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The Effects of Agricultural By-Products Supplemental Feeding on the Performance of Moghani Ewes in Nomadic Environments

Research Article

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ABSTRACT

Production of fodder is one of the key challenges in the nomadic sheep farming system in Iran. Thus, providing nutritional supplements for grazing sheep is crucial for the success of this farming style. On the other hand, using agricultural by-products is a vital option to address this need. This study aims to assess the impact of supplementing Moghani sheep in the nomadic system with wheat straw, corn straw, soybean straw, peanut straw, rapeseed straw, and potato vine as available agricultural by-products. The study involved 147 pregnant ewes (at 3.5 months gestation) in a completely randomized design with one control groups and six treatments, three replicates per treatment, and seven sheep per replicate. The experimental treatments include ration consisting of 30% alfalfa, 10% wheat straw (Treatment 1), ration consisting of 40% potato vine (Treatment 2), ration consisting of 40% corn straw (Treatment 3), ration consisting of 40% soybean straw (Treatment 4), ration consisting of 40% rapeseed straw (Treatment 5), ration consisting of 40% peanut straw (Treatment 6). All rations contained 60% concentrate. Results of *in vitro* gas production revealed that in the first 12 hours of this test, the peanut straw had the highest gas production, while after 12 hours, the highest gas production was related to soybean straw. Results indicated, supplementing with peanut straw improved the weight-related traits and the highest milk yield in the three months of lactation ($P<0.05$). This outcome could be attributed to the low acid detergent fiber (ADF; 33.46%), neutral detergent fiber (NDF, 43.66%) content, high ether extract (EE; 2.06%) and dry matter digestibility (DMD; 64.92%) of peanut straw. However, numerically, peanut straw improved the conception rate and lambing percentage. Overall, using agricultural by-products as supplementary feed for ewes on pastures enhances productive and reproductive traits and increases overall productivity.

KEY WORDS agricultural by-product, Moghani sheep, peanut straw, supplementary feeding.

INTRODUCTION

The different climates and the need to move from place to place in the different seasons to provide food for sheep and goats, has resulted into the formation of nomadic sheep rearing. The importance of conducting studies on nomadic farming becomes apparent when we know that 58.5% of the sheep and 39.7% of the goats in Iran are reared by the nomads (Ansari-Renani, 2016). Iran is located in one of the driest regions globally, with approximately 78.1% of its area characterized by arid (33.5%) and semi-arid (44.6%) climates (Najafi and Alizadeh, 2023). Therefore, all breeds of sheep in Iran, except for one breed, have developed a fat tail during the domestication process. High fat tail weight is a major factor for tropical climate condition during domestication of sheep, but it lost its importance because of losing market demand and efficient auxiliary feeding during drought (Nobari *et al.* 2021). Fodder production in such conditions is expensive and has a high risk due to the competition with agricultural products (on land and water resources). Nomadic and rural livestock farms are dependent on pastures for feeding. The impact of recurring droughts and overexploitation of pastures leads to reduced pasture fodder production, potentially resulting in nutritional deficiencies in nomadic livestock. Therefore, supplementary feeding of sheep is indispensable, and providing such supplements through agricultural by-products can be a suitable option to meet the nutritional requirements of sheep and reduce feeding costs. On the other hand, about 70% of the agricultural land is used for the production of livestock feed (FAO, 2009), they are considered the biggest competitors of humans in the field of agricultural production. Therefore, the use of agricultural by-products for livestock feeding and, also the optimal use of produced plants for livestock can provide more land for humans to provide human-specific crops. In recent years, many studies have been conducted to investigate the effect of by-products to feed different livestock species for various purpose. Marzouk *et al.* (2017) investigated the effect of using different levels of a by-product (olive cake) as a partial replacement of berseem hay on sheep performance. Results indicated that replacing berseem hay with up to 20% olive cake significantly improved digestibility and nutritional values compared to the control group. Positive effects were observed on litter weight, milk production, and lamb weight gain. Thus, incorporating up to 20% olive cake into sheep diets has beneficial effects without negative impacts on growth and milk yield. In another study on Holstein cattle, it was found that using greater amount of by-products instead par or human-edible concentrate led to increase human-edible feed conversion efficiency, net food production and also improved the performance of high-producing Holstein cattle (Naderi *et al.* 2022). Results of study on fattening Angus bulls, rations with various amount of potato vine silage were given to the bulls. The results showed that the treatments had no significant effect on the growth performance of cattle, but they significantly altered the biochemical routine indexes and antioxidant indexes of beef cattle serum (Deng *et al.* 2023).

In general, the effect of using agricultural by-products cannot be accepted as a fixed rule because plant species, animal breeds, processing methods and environmental conditions are different. Therefore, studies should be conducted based on livestock species and breeds, plant species, by-product processing methods, climatic conditions and livestock-rearing systems.

The nutritional requirements of pregnant ewes markedly increase during late gestation due to the growing demands of the developing fetus (Redmer *et al.* 2004). Adequate nutrition during this critical period is essential, as it can significantly influence the performance of the ewes and lambs (Moutik *et al.* 2019). Thus, providing supplementary feeding during this period can greatly enhance the overall health and viability of both the ewes and their offspring. Therefore, the current study aimed to investigate the effect of supplementary feeding of Moghani sheep in nomadic conditions during the last 45 days of gestation, using wheat straw, corn straw, soybean straw, peanut straw, rapeseed straw and potato vine as available agricultural by-products.

MATERIALS AND METHODS

Experiments

The aspects related to animal welfare in the present study conducted according to the recommendations of the Federation of Animal Science Societies of the United States (FASS, 2020) and under the supervision of the Animal Science Group of the Agricultural Research, Education, and Extension Center of Ardabil Province. The study assessed the effect of supplementary feeding using agricultural by-products including potato (*Solanum tubersum*) vine, corn (*Zea mays*) straw, soybean (*Glycine max*) straw, rapeseed (*Brassica napus*) straw and peanut (*Arachis hypogaea*) straw on pregnant sheep under nomadic conditions. Two studies were carried out.

Chemical composition, digestibility, and gas production analysis of the studied fodders

The chemical compositions of the experimental fodders (potato vine, corn straw, soybean straw, rapeseed straw and peanut straw), such as dry matter, organic matter, ash, crude protein, and crude fat determined by the standard method (AOAC, 2012). Also, neutral detergent fiber (NDF) and acid detergent fiber (ADF) content was determined by the method of Van Soest *et al.* (1991).

Dry matter digestibility (DMD), organic matter digestibility (OMD) and dry organic matter digestibility (DOMD) for all under-study fodder samples were determined by the two-stage Tilley and Terry technique (Tilley and Terry, 1963). Also, the *in vitro* gas production test was performed according to Menke and Steingass's (1988) method. The produced gas per sample was measured after 2, 4, 6, 8, 12, 24, 48, 72 and 96 hours of *in vitro* incubation.

Feeding of the pregnant ewes

For this purpose, 147 pregnant ewes (at 3.5 months pregnant) were included in a completely randomized design with one control groups and six treatments and three replicates (with seven observations per replicate) per treatment. The rations used in this study contained 60% concentrate and 40% fodder. The pregnant ewes in each treatment were fed 700 grams of the special ration of the same treatment every night (after returning from the pasture) during the last 45 days of pregnancy. Since, about 90% of the fetal mass growth occurs during the last third of the sheep pregnancy (Redmer *et al.* 2004). Thus, supplementary feeding during this period will be vital, especially for grazing sheep in the pasture. It is worth noting that the sheep belonging to each replicates (7 sheep) were fed inside a wooden pen measuring 5×4 meters. A week before the start of the experiment, an adaptation period was implemented to help the sheep adapt to the new conditions. The composition of the rations was based on NRC, (2007) guidelines (Table 1), ensuring equal levels of crude protein and metabolizable energy across treatments, with variations in ingredient percentages. The experimental treatments include: 1- ration consisting of 30% alfalfa, 10% wheat straw and 60% concentrate, 2- ration consisting of 40% potato vine and 60% concentrate, 3- ration consisting of 40% corn straw and 60% concentrate, 4- ration consisting of 40% soybean straw and 60% concentrate, 5- ration consisting of 40% rapeseed straw and 60% concentrate, 6- ration consisting of 40% peanut straw and 60% concentrate. We also had a control group consisting of sheep that were only grazed on pasture and received no supplementary forage or concentrate during excrement.

Data was collected on weight-related traits for ewes (pre-experiment ewes weight and weight gain of ewes) and lambs (birth weight, weaning weight and pre-weaning weight gain), milk yield, and three reproduction-related traits (conception rate, lambing percentage and pre-weaning mortality). The ewes were weighed before the start and after the end of the experiment. The difference in the weight of the sheep at the end of the experiment compared to the beginning of the experiment, divided by the number of days, was regarded as the daily weight gain of the sheep. The birth weight of the lambs was measured after drying the lambs and before feeding them colostrum. The weaning of the lambs was conducted when they reached three months of age.

Conception rate was calculated as the percentage of ewes bred that produce lambs. Conception rate was expressed as number of ewes lambing / number of ewes bred × 100 and lambing percentage was calculated as the number of lambs born / number of ewes lambing × 100. Also, pre-weaning mortality was expressed as the (number of lambs born – number of lambs weaned) / number of lambs born × 100 (Khojasteh *et al.* 2012).

Statistical analysis

The data analysis of this experiment was done using the general linear model (GLM) procedure of SAS 9.1 software (SAS, 2002) according to a completely randomized design by the following model:

$$Y_{ijk} = \mu + T_i + e_{ijk}$$

Where:
Y_{ijk}: evaluated trait.
T_i: effect of treatment.
e_{ijk}: random error.

Duncan's test was applied to compare the mean of the treatments and the significance level for this purpose was considered at $P \leq 0.05$.

RESULTS AND DISCUSSION

Taking into account the nutritional needs of food-producing animals, replacing conventional foods with agricultural by-products has the potential to boost the global food supply by approximately 13% in terms of calories, and by 15% regarding protein levels (Sandstrom *et al.* 2022).

In the present study, seven different agricultural by-products were used as supplementary feed for pregnant ewes. Except for alfalfa, which is grown specifically for livestock feed, the other six items were agricultural by-products (Table 2).

Among the experimental by-products, potato vine had the highest crude protein (8.91%). Also, the highest crude fiber, ether extract and ash belonged to soybean straw (51.60%), peanut straw (2.06%) and potato vine (20.73%), respectively. The digestibility coefficient of the agricultural by-products along with alfalfa hay as common fodder are presented in Table 3. Obtained results revealed that peanut straw had the highest DMD (64.92%) and DOMD (55.78%), also the highest OMD (62.58%) belonged to potato vine.

The results indicated that soybean straw had the highest gas production after 96 hours of *in vitro* incubation ($P<0.05$). The gas production from peanut straw exhibited a consistently increasing trend throughout the duration, unlike the other tested feeds (Figure 1).

Wheat and rapeseed straws is displayed a comparable gas production pattern, with both of these straws yielding the least amount of gas.

In vitro measurement of gas production is a quick method to predict some characteristics of animal feed, including microbial protein production potential as well as volatile fatty acids. In other words, gas production reveal food component digestibility by rumen microbes and, consequently, of rumen microbial biomass (Sommart *et al.* 2000).

The evidence obtained from the gas test, especially in the first 12 hours of the test, was consistent with the results of determining the digestibility of different food items, showing that wheat straw and rapeseed straw had the lowest gas production and digestibility.

Table 1 Ingredients of used diets in the current study for treatments (T) 1-6

Intergradient (%)	Diets					
	1(T1)	2(T2)	3(T3)	4(T4)	5(T5)	6(T6)
Alfalfa hay	30	-	-	-	-	-
Wheat straw	10	-	-	-	-	-
Corn straw	-	40	-	-	-	-
Soybean straw	-	-	40	-	-	-
Peanut straw	-	-	-	40	-	-
Rapeseed straw	-	-	-	-	40	-
Potato vine	-	-	-	-	-	40
Barley	39.5	33.5	35.5	35	39	38.5
Wheat bran	12	11	6.5	11	9.5	2
Soybean meal	4	6	6	6	5	8
Cottonseed meal	3	8	10	6.5	5	10
Mineral-vitamin supplement*	0.5	0.5	0.5	0.5	0.5	0.5
Di-calcium phosphate	0.5	0.5	0.5	0.5	0.5	0.5
Calcium carbonate	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Chemical composition[1]						
Crude protein (%)	13.42	13.47	13.41	13.45	13.52	13.42
EE (%)	2.54	2.77	2.74	2.71	2.63	1.96
NDF (%)	36.53	36.28	36.49	35.21	35.39	36.30
ADF (%)	21.83	22.80	23.46	21.97	23.14	24.49
Ash (%)	6.18	3.36	6.26	6.30	6.19	8.33
Metabolizable energy (Mcal/Kg)	2.42	2.42	2.40	2.49	2.43	2.34

* Provides per kg of mixed ration: vitamin A: 975000 IU; vitamin D_3: 750000 IU; vitamin E: 1800 IU; Zn: 143.0; Mn: 76.0 g; Cu: 48.6 g; Se: 19.5 g; Fe: 18.4 g; Ca: 8 g and Co: 1.3.
EE: ether extract; NDF: neutral detergent fiber and ADF: acid detergent fiber.

Table 2 Chemical composition of different agricultural by-products and alfalfa hay (%)

Item	Dry matter	Crude protein	Crude fiber	NDF	ADF	Ether extract	Ash	Glucose
Wheat straw	94.76	3.07^{e}	35.66^{c}	71.73^{ab}	38.86^{c}	1.26^{abc}	9.05^{bc}	2.29^{bc}
Soybean straw	93.36	4.27^{de}	51.60^{a}	74.26^{a}	55.73^{a}	1.46^{abc}	5.83^{d}	1.83^{c}
Rapeseed straw	95.70	3.90^{d}	45.46^{b}	74.73^{a}	50.26^{b}	0.86^{bc}	5.16^{d}	2.26^{bc}
Corn straw	93.92	5.98^{c}	36.26^{c}	68.93^{bc}	40.26^{c}	0.70^{c}	6.93^{cd}	3.32^{b}
Peanut straw	94.10	6.97^{bc}	38.00^{c}	43.66^{e}	33.46^{d}	2.06^{a}	9.35^{bc}	7.39^{a}
Potato vine	93.92	8.91^{b}	36.66^{c}	51.33^{d}	37.66^{c}	1.93^{ab}	20.73^{a}	3.35^{b}
Alfalfa hay	93.35	13.00^{a}	38.66^{c}	66.60^{c}	40.13^{c}	1.66^{abc}	10.23^{b}	1.61^{c}
SEM[2]	0.42	0.76	1.34	2.55	1.66	0.15	1.13	0.43
P-value	0.83	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

NDF: neutral detergent fiber and ADF: acid detergent fiber.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the mean.

Table 3 Digestibility of different agricultural by-products and alfalfa hay (%)

Item	DMD	OMD	DOMD
Wheat straw	36.25^{e}	32.04^{e}	29.79^{e}
Soybean straw	50.62^{d}	48.23^{d}	43.87^{d}
Rapeseed straw	32.67^{f}	28.51^{f}	26.71^{f}
Corn straw	53.71^{c}	51.18^{c}	46.67^{c}
Peanut straw	64.92^{a}	62.01^{a}	55.78^{a}
Potato vine	58.67^{b}	62.58^{a}	48.13^{bc}
Alfalfa hay	59.25^{b}	55.98^{b}	49.78^{b}
SEM	1.76	1.98	1.56
P-value	0.0001	0.0001	0.0001

DMD: dry matter digestibility; OMD: organic matter digestibility and DOMD: dry organic matter digestibility.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the mean.

The difference in the amount of gas production for different forages can be related to the quantities and degradability of nonstructural carbohydrates and NDF that affects the ruminal microbes, enzyme activity and amount of gas production during fermentation (Miranda-Romero *et al.* 2020).

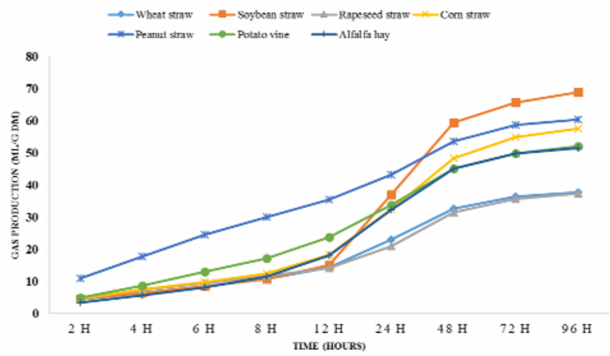

Figure 1 Results of gas production test on different agricultural by-products and alfalfa hay

The use of peanut straw compared to other treatments improved the performance in all weight-related traits (Table 4). A study on salt range lambs in Pakistan revealed that adding peanut straw up to 30% of the ration significantly improves body length, heart girth, live weight and average daily gain (Fiaz *et al.* 2022). One of the reasons for the positive effect of peanut straw on weight-related traits may be related to their higher digestibility and gas production compared to other feeds. In a study, it was found that replacing wheat straw with peanut straw leads to an increase in dry matter and nutrient intake, digestibility and nitrogen retention in sheep (Khan *et al.* 2013). Also, most of the peanut straw protein is soluble, therefore it supplies ruminal ammonia nitrogen and along with high fermentable fiber leads to an increase in microbial protein production (Foster *et al.* 2009).

Improvements in birth weight and weaning weight in lambs whose mothers (especially in treatments 4-6) received supplemental feeding indicated that the use of supplementary feeding in the last weeks of pregnancy of ewes, by improving the development of the fetus and mammary glands, leads to a significant increase in birth weight and weaning weight. In other words, with the increase of feed in the form of supplementary nutrition, more nutrients are available to the ewe and the lamb (more milk production by the ewe), which leads to an improvement in the weight gain of the ewes and the lambs and improves the survival condition of the lambs (Oldham *et al.* 2011).

This aligned with the findings of a study indicating that supplementary feeding of ewes during late pregnancy positively impacts the performance of ewes after lambing and also the growth of their lambs (Campos *et al.* 2022). The effect of using rapeseed straw was not statistically significant compared to the treatment without supplementary feeding ($P \leq 0.05$). This could reflect the low crude protein and fat content as well as the high fiber content in rapeseed straw, leading to low energy production and low nutritional value.

The ewes fed with peanut straw produced the most milk in all three months of lactation ($P \leq 0.05$). The lowest amount of milk production in the lactation period was related to the control group, which shows the high importance of proper supplementary feeding of the ewes that graze in the pasture (Table 5).

The significantly highest milk production in all three months of lactation were from the group of ewes that received peanut straw as supplementary feed. According to the previously mentioned results, peanut straw had the highest ether extract (EE) (2.06%), glucose (7.39%), and DMD (64.92%) with the optimal amount of protein (6.97%) and the lowest amount of NDF (43.66%) and ADF (33.46%), suggesting sufficient energy and protein for milk production.

Table 4 Effect of different treatments on the weight-related traits of the ewes and lambs (kg)

Treatments	Pre-experiment ewes weight	Weight gain of ewes	Birth weight	Pre-weaning weight gain	Weaning weight
No supplementary (Control)	45.90	2.00^{d}	3.34^{c}	14.90^{c}	18.24^{c}
Alfalfa hay + wheat straw	45.43	3.29^{c}	3.97^{b}	16.70^{ab}	20.67^{b}
Soybean straw	45.29	4.81^{b}	3.85^{bc}	16.39^{ab}	20.24^{b}
Rapeseed straw	46.33	2.14^{d}	3.51^{c}	15.73^{bc}	19.24^{bc}
Corn straw	46.33	3.90^{c}	4.18^{b}	16.78^{ab}	20.59^{b}
Peanut straw	46.19	5.62^{a}	4.72^{a}	17.83^{a}	22.55^{a}
Potato vine	46.43	3.33^{c}	4.13^{b}	16.63^{ab}	20.67^{b}
SEM	0.17	0.14	0.06	0.20	0.21
P-value	0.42	0.0001	0.0001	0.005	0.0001

The means within the same column with at least one common letter, do not have significant difference ($P > 0.05$).
SEM: standard error of the mean.

Table 5 Effect of different treatments on the milk production per day in the three months after lambing (grams)

Treatments	First month milk production	Second month milk production	Third month milk production
No Supplementary (Control)	136^{d}	194^{c}	195^{bc}
Alfalfa hay + wheat straw	176^{bc}	222^{ab}	230^{ab}
Soybean straw	191^{ab}	227^{ab}	259^{a}
Rapeseed straw	162^{c}	227^{ab}	205^{bc}
Corn straw	170^{bc}	202^{ab}	221^{bc}
Peanut straw	204^{a}	255^{a}	274^{a}
Potato vine	184^{ab}	220^{ab}	220^{bc}
SEM	3.70	4.50	4.72
P-value	0.01	0.0001	0.0001

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the mean.

Table 6 Effect of different treatments on the reproduction-related traits of the ewes and lambs (%)

Treatments	Conception	Lambing	Pre-weaning mortality
No Supplementary (Control)	80.95	76.19	11.11
Alfalfa hay + wheat straw	90.47	95.34	5.26
Soybean straw	90.47	95.34	5.26
Rapeseed straw	85.71	90.47	11.11
Corn straw	90.47	90.47	5.26
Peanut straw	95.24	100.00	5.26
Potato vine	90.47	95.34	5.26
P-value	0.27	0.66	0.37

Since milk is considered one of the economic products in the nomadic sheep rearing style, therefore, the use of peanut straw, on the one hand due to its low price and on the other hand due to the increase in milk production can be suitable for supplemental feeding of pregnant and lactating sheep. A study on the effects of feeding with agricultural by-products on milk production showed that the milk yield of sheep fed a diet containing honey increased by about 26.3% compared to the control diet. The increase in milk production in ewes led to a significant difference in the growth of lambs during the lactation period (Moutik *et al.* 2019).

Based on the obtained results, different treatments had no significant effect on reproduction-related traits (Table 6). However, numerically, peanut straw improved the conception rate and lambing percentage. One of the possible reasons for the positive effect of peanut straw on the reproduction of ewes can be attributed to its higher energy due to having a higher percentage of fat. Comparing the results related to reproduction in sheep that did not receive supplementary nutrition with the group that did receive such nutrition revealed that the lack of supplementary feeding in pregnant sheep can lead to reduced reproduction potential and consequent economic losses. The results of the current study were consistent with findings from a study on supplementary feeding of Lori-Bakhtiari ewes during the last 45 days of pregnancy. This previous research indicated that productivity and reproduction in ewes, as well as weaning weight and daily weight gain in lambs, were significantly higher in the group that received the supplementary ration compared to the control group (Gholami and Mostafa-Tehrani, 2022).

CONCLUSION

The results of this study indicate that supplementary feeding of sheep grazing in pastures, even with agricultural by-products, has a positive influence on various economic traits, including weight, reproduction-related traits, and milk production. Among the by-products evaluated, feeding sheep with peanut straw yielded the most significant improvements in these traits, as supported by statistical analyses (P<0.05). Specifically, ewes that received peanut straw exhibited enhanced weight gain and increased milk production across all lactation months compared to the control group and other treatments. While the use of rapeseed straw did not show a statistically significant effect on reproduction-related traits, peanut straw numerically improved conception rates and lambing percentages, suggesting its potential benefits in reproductive performance due to its higher energy and protein content. These findings underscore the importance of incorporating cost-effective by-products like peanut straw into the diet of sheep, particularly in nomadic settings where nutrient availability fluctuates seasonally. Further research on the implications of feeding various agricultural by-products, coupled with educational initiatives for nomadic and rural shepherds about their benefits, could lead to reduced feeding costs and improved economic returns for sheep producers.

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