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Nutritive value of different varieties of almond (*Prunus dulcis*) hulls

Saeid Jafari[1], AliReza Alizadeh[1] and Ali Imani[2]

[1]Department of Animal Science, Saveh Branch, Islamic Azad University, Saveh, Iran
[2]Horticulture Research Department, Seed and plant Improvement Institute, Karaj 31585-4119, Iran.

Abstract

This study was designed to examine the chemical composition, total tannin and total phenolic compounds in four prominent varieties of almond (*Prunus Dulcis*) hulls and compared their nutritive value to that of sugar beet pulp (B) and alfalfa (A). Samples of 4 varieties of almond: *Rabei* (R), *Mamaei* (M), *shahroud15* (SH15) and *Shokoufe* (SH) were collected around August from several regions in Iran. The results revealed that DM, CP, NDF, ADF, Ash, ADL, EE, TT, Ca and P concentration were significantly high in SH15 variety. However, TP and NFC were significantly high in R variety. At 2 h, the gas production was significantly high in SH15 variety, however, at 4, 6 and 8 h, it was significantly high in R variety. At 12, 24, 48, 72h and 96 h, gas production was significantly high in B. There was no difference in gas production parameters between Alfalfa and hulls of SH15, R, M and SH almond varieties. The study concluded that the nutritive values of the hulls of Iranian almond varieties are variable. It was also concluded that alfalfa hay can be substituted by Iranian almond hulls in ruminant ration.

Keywords: Almond Hulls, Chemical composition, Gas production

Introduction

With the dramatic rise in prices of corn, alfalfa and other traditional feed ingredients, nutritionist are getting more creative and turning to other non-traditional products. Almond (*Prunus Dulcis*) hulls are a plant waste that obtained by drying the portion of the almond fruit that surrounds the hard shell (Aguilar et al., 1984). Unlike many other horticultural by-products (pulps, pomaces), almond hulls are dried in harvesting process. Low moisture content makes almond hulls attractive feed for livestock allowing for long-term storage around the world (Reed and Brown, 1988).

Almond hulls are found more in areas of almond production. Production of almonds and the by-product has been increased rapidly in recent years. According to the FAO (2006), world production of almond in the year 2006 was 1.76 million tons. The five major producers are the USA (710,000 tons), Spain (220,000 tons), Syria (119,000 tons), Italy (110,000 tons) and Iran (108,000 tons). It was also reported that there was no information about the production of hulls but it was estimated to be about 35 percent of total weight of almond.

According to a study on almond hulls, the chemical composition of this by-product is considered to be a concentrate ingredient because of its low fibre content (Morrison, 1959). In another study, it was indicated that grinding of almond hull has no effect on intake but it decreases organic matter and crude fibre digestibility (Alibés et al., 1983).

The digestibility of the various nutrient components in diets of lactating goats containing 25 and 35% almond hull was low; but dietary matter (DM) intake was high (Reed and Brown, 1988). They also showed that weight gain was higher for 35% almond hull diet than for 25% almond hull.

The feeding value of almond hulls has been studied in the United States (Velasco et al., 1965); where the processing of almonds usually separates hulls and shells from the grain, resulting in a residue of lower quality. Various workers examined the carbohydrate content of almond hulls and reported total sugar contents over 250g/kg DM (Aguilar et al., 1984). They also indicated that variability was high among American almond hulls even within varieties, but CP (crude protein) and ash contents were consistent across varieties. The examination of hulls as a feedstuff indicated that

Corresponding author: AliReza Alizadeh M. Masouleh, Depatment of Animal Science, Saveh Branch, Islamic Azad University, Saveh 39187/366, Iran-Tel: +982554233314.

hulls contained 100 to 170 g/kg crude fibers (CF), 20 to 50 g/kg crude protein (CP), and a range from 180 to 300g/kg for sugars (Homedes, 1985).

Almond hulls have fairly high energy value for ruminant animals and they have comparable energy value of barley (Aguilar et al., 1984). A recent research (Con et al., 2007) on Killis goat showed that diets with 20 or 40% wheat straw or almond hulls and shells had a high DM intake with no effect on digestibility or blood parameters except it decreased blood urea level. Thus almond hull and shell seem to be safe and palatable roughage for goats.

Although the hulls are used in both feedlot and dairy rations but there seems to be very limited information on the nutritional value of almond hulls in the literature. Thus, this study aimed to describe the chemical composition, total tannin and total phenolic compounds of almond hulls cultivated in Iran and to compare the nutritive value of this by-product with those of sugar beet pulp and alfalfa.

Materials and Methods

Samples of almonds (*Prunus Dulcis*) varieties were randomly collected around August and September, 2009 from East (*Shahrekord*), North East (*Mashhad*) and Central (*Delijan*) regions of Iran. The collected varieties were *Rabei* (R), *Mamaei* (M), *shahroud15* (SH15) and *Shokoufe* (SH). *Alfalfa* (A) and *Sugar beet pulp* (B) were provided by Animal Science Research Institute of Iran (ASRI).

The chemical analyses were conducted in triplicates. In this study, DM, CP, ether extract (EE) and ash contents of the feeds were determined based on procedures of AOAC (1990). Neutral detergent fibre (NDF), acid detergent fiber (ADF) and lignin were determined according to Van Soest et al. (1991). Both ADF and NDF were expressed inclusive of residual ash. Total phenolic compounds and total tannin were measured by spectrophotometer as described by Makkar et al. (1993) using Folin-Cicalteu method. Tannins were quantified as the difference between phenolics before and after tannin removal from the extract using polyvinyl pyrolidone. The estimation of gas production was obtained by the method of Menke and steingass (1988). The gas Production data were fitted into the exponential equation (Ørskov and McDonald, 1979) as follow:

$$P = a + b\,[1 - e^{-(c * t)}]$$

Where P: fraction degraded in the time t, a: rapidly degradable fraction, b= slowly degradable fraction, e: the base of the natural logarithm and equal to 2.718, c: fractional degradation rate and t= incubation time.

The *in vitro* organic matter digestibility (OMD) and metabolizable energy (ME) content were estimated from the net 24h gas volume, CP and ash contents according to the equations described by Menke and Steingass (1988).

In vitro OMD= 14.88+ 0.889GV + 0.45CP+ 0.0651XA

In vitro ME=2.20+ (0.136×GV) + (0.0057×CP) + (0.00029×EE)

Where, OMD is organic matter digestibility (g/100 g); ME is metabolizable energy content (MJ/kg DM) and GV is net gas volume at 24h fermentation (ml/200 mg DM). EE and CP contents are calculated as g/kg DM whereas XA, the Ash content was calculated as g/100 g DM).

Statistical analysis

The data were analyzed statistically by one way analysis of variance (SAS, 2003). The statistical significance of the differences between means was tested using the Duncan multiple range test.

Table 1: *Chemical composition of the examined varieties of almond hulls (g/kg DM)

Trait	R	M	SH15	SH	SEM
DM (g/kg feed)	954.2 ^{b}	947.5 ^{b}	962.3 ^{a}	928.3 ^{c}	0.37
CP	32.7 ^{a}	26.5 ^{b}	32.0 ^{a}	23.2 ^{c}	0.14
NDF	280.5 ^{c}	294.4 ^{b}	32.64 ^{a}	32.40 ^{a}	0.63
ADF	188.3 ^{c}	198.5 ^{b}	251.2 ^{a}	252.2 ^{a}	0.22
Ash	81.2 ^{c}	86.1 ^{b}	128.3 ^{a}	62.7 ^{d}	0.14
ADL	92.4 ^{d}	104.3 ^{c}	143.1 ^{a}	115.5 ^{b}	0.18
EE	4.4 ^{c}	4.4 ^{c}	9.1 ^{a}	8.4 ^{b}	0.004
TP	35.7 ^{a}	34.1 ^{b}	32 ^{c}	33.6 ^{b}	0.03
TT	25.6 ^{b}	23.2 ^{c}	28.4 ^{a}	26.6 ^{b}	0.05
Ca	3.7 ^{b}	3.7 ^{b}	4.3 ^{a}	3.8 ^{b}	0.006
P	0.8 ^{c}	0.8 ^{c}	2.1 ^{a}	0.9 ^{b}	0.0014
NFC	601 ^{a}	588 ^{ab}	504 ^{c}	582 ^{b}	73

*Determined according to the method of Alizadeh et al. (2010)

DM: dry matter; CP: crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber, ADL: acid detergent lignin; EE: ether extract; TP: Total Phenolic compounds, TT: Total Tannin; Ca: calcium; P: phosphorus; Non fiber carbohydrates Nonfiber carbohydrates = 1000− (g aNDF + g CP + g EE + g ash/kg of diet DM) *R: Rabei; M: Mamaei; SH15: Shahroud 15; SH: Shokoufe;* Values on the same row with different superscript letters are significantly different (P<0.05)

Results

The chemical composition, total tannin, total phenolics contents in the hulls of the four varieties of almond are given in Table (1). The results showed that the almond hulls varieties are significantly (P<0.05) different in all of the chemical composition traits contents, as measured by chemical analysis also based on the gas production analysis. The results revealed that for DM, CP, NDF, ADF (also in SH), Ash, ADL, EE, TP, Ca and P concentration, SH15 variety the highest (P<0.05). However, TP and NFC were significantly higher in R variety than in the other groups. Cumulative gas production profiles are presented in Table 2. At 2 h, the gas production was significantly higher in SH15 variety, however, at 4, 6 and 8 h, it was significantly higher in R variety. At 12, 24, 48, 72 and 96 h, gas production was significantly higher in B variety. The kinetics of gas production obtained from the exponential model is presented in Table 3. Among almond hulls, a+b (ml/g DM) and c (particles /minute) parameters were significantly high in B and M (also in R) varieties, respectively.

The energy values of the examined forages were calculated from the amount of gas produced at 24 h of incubation. The predicted metabolizable energy (ME, MJ/kg DM), and organic matter digestibility (OMD) of hulls, A and B are presented in Table 4. The ME and OMD were significantly higher in B compared to the other groups.

Table 2: *In vitro* gas production of different almond varieties in different incubation times (ml/g DM)

Traits	GP_2	GP_4	GP_6	GP_8	GP_{12}	GP_{24}	GP_{48}	GP_{72}	GP_{96}
R	11.7^{b}	27.69^{a}	38.9^{a}	50.1^{a}	62.4^{b}	73.5^{b}	79.1^{b}	80.04^{b}	81.0^{b}
M	11.8^{ab}	28.04^{a}	38.9^{a}	49.9^{a}	61.8^{b}	72.9^{b}	78.6^{b}	79.2^{b}	80.2^{b}
SH15	12.59^{a}	23.7^{c}	30.5^{cd}	38.1^{c}	47.6^{d}	57.2^{d}	62.4^{d}	63.3^{a}	64.2^{d}
SH	9.51^{d}	25.8^{b}	34.2^{b}	44.3^{b}	51.04^{c}	62.1^{c}	68.8^{c}	71.8^{c}	72.3^{c}
B	9.1^{d}	21.9^{d}	31.7^{c}	46.1^{ab}	66.6^{a}	87.2^{a}	94.4^{a}	97.03^{a}	98.04^{a}
A	10.74^{c}	19.8^{e}	29.7^{d}	37.04^{c}	46.3^{d}	56.09^{d}	62.09^{d}	63.9^{d}	65.2^{d}
SEM	0.44	0.64	0.7	2.2	0.87	1.1	1.38	1.45	1.4

Values on the same column with different letters are significantly different (P < 0.05); $GP_{2\ to\ 96}$: incubation time (2 h to 96 h); R*: Rabei;* M*: Mamaei,* SH15*: Shahroud 15,* SH*: Shokoufe,* B*:Sugar Beet Pulp;* A*:Alfalfa*

Table 3: Parameters of the exponential equation of gas production during the different almond varieties hulls, alfalfa and sugar beet pulp incubation

Parameters	R	M	Sh15	Sh	B	A	SEM
A+b (ml/g DM)	79.5^{b}	78.9^{b}	63.1^{d}	70.1^{c}	97.2^{a}	63.4^{d}	1.4
C (ml/h)	0.13^{a}	0.13^{a}	0.11^{bc}	0.12^{ab}	0.09^{d}	0.10^{cd}	0.006

Values on the same row with different letters are significantly different (P<0.05); R*: Rabei;* M*: Mamaei,* SH15*: Shahroud 15,* SH*: Shokoufe,* B*: Sugar Beet Pulp;* A*: Alfalfa*

Table 4: Metabolizable energy and organic matter digestibility of the different almond variety hulls, alfalfa and sugar beet pulp

Sample	A	R	M	SH15	SH	B	SEM
OMD (%)	70.5^{c}	82.3^{b}	81.5^{b}	68.02^{d}	71.5^{c}	97.1^{a}	3.9
ME (MJ/Kg DM)	10.4^{c}	12.4^{b}	12.2^{b}	10.1^{d}	10.7^{c}	14.6^{a}	0.2

Values on the same row with different letters are significantly different (P < 0.05); R*: Rabei;* M*: Mamaei,* SH15*: Shahroud 15,* SH*: Shokoufe,* B*: Sugar Beet Pulp;* A*: Alfalfa*

Discussion

There are many factors affecting chemical composition and mineral content in almond hulls like stage of growth, maturity, variety, drying method and environment (Homedes., 1985). These factors interact to confer an influence on the nutritive value of the almond hulls. Morrison (1957) and Velasco et al. (1965) reported that CF, CP and EE contents in almond hulls were low. Homedes (1985) reported the protein content of American almond hulls ranged from 54 to 64 g/kg DM. Aguilar et al. (1984) reported the CP content in the varieties of Neplus, Merced and Nonpareil ranged from 50 to 70 g/kg DM. Almond hulls studied in this paper were lower in terms of CP content than reported by Aguilar et al. (1984) and Homedes (1985). This study justify that the chemical composition of almond hulls varies within variety. In the current study, the CP content, however, varies significantly among the almond varieties. This variation does not represent wide range of differences similar to that in ash and lignin contents. Norallahi et al. (2005) reported NDF (211 g/kg DM) and ADF (117 g/kg DM) of almond hulls harvested from central region in Iran. These results indicated that there is a wide range of difference even among Iranian almond hulls. The ranges of NDF and ADF reported by Homedes (1985) were 210-290 and 244-296 g/kg DM, respectively. He also noted the variation among local Iranian and foreign almond hulls for these contents. It has been established that ADF is a superior index of nutritive value in many feed stuffs. ADF has been found to have the highest correlation with digestible energy in almond hulls (Aguilar et al., 1984).

In the present study, ash content varied from 62.7 to 128.3 g/kg DM. This range is higher than that reported for the American almond hulls (Homedes., 1985). When the ash content is more than 9%, the feed is considered as "hull and dirt" (Homedes., 1985). So, every effort should be made to keep the twig out of almond hulls because these materials have high fibre (32.5%) and lignin (32.8%) contents and are very indigestible (Velasco et al., 1965).

High amount (4.5% of total hull weight) of phenolics such as tannins, rhamnetin, quercetin and kaempherol aglycones have been reported in almond hulls (Cruess et al., 1947). Other phenolic compounds, such as chlorogenic and benzoic acid derivatives were also found, but in lower quantities (Shahidi, 2002).

In vitro gas production after 24 h incubation has an indirect relationship with metabolisable energy in feedstuffs (Menke and Steingass, 1988). Gas production can be regarded as an indicator of carbohydrates degradation. Produced gas volume is a good parameter to predict substrate's digestibility, fermentation's end product and microbial protein synthesis in the *in vitro* system (Menke and Steingass, 1988). Gas production is basically the result of fermentation of carbohydrates to acetate, propionate and butyrate (Akinfemi et al., 2009). The fastest rate of gas production (c parameter of the exponential equation) was observed in hulls of the varieties R and M and this is possibly influenced by the soluble carbohydrate fraction.

The absence of difference in gas production parameters between A and hulls of SH15, R, M and SH almond varieties suggests that part of alfalfa hay can be substituted by Iranian almond hulls in ruminant ration. One of the main reasons for lower gas production in alfalfa incubation compared to that in hulls is the presence of lignin which protects carbohydrates from being attacked by rumen microbes (Reed et al., 1988). Also, increased gas production in R and M varieties was coincided with high NFC content of this valuable by-product.

Conclusion

We concluded that the nutritive values of the hulls of Iranian almond varieties are variable. The study indicated that these hulls could be a valuable alternative as a feed ingredient for ruminants such as alfalfa.

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