an increase in feed cost could decrease overall profit. Elfadl *et al.* (2015) investigated factors affecting the productivity and profitability of beef fattening enterprises in Egypt. The results showed that the most important factors dictating beef enterprises' profitability were the selling and purchasing price of animals, along with feed cost.

The aim has tried to investigate the consequences of replacing barley with different processed corn on growth performance factors such as body weight, dry matter intake (DMI), feed conversion ratio (FCR), microbial protein synthesis, and also the profitability of fattening lambs. This study hypothesized that replacing barley with corn-based rations could improve both growth performance and gross profit of fattening lambs.

## MATERIALS AND METHODS

The protocol (Approval No. AEC392p/02129) used in this study was approved by the Animal Ethical Committee at Gorgan University of Agricultural Sciences and Natural Resources in Gorgan, Iran concerning animal experimentation and care of animals under study.

### Animal and housing

The feeds were formulated according to NRC (2007) recommendations for fattening sheep with equal quantity of energy and protein as seven treatments including 1) 40% barley (control), 2) 20% grinding corn, 3) 40% grinding corn, 4) 20% steam flaking corn, 5) 40% steam flaking corn, 6) 20% pelleting corn and 7) 40% pelleting corn (Table 1). Five Afshari ram lambs were allocated to each treatment. The animals were kept in a separate pen individually for 84 days on the animal research farm of Gorgan University of Agricultural Science and Natural Resources, Gorgan, Iran, 2018.

### Estimation of microbial protein

Purine derivatives (PD) in urine include uric acid, allantoin, xanthine + hypoxanthine. Estimation of microbial N was performed based on the colorimetric method (Chen and Gomes, 1989). Daily urine samples were collected in a plastic bucket containing 100 mL of 10% (vol/vol) sulphuric acid solution to reduce the ultimate pH below 3. Every morning the total urine produced by the animal was measured individually and to prevent the precipitation (particularly of uric acid) of PD urine samples during storage, a sub-sample of 10 ml of the daily amount was diluted with 40 ml distilled water and then stored at −20 ˚C for the estimation of PD. The samples collected from each sheep were pooled to give one pooled sample for analysis (Chen and Gomes, 1989). Urine was collected daily into a container with approximately 100 mL of 10% $H_2SO_4$. Daily subsamples were stored at -20 ˚C until being analyzed. Urine samples were analyzed for allantoin, uric acid, xanthine, and hypoxanthine following the procedure reported by Chen and Gomes (1989). The total PD excretion (in sheep sum of all 4 compounds allantoin, uric acid xanthine, and hypoxanthine) is used for the estimation of microbial protein synthesis.

### Statistical analysis

In the first part of the study, growth performance data were analyzed as a completely randomizeddesign using the general linear model (GLM) procedure of SAS software (SAS, 2003). The significant differences between treatments means were detected by the Tukey-Kramer test at $P < 0.05$.

**Table 1** Feed ingredients and chemical composition of experimental diets of fattening lambs

| Feedstuff (% of dry matter) | 40% barley | 20% grinding corn | 42% grinding corn | 20% steam flaking corn | 40% steam flaking corn | 20% pelleting corn | 40% pelleting corn |
|---|---|---|---|---|---|---|---|
| Barley | 40.00 | 20.00 | - | 20.00 | - | 20.00 | - |
| Grinding corn | - | 20.00 | 40.00 | - | - | - | - |
| Steam flaking corn | - | - | - | 20.00 | 40.00 | - | - |
| Pelleting corn | - | - | - | - | - | 20.00 | 40.00 |
| Alfalfahay | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| Wheat bran | 13.50 | 11.50 | 9.50 | 11.50 | 9.50 | 11.50 | 9.50 |
| Soybean meal | 8.00 | 10.00 | 12.00 | 10.00 | 12.00 | 10.00 | 12.00 |
| Wheat straw | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Sugar beet pulp | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Zeolite | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| NaCl | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Vitamin and mineral[1] | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| $Ca_2(po_4)$ | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Caco3 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Sodium bicarbonate | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **Chemical composition** | | | | | | | |
| Dry matter (%) | 88.64 | 88.64 | 88.64 | 88.64 | 88.64 | 88.64 | 88.64 |
| Metabolisable energy (Mcal/kg) | 2.59 | 2.58 | 2.59 | 2.58 | 2.59 | 2.583 | 2.59 |
| Crude protein (%) | 14.53 | 14.49 | 14.45 | 14.49 | 14.45 | 14.49 | 14.45 |
| Calcium (%) | 0.9758 | 0.9306 | 0.9758 | 0.9306 | 0.9758 | 0.9306 | 0.9758 |
| Phosphorus (%) | 0.38 | 0.42 | 0.38 | 0.42 | 0.38 | 0.42 | 0.38 |

[1] Vitamin and mineral premix - composition per kg feed: Zn: 4.9 mg; Mn: 4.05 mg; Cu: 0.45 mg; I: 0.075 mg; Se: 0.1 mg; vitamin A: 2500 IU; vitamin D: 400 mg; Vitamin E: 2.5 IU.

Many studies have revealed that alighter initial weight could result in a higher fattening efficiency (Orskov *et al.* 1971; Tuncel *et al.* 1985; Koc, 1996; Sayili *et al.* 2009; Javanmard *et al.* 2014). Therefore, in this study initial weight was included in ANOVA analysis as a covariate factor, and data were analyzed using the following statistical model:

$$Y_{ij}= \mu + T_i + \beta(x_{ij}-\bar{x}) + \varepsilon_{ij}$$

Where:
$Y_{ij}$: observation associated with the i-th treatment and j-th replicate.
μ: total mean.
$T_i$: effect of the i-th treatment.
B: slope.
$x_{ij}$: lambs' initial weight.
$\bar{x}$: mean of initial weight.
$\varepsilon_{ij}$: error term.

In the second part of the study, an economic model and parametric approach were used to evaluate the effects of differentrations on the profitability and production elasticity of fattening lambs. In the gross profit model, the gross profit (lambs sale value minus feed cost) is a dependent variable and initial weight, daily body weight gain, feed, feed cost, and a dummy variable (for evaluating the effect of ration type) as explanatory variable were included. The initial regression was:

$$Y= b_0 + b_1 \times X_1 + b_2 \times X_2 + b_3 \times X_3+ b_4 \times X_4+ b_5 \times X_5$$

Where:
Y: gross profit as difference in lambs sale price and feed cost ($).
$X_1$: initial weight (kg).
$X_2$: daily body weight gain (gr/day).
$X_3$: feed cost ($).
$X_4$: feed (kg).
$X_5$: dummy variable (0 for barley (control) ration and 1 for otherwise).

In the elasticity model, partial elasticity of production concerning the feed as a dependent variable and initial weight plus 6 dummy variables as explanatory variables were utilized. Because there were seven rations, six dummy variables were needed to quantify the effect of rations. The initial regression was:

$$Z= b_0 + b_1 \times X_1 + b_2 \times D_2 + b_3 \times D_3 + b_4 \times D_4+ b_5 \times D_5+ b_6 \times D_6 + b_7 \times D_7$$

Where:
Z: partial elasticity of production concerning the feed.

$D_2$: dummy variable (1 for the ration of 20% grinding corn and 0 for otherwise).
$D_3$: dummy variable (1 for the ration of 40% grinding corn and 0 for otherwise).
$D_4$: dummy variable (1 for the 20% steam flaking corn and 0 for otherwise).
$D_5$: dummy variable (1 for the 40% steam flaking corn and 0 for otherwise).
$D_6$: dummy variable (1 for the ration 20% pelleting corn and 0 for otherwise).
$D_7$: dummy variable (1 for the ration 40% pelleting corn and 0 for otherwise).

Different functional forms were investigated to find the proper model. Finally, a linear form for the profit model and a logarithmic form for the elasticity model was chosen. Estimation of the regression models and statistical analysis of the mean differences was done by EVIEWS (2013) and the SAS (2003) respectively.

## RESULTS AND DISCUSSION

**Growth performance analysis**

Table 2 shows the results regarding the effects of dietary treatments onthe growth performance of lambs. Animals had a daily body weight gain from 167 to 225 grams/day and a mean FCR of about 8.46. There was no significant difference between dietary treatments for final body weight, daily weight gain, FCR, and gross profit (P<0.05). Also, DMI for the rations including Pelleting corn was higher (P<0.05) than the control ration (40% barley). Replacing barley with processed corn could improve both body gain and FCR. These results could be because of improved ruminal, post-ruminal, and thus total tract digestibility in lambs fed corn or a mixture of barley and corn that resulted in more efficient FCR (Yahaghi *et al.* 2012). The present results are in agreement with previous studies (Haddad and Nasr 2007; Lehmann and Meeske, 2007; Yahaghi *et al.* 2012) which reported that combinations of cereal grains enhance growth performance through associative effects among feeding ingredients on rumen fermentation. Several factors could improve growth performance including more efficient rumen fermentation, increased rumen bypass starch and digestion in the small intestine, and more essential amino acids for tissue synthesis resulting from better availability of intact amino acids (Yu *et al.* 1998). Also, lambs fed with pure corn or a combination of barley and corn showed higher DMI compared with the pure barley (control) ration. These results were in contrast with Yahaghi *et al.* (2012) but agreed with Haddad and Nasr (2007).

On the other hand, although rations including corn or a mixture of barley and corn had a greater feed cost, their increased efficiency in FCR ultimately resulted in more profitability.

Utilization of ration 40% Grinding Corn tended to increase profitability the most because this ration resulted in the best FCR and the cost of this ration was less than others. Replacing 40% barley with grinding corn despite the higher price of corn also tended to increase profitability. Of course, these results could be much different if the price and cost-share of the corn and barley in the rations varied. The market price of corn was about 10% greater than the price of local barley during the study period. Depending on the barley or other cereal market prices and then their relative cost-shares the above results may differ.

The highest (P<0.05) feed costs were belong to the rations 40% steam flaking corn and 40% pelleting corn and the ration of 40% barley had the least (P<0.05) feed costs. These results could be different based on the relative market prices of corn and barley.

In this study, because the market price of corn was about 10% greater than the price of local barley during the study period, replacing barley with processed corn significantly increased the feed costs. Comparing the ration 40% barley *vs.* the other rations revealed significant differences between means of final body weight, DMI, and daily weight gain at 0.05 and FCR and gross profit at 0.10 probability level.

The treatments did not affect the amount of microbial protein and purine derivatives. However, the rate of allantoin, uric acid, xanthine, hypoxanthine, and microbial protein ina 100% pelleted corn diet was the highest with a significant difference compared to other treatments. Independent comparisons also showed that diets with pelleted corn compared to diets with ground corn and steam flaking corn produced higher allantoin and microbial protein.

It is possible due to the type of heat treatment that has been done on it changes the pattern of fermentation in the rumen and simultaneously releases energy and protein sources in the rumen. The source of protein in this study was alfalfa hay and soybean meal, which has a high degradable protein in the rumen. In the study of Brassard *et al.* (2015), it was found that the type of grain affects the synthesis of microbial protein. Excretion of purine derivatives was higher when corn was used with unheated soybean meal than when corn was used with heated soybean meal, and the opposite was observed with barley. Matras *et al.* (1991) investigated the interaction between different grains (barley *vs.* sorghum) and the degradability of proteins (various compounds of urea, blood powder, and corn gluten meal) to produce purine derivatives.

**Table 2** Effects of barley replacement with different corn processing on growth performance in Afshari fattening lambs ration

| Parameter | Dietary treatments | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40% barley | 20% GC | 40% GC | 20% SFC | 40% SFC | 20% PC | 40% PC | SEM | P-value | Contrast P-value[1] |
| IBW (kg) | 34.0 | 36.0 | 36.0 | 35.8 | 36.5 | 33.7 | 35.6 | 0.590 | 0.8480 | 0.1714 |
| FBW (kg) | 48.0 | 53.2 | 54.5 | 52.6 | 54.3 | 51.0 | 54.6 | 0.672 | 0.1110 | 0.0098 |
| ADG (g) | 167 | 205 | 220 | 200 | 211 | 206 | 225 | 6.856 | 0.1769 | 0.0098 |
| FCR | 9.48 | 8.40 | 7.57 | 8.24 | 8.28 | 9.43 | 7.85 | 0.329 | 0.2675 | 0.0853 |
| DMI (g) | 1728$^{b}$ | 1826$^{ab}$ | 1791$^{ab}$ | 1787$^{ab}$ | 1856$^{ab}$ | 1863$^{a}$ | 1887$^{a}$ | 15.976 | 0.0003 | 0.0184 |
| Feed cost ($) | 5.29$^{a}$ | 5.72$^{b}$ | 5.74$^{b}$ | 5.98$^{b}$ | 6.75$^{c}$ | 6.06$^{b}$ | 6.49$^{c}$ | 0.888 | < 0.0001 | < 0.0001 |
| Gross profit ($) | 3.1 | 11.8 | 16.6 | 7.4 | 3.5 | 8.6 | 10.9 | 2.286 | 0.3549 | 0.0956 |

[1] Contrast: mean of ration 40% barley *vs.* the other rations.
GC: grinding corn; SFC: steam flaking corn and PC: pelleting corn.
IBW: initial body weight; FBW: final body weight; ADG: average daily gain; FCR: feed conversion ratio and DMI: dry matter intake for day.
SEM: standard error of the means.

**Table 3** Effects of barley replacement with different corn processing on urinary purine derivatives and microbial protein supply in lambs fed

| Urine purine derivatives (Mmol/day) | 100% barley | Grinding corn | | Steam flacking corn | | Pelleting corn | | SEM | P-value | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 50% | 100% | 50% | 100% | 50% | 100% | | Anova | Control treatment *vs.* other treatments | Grinding *vs.* steam flacking | Grinding *vs.* pelleting | Pelleting *vs.* steam flacking | %50 *vs.* %1006 |
| Allantoin | 3.855 | 2.09 | 5.32 | 1.10 | 2.82 | 7.51 | 17.53 | 1.586 | 0.160 | 0.431 | 0.554 | 0.053 | 0.034 | 0.115 |
| Uric acid | 2.58 | 0.12 | 3.11 | 2.35 | 1.48 | 0.67 | 3.66 | 0.534 | 0.832 | 0.719 | 0.882 | 0.802 | 0.909 | 0.367 |
| Hypoxanthine + xanthine | 0.715 | 0.25 | 0.94 | 0.38 | 0.48 | 0.91 | 2.35 | 0.205 | 0.243 | 0.677 | 0.702 | 0.095 | 0.068 | 0.119 |
| Total excreted purine derivatives | 7.155 | 2.45 | 9.36 | 3.84 | 4.78 | 9.09 | 23.55 | 2.056 | 0.243 | 0.678 | 0.716 | 0.094 | 0.069 | 0.119 |
| Total absorbed purine derivatives | 7.77 | 2.14 | 10.33 | 3.82 | 4.92 | 10.06 | 27.21 | 2.438 | 0.240 | 0.680 | 0.719 | 0.093 | 0.068 | 0.118 |
| Microbial protein (g) | 39.76 | 20.20 | 43.25 | 34.52 | 23.49 | 54.73 | 95.45 | 7.491 | 0.099 | 0.767 | 0.874 | 0.022 | 0.016 | 0.224 |
| Microbial nitrogen (g) | 5. 65 | 1.56 | 7.51 | 2.78 | 3.58 | 7.31 | 19.78 | 1.772 | 0.240 | 0.680 | 0.718 | 0.093 | 0.068 | 0.118 |
| Nitrogen in DOMR (g/kg)[1] | 16.69 | 20.46 | 16.06 | 17.89 | 16.17 | 13.63 | 24.10 | 1.275 | 0.430 | 0.712 | 0.719 | 0.859 | 0.592 | 0.604 |

SEM: standard error of the means.

They observed that the release of energy is very slow for sorghum and occurs rapidly for the barley, and concluded that the use of a protein and grain source with a similar rate of degradability is of great importance. In ruminal fluid, ammonia, as a nitrogenous compound, plays a key role in the breakdown and synthesis of microbial proteins (McDonald *et al.* 2011). Seo *et al.* (2010) reported higher microbial protein synthesis, and Aldrich *et al.* (1993) reported greater microbial nitrogen permeability relative to diets that were balanced for the simultaneous release of nitrogen and protein. But Casper *et al.* (1999) in a study of dairy cows and Rotger *et al.* (2006) in a study of fattening cows did not find any relationship and interaction between the degradability of protein and carbohydrate sources on microbial protein production.

Different functional models were fitted to find the proper model for each variable. After testing for autocorrelation, heteroscedasticity, multicollinearity, and normality of error terms, assessments indicated that the semi-logarithmic model was appropriate for gross profit, while the logarithmic model was suitable for the elasticity of production (Tables 4 and 5). The estimated models are as below:

Gross profit= 386.920 -16.077 × LOG (INITIALWEIGHT) + 60.776 × LOG (DAILY BODY WEIGHT GAIN) - 64.306 × LOG (FEED COST) + 26.004 × LOG (DMI) + 1.650 × D

LOG (ELASTICITY)= 5.56236 -1.58488 × LOG (INITIALWEIGHT) + 0.07544 × D2 + 0.09742 × D3 + 0.06752 × D4 + 0.08585 × D5 + 0.07541 × D6 + 0.10407 × D7

**Table 4** The results of estimating regression model of gross profit

| Variable | Coefficient | Std. Error | t-statistic | Prob. |
|---|---|---|---|---|
| Log initial weight | -16.077*** | 5.067 | -3.173 | 0.0036 |
| Log daily body weight gain | 60.776*** | 3.242 | 18.748 | 0.0000 |
| Log feed cost | -64.306*** | 4.022 | -15.988 | 0.0000 |
| Log dry matter intake | 26.004** | 10.956 | 2.374 | 0.0245 |
| D[1] | 1.650* | 0.969 | 1.702 | 0.0994 |
| C | 386.920*** | 26.433 | 14.637 | 0.0000 |
| R-squared | 0.988 | | | |
| Adjusted R-squared | 0.986 | | | |
| F-statistic | 464.216 | | | |
| Prob (F-statistic) | 0.000 | | | |

[1] 0 for barley (control) ration and 1 otherwise.
*, **, ***: indicate significance at 10%, 5% and 1% level, respectively.

**Table 5** The results of estimating regression model of partial elasticity of production with respect to the feed

| Variable[1] | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| Log initial weight | -1.58489*** | 0.10372 | -15.28058 | 0.0000 |
| D2 | 0.07544* | 0.03711 | 2.03269 | 0.0524 |
| D3 | 0.09742** | 0.03707 | 2.62814 | 0.0142 |
| D4 | 0.06752* | 0.03709 | 1.82040 | 0.0802 |
| D5 | 0.08585** | 0.03739 | 2.29623 | 0.0300 |
| D6 | 0.07541** | 0.03885 | 1.94104 | 0.0632 |
| D7 | 0.10407*** | 0.03693 | 2.81796 | 0.0091 |
| C | 5.56236*** | 0.36607 | 15.19468 | 0.0000 |
| R-squared | 0.905 | | | |
| Adjusted R-squared | 0.879 | | | |
| F-statistic | 35.406 | | | |
| Prob (F-statistic) | 0.000 | | | |

D2: dummy variable (1 for the ration 20% grinding corn and 0, otherwise); D3: dummy variable (1 for the ration 40% grinding corn and 0, otherwise); D4: dummy variable (1 for the 20% steam flaking corn and 0, otherwise); D5: dummy variable (1 for the 40% steam flaking corn and 0, otherwise); D6: dummy variable (1 for the ration 20% pelleting corn and 0, otherwise) and D7: dummy variable (1 for the ration 40% pelleting corn and 0, otherwise).
*, **, ***: indicate significance at 10%, 5% and 1% level, respectively.

In the Table 3 was shows the results regarding the regression model for the gross profit. In this model except for D (P>0.05), all other coefficients were significant (P<0.05). Also, the overall model F-statistic was significant at a 5% level, so the predictive capability of the model as a whole was significant. Adjusted R-squared was over 98%, meaning this model could explain over 98% of the variation in gross profit. The results showed that the initial weight of the lambs had an inverse effect on their profitability so that every additional percent in initial weight could result in $16.08 less gross profit. Also, the daily body weight gain coefficient indicates that everyone more percent body weight gain will increase the gross profit by approximately $60.78. In contrast, every percentage increase in feed cost could decrease the gross profit by about $64.31. The coefficient of DMI shows that one more percent DMI could result in $26 more gross profit. Dummy variables did not show a significant effect on the gross profit at 5% but at a 10% probability level, it indicates a positive relationship that shows the utilization of rations other than 40% barley (control ration) could increase the gross profit, on average, about $1.65.

In the Table 4 shows the results regarding the regression model for the elasticity of production. The results indicated that coefficients of D3, D5, and D7 were significant (P<0.05). The overall model F-statistic was significant at 1% probability level that confirms the predictive capability of the model in general. The adjusted R-squared shows that the estimated model can explain about 88% of the variations in elasticity. The results also indicate that the initial weight of lambs has an inverse effect on their elasticity so that one percent increase in initial weight could result in 1.58 percent decrease in the partial elasticity of production with respect to the ration. Also, utilization of any rations of 40% grinding corn, 40% steam flaking corn and 40% pelleting corn could significantly increase the values of elasticity of production relative to the control ration (40% barley). The utilization of ration 40% pelleting corn resulted in the most increase in the value of elasticity of production relative to the ration 40% barley as the control treatment.

The inverse effects of the initial weight of lambs and feed cost on gross profitability revealed that less initial weight and feed cost could significantly (P<0.05) result in more profitability. However, a greater daily body weight gain and

DMI could significantly ($P<0.05$) increase the gross profit. Also, the utilization of processed corn instead of pure barley could increase the gross profit. The negative effect of feed cost on profitability was agreed with Cevger (2003), Ramsey *et al.* (2005), and Elfadl *et al.* (2015). Also, the positive effect of daily body weight gain was similar to the findings of Elfadl *et al.* (2015).

The partial elasticity of production in this study explains the percentage increase in body weight due to a one percent increase in the amount of ration. So, the negative estimated coefficient of initial weight indicates that the lighter lambs grow more rapidly than the heavier ones. Although, all corn-based rations resulted in less FCR and more growth rate overall, 40% pelleting corn could create a more accelerated growth rate compared to the other processed corn. These findings are consistent with the results of producing microbial protein in the rumen that show 40% pelleting ration had the highest microbial protein rather than other ration.

The elasticity of production is a measure of the responsiveness of the production function to the change in one input, also called the output elasticity, is the percentage change in production divided by the percentage change in the quantity of an input used for that production. For example, if increases in feed by 10% result in weight increases by 20%, the elasticity of production will be elasticity of production= 20% / 10%= 2. It is also called the partial output elasticity because it refers to the change in the output when only one output changes (that is, it's the partial derivate of the production function, as opposed to the total derivative).

High-efficiency lambs had a higher level of ammonia nitrogen in the rumen than low-efficiency lambs. Higher amounts of microbial nitrogen and microbial protein in both simple and interaction effects were observed in the high efficiency than low-efficiency lambs indicating rumen microbes in high effective animals had the maximum operation of synchronization of energy and nitrogen sources (Zhang *et al.* 2020).

## CONCLUSION

Replacing barley with processed corn for the fattening lambs improved body gain, FCR, DMI, microbial protein synthesis, and gross profit. Therefore, improving growth performance factors and profitability was accepted overall. The economic models showed that the initial weight and feed cost had negative and daily body weight gain and DMI had a positive effect on the gross profit. In addition, the higher initial weight could decrease partial production elasticity, but utilization of the corn-based rations resulted in more growth rate overall. Of course, the 40% pelleting corn could create a more accelerated growth rate, microbial protein synthesis, and profitability compared to the other processed corn. As a result, replacing barley with processed corn could improve both the growth performance and profitability of fattening lambs.

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## REFERENCES

Aldrich J.M., Muller L.D., Varga G.A. and Griel L.C. (1993). Nonstructural carbohydrate and protein effects on rumen fermentation, nutrient flow, and performance of dairy cows. *J. Dairy Sci.* **76,** 1091-1105.

Brassard M.E., Chouinard P.Y., Berthiaume R., Tremblay C.F., Gervais R., Martineau R. and Cing-mars D. (2015). Effects of grain source, grain processing, and protein degradability on rumen kinetics and microbial protein synthesis in Boer kids. *J. Anim. Sci.* **93,** 5355-5366.

Casper D.P., Maiga Brouk M.J. and Schingoethe D.J. (1999). Synchronization of carbohydrate and protein sources on fermentation and passage rates in dairy cows. *J. Dairy Sci.* **82,** 1779-1790.

Cevger Y. (2003). Quantitative methods to determine factors affecting profits of lamb fattening enterprises. *Vet. Med. Czech.* **48,** 25-31.

Chalupa W. (1975). Rumen bypass and protection of proteins and amino acids. *J. Dairy Sci.* **58,** 1198-1218.

Chen G. and Russell J.B. (1989). More monensin-sensitive, ammonia-producing bacteria from the rumen. *Appl. Environ. Microbiol.* **55,** 1052-1057.

Clark J.H., Klusmeyer T.H. and Cameron M.R. (1992). Microbialprotein synthesis and flows of nitrogen fractions to the duodenum of dairy cows. *J. Dairy Sci.* **75,** 2304-2323.

Elfadl E.A., Abo Fardos A.M. and Radwan H.A.A. (2015). Quantitative methods to determine factors affecting productivity and profitability of beef fattening enterprises in Egypt. *Glob. Vet.* **14,** 77-82.

Galyean M. and Rivera J. (2003). Nutritionally related disorders affecting feedlot cattle. *Canadian J. Anim. Sci.* **83,** 13-20.

Ghoorchi T., Lund P., Larsen M., Hvelplund T., Hansen-Moller J. and Weisbjerg M.R. (2013). Assessment of mobile bag method for estimating of *in vivo* starch digestibility. Animal. **7,** 265-271.

Haddad S.G. and Naser R.E. (2007). Partial replacement of barley grain for corn grain. Associative effects on lambs' growth performance. *Small Rumin. Res.* **72,** 92-95.

Herrera-Saldana R.E., Huber J.T. and Poore M.H. (1990). Dry matter,crude protein, and starch degradability of five cereal grains. *J. Dairy Sci.* **73,** 2386-2393.

Horadagoda A., Fulkerson W., Barchia I., Dobos R. and Nandra K. (2008). The effect of grain species, processing, and time of feeding on the efficiency of feed utilization and microbial protein synthesis in sheep. *Livest. Sci.* **114,** 117-126.

Javanmard M.R., Kazemi-Bonchenari M. and Afshar S. (2014). Investigation on optimal initial live weight and sex effect for fattening in fat-tailed Lori-Bakhtiari sheep in intensive rearing system. *J. Anim. Sci.* **3,** 240-245.

Koc H. (1996). The effect of sex and initial body weight of the fattening and carcass characteristics of Karaman lambs and economic analysis of fattening. MS Thesis. Gaziosmanpasa Univ., Tokat, Turkey.

Lehmann M. and Meeske R. (2007). Substituting maize grain with barley grain in concentrates fed to Jersey cows grazing Kikuyu-ryegrass pasture. *South African J. Anim. Sci.* **36,** 175-180.

Matras J., Bartle S.J. and Preston R.L. (1991). Nitrogen utilization in growing lambs: Effects of grain (starch) and protein sources with various rates of ruminal degradation. *J. Anim. Sci.* **69,** 339-347.

McAllister T.A., Rode L.M., Major D.J., Cheng K.J. and Buchanan-Smith J.G. (1990). Effect of ruminal microbial colonization on cereal grain digestion. *Canadian J. Anim. Sci*. **70,** 571-579.

McDonald P., Edwards R.A., Greenhalgh J.F.D., Morgan C.A., Sinclair L.A. and Wilkinson R.G. (2011). Animal Nutrition. Longman Group, Harlow, United Kingdom.

NRC. (2007). Nutrient Requirements of Small Ruminants, Sheep, Goats, Cervids, and New World Camelids. National Academy Press, Washington, D.C., USA.

Ørskov E.R., Fraser C., Gill J.C. and Corse E.L. (1971). The effect of an intensive production system of the type of cereal and time of weaning on the performance of lambs. *Anim. Prod. Sci.* **13,** 485-492.

Owens F.N. (2005). Impact of grain processing and quality on Holstein steer performance. Pp. 121-140 in Proc. Manag. Market. Qual. Holstein Steers Conf., University of Minnesota, Rochester, Minnesota, USA.

Ramsey R., Doye D., Ward C., Mc-Grann J., Falconer L. and Bevers S. (2005). Factors affecting beef cow-herd costs, production, and profits. *J. Agric. Appl. Econ.* **37,** 91-99.

Rotger A., Ferret A., Calsamiglia S. and Manteca X. (2006). Effects of nonstructural carbohydrates and protein sources on intake, apparent total tract digestibility, and ruminal metabolism were studied *in vivo* and *in vitro* with high-concentrate beef cattle diets. *J. Anim. Sci.* **84,** 1188-1196.

SAS Institute. (2003). SAS®/STAT Software, Release 9.1. SAS Institute, Inc., Cary, NC. USA.

Sayili M., Cimen M. and Karaalp M. (2009). The effects of different initial weight and sex on the fattening performance and economic analysis of fat-tailed lambs in pasture feeding in Turkey Bulgarian. *J. Agric. Sci.* **15,** 435-440.

Seo K.J., Yang J., Kim H.J., Upadhaya S.D., Cho W.M. and Ha J.K. (2010). Effects of synchronization of carbohydrate and protein supply on ruminal fermentation, nitrogen metabolism, and microbial protein synthesis in Holstein steers. *Asian-Australasian J. Anim. Sci*. **23,** 1455-1461.

Stern M.D., Varga G.A., Clark J.H., Firkins J.L., Huber J.T. and Palmquist D.L. (1994). Evaluation of chemical and physical properties of feeds that affect protein metabolism in the rumen. *J. Dairy Sci.* **77,** 2762-2786.

Storm E. and Ørskov E.R. (1983). The nutritive value of rumen micro-organisms in ruminants. *British J. Nutr.* **50,** 463-470.

Tuncel E., Yildirim Z. and Ak I. (1985). The effect of initial live weight on fattening performance in Malaya lambs. *J. Agric. Fac. Uludag Univ*. **6,** 57-63.

Yahaghi M., Liang J.B., Balcells J., Valizadeh R., Alimon A.R. and Ho Y.W. (2012). Effect of replacing barley with corn or sorghum grain on rumen fermentation characteristics and performance of Iranian Baluchi lamb fed high concentrate rations. *Anim. Prod. Sci.* **52,** 263-268.

Yu P., Huber J.T., Santos F.A.P., Simas J.M. and Therurer C.B. (1998). Effects of ground, steam-faked, and steam-rolled corn grains on performance of lactating cows. *J. Dairy Sci.* **81,** 777-783.

Zhang J., Zheng N., Shen W., Zhao S. and Wang J. (2020). Synchrony degree of dietary energy and nitrogen release influences microbial community, fermentation, and protein synthesis in a rumen simulation system. *Microoranisms.* **8(2),** 231-239.

Ziani K. and Khaled M.B. (2015). Partial substitution of barley for corn. effect on "Hamra" lamb growth performance, carcass and meat characteristics. *Trop. Anim. Health Prod*. **23,** 1573-7438.