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## Determination of chemical composition, mineral content, antioxidant capacity and rumen degradability in various varieties of wasted date palm

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### ABSTRACT

This experiment was carried out in order to characterise six varieties of wasted date palm (WDP). In particular, chemical composition, including mineral content, phenolic compounds and antioxidant activity of varieties were determined. Dry matter (DM) disappearance in samples was determined at 0, 2, 4, 8, 12, 24, 48 h using the *in situ* method. The results of chemical composition showed that WDP varieties contained 3.23–6.27% Crude Protein (CP), 6.02–32.27% Neutral Detergent Fiber (NDF), 3.83–23.97% Acid Detergent Fiber (ADF), and 54.98–88.38% Non-Fibrous Carbohydrate (NFC) (DM basis). Kharak variety had the highest NDF and as result had the lowest NFC compared to other varieties ( $p < .05$ ). In addition, all varieties were good sources of minerals, especially potassium and calcium. The total phenolic compounds value was in the range of 2.96 to 9.43% where Koloteh variety had the lowest value and Kharak variety had the highest value. The Kharak variety had the highest flavonoids content and antioxidant activity compare to other varieties ( $p < .05$ ). The result of degradability showed that rapidly degradable fraction (a) of dry matter was high in all varieties except in Kharak. The Estameran had the highest and Kharak had the lowest potentially degradability fraction (D). Thus, according to the results of this experiment, it can be concluded that WDP can be used as part of the diet of ruminants that helps to reduce the costs.

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Rumen degradability; total phenolic compounds; flavonoids; *in situ* method

### Introduction

The shortage and high cost of animal feed in semi-arid countries are the major problems in animal husbandry. Therefore, using agricultural by-products as the alternative feed resources is a logical and suitable strategy in these regions. Most of the farmers in Iran are using all agricultural by-products such as wasted date palm (WDP) as feedstuff for their animals. Dates of palm tree (*Phoenix dactylifera* L.) are popular in the Middle Eastern Countries. Global production of date fruits exceeds 7 million metric tons annually in the world. Iran produced one million metric tons of dates in 2010, i.e. is the second largest producer country in the world (FAO 2010). In Iran, about 20–30% of date palm production (approximately 200–300 thousands tones) is considered as wasted product (not edible for human), and they are either discarded or used as animal feed, because of inadequate texture (too soft or too hard), or simply due to their low quality (MAJ 2011).

However, this by-product is rich in *nutrients* and bio-active compounds, which can be extracted and used as value added materials (Cheikh-Rouhou et al. 2006). It can also be used to feed animals with high-energy supplements (Al Yousef et al. 1994).

These fruits are rich in simple sugars like glucose and fructose (65–80%), and represent a good source of fibres (6.4–11.5%) as well as some essential minerals (0.10–916 mg/100g) (Al-Farsi et al. 2005a, 2005b). In addition, dates are characterised by low-fat content (0.2–0.5%) and lack of starch (Sawaya et al. 1982).

Al-Dobaib et al. (2009) reported that WDP can replace up to 30% of the grain ration of diet (corn and barley grain) in the diet of dairy goats. In other study, Dayani et al. (2012) reported that date pulp can be considered as a feed in ration of small ruminant and have more beneficial chemical nutrient components and nutritional values than its Pit (remaining product after pits removal from whole dates) and Lerd (produced after sugar extraction from pulp).

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The interesting nutritional value of date is also due to its natural antioxidant content that can be transferred to milk and meat of ruminant improving the quality of these products (Emami et al. 2015a; Santos et al. 2014). To date, there is very limited data regarding the characteristics of different varieties of WDP by product in animal nutrition. Therefore, the aim of this study was to determine the polyphenol and mineral contents, antioxidant capacity and the nutritive value of various varieties of WDP.

## Materials and methods

### Origin of samples

Six different WDP samples used in the experiments were collected from south (Shadgan, Khuzestan area) and south-east (Jiroft, Kerman area) of Iran. Samples divided to three groups: soft dates (SD) Mozafati, Koloteh, Mordasang dates, semi-dry dates (SDD) Estameran and Zahedi dates, and one type of dry date (DD) Kharak date.

### Proximate analysis

Dry Matter (DM) was determined by oven-drying at 90 °C to constant weight. The Crude protein (CP) determined by Kjeldahl nitrogen (ID 920.152), the percentage of CP was estimated by multiplying the total nitrogen content by a factor of 6.25. Ash was determined by combustion of the sample in a muffle furnace at 550 °C for 24 h (Shimifan, F-47, Iran) (ID 942.05). Ether extract content were determined by Soxtec device (Foss model 2050, Sweden (ID 920.39) using procedures of AOAC International (AOAC 2000), Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by Van Soest et al. (1991). Non-Fibrous Carbohydrate (NFC) content was estimated by difference of mean values, i.e. 100 – (Sum of percentages of moisture, NDF, ash, protein and fats). Gross energy values were determined by bomb calorimeter (PARR 1266, USA). To measure the minerals content, the ash was dissolved in HNO<sub>3</sub> with 50 g/l of LaCl<sub>3</sub> and the mineral content (Ca, Mg, Na, Fe and K) were analysed separately, using an atomic absorption spectrophotometer (Analytical jend, contra 700, Germany) (Larrauri et al. 1996). Phosphorus content (P) was determined by the phosphomolybdate method (DeFrain et al. 2004).

### Preparation of the extracts

The WDP crushed and cut to small pieces with a sharp knife, then extracted according to the method of

(Al-Turki et al. 2010) with slight modifications. Two grams of a lyophilised WDP were mixed with 100 ml of aqueous acetone 60% (v/v) for 60 min at room temperature. The extracts were then centrifuged at 4000g, for 30 min (Hettich universal Centrifuges, D-7200), paper filtered and stored at 4 °C until later analyses.

### Total phenolic compounds, flavonoids and antioxidant capacity

Total phenolic compounds (TPC) and total tannin (TT) were estimated using Folin–Ciocalteu reagent as described by (Makkar 2003).

For the condensed tannin (CT) fraction, the extract was treated with Butanol-HCL in the presence of ferric ammonium sulphate and CT was expressed as leucocyanidin equivalent as follows:

$$CT = (A_{550 \text{ nm}} \times 782.6) / (\text{Weight of sample dry matter})$$

where: A<sub>550 nm</sub>: is absorbance at 550 nm. The colorimetric data (in absorbance units) were converted to leucocyanidin equivalents based on the assumption that the colour yield of CT, E1%, 550 nm, is 460 (Porter et al. 1985).

The determination of total flavonoids (TF) was performed according to the colorimetric assay described by (Kim et al. 2003). A calibration curve was prepared with catechin and the results were expressed as mg catechin equivalents (CEQ)/100g.

The free radical scavenging activity of WDP samples were measured by the DPPH method proposed by (Brand-Williams et al. 1995) with a slight modification. Briefly, 100 μl of each sample was added to 2 ml of DPPH in ethanol solution (100 mM) in a test tube. After incubation at 37 °C for 30 min, 1 ml of chloroform was added and centrifuged at 3000 g for 5 min. the absorbance of clear solution was determined at 517 nm using spectrophotometer. An ethanolic solution of DPPH (100 mM) was used as control and the percentage of DPPH radical scavenging activity was calculated according to the following equation:

$$\text{Scavenging activity (\%)} = \frac{[(\text{absorbance of the control} - \text{absorbance of the sample}) / \text{absorbance of the control}] \times 100}{}$$

The antioxidant activity of WDP extracts was determined using a modified method of the assay of FRAP of Benzie and Strain (1999).

The FRAP reagent contained 2.5 ml of a 10 mM tripydyltriazine (TPTZ) solution in 40 mM HCl plus 2.5 ml of 20 mM FeCl<sub>3</sub> 6H<sub>2</sub>O and 25 ml of 0.3 M acetate buffer at pH 3.6. Freshly prepared FRAP reagent (3.0 ml) were warmed at 37 °C and mixed with 40 of WDP extract

and the reaction mixtures were later incubated at 37 °C. Absorbance at 593 nm was read with reference to a reagent blank containing distilled water which was also incubated at 37 °C for up to 1 h instead of 4 min, which was the original time applied in FRAP assay. Aqueous solutions of known Fe (II) concentrations in the range of 100–2000IM (FeSO<sub>4</sub>·7H<sub>2</sub>O) were used for calibration

### In situ degradability of DM

A nylon bag method (AFRC 1992) was used to determine the DM degradability of the WDP samples by suspending the bags in the rumens of three rumen-fistulated Holstein heifers of 430 ± 27 kg live weight. The heifers were fed with a diet containing 2.7 kg of alfalfa hay, 1.75 kg of corn silage, and 2.25 kg of concentrate per heifer daily.

Dried samples of experimental samples were milled through a 4 mm sieve were ground (Ika, model MF10, Germany). Five grams DM of each sample was put in each nylon bag, and incubated in the rumen for 2, 4, 8, 12, 24 and 48h. After each incubation, the bags were hand-washed thoroughly in cold running water until the rinsing water was clear, and oven-dried at 55 °C to a constant weight. The value of degradability at time 0 was obtained by washing three bags per sample for 1 h using cold water. Bags and contents were weighed to estimate degraded DM. The percentage of ruminal degradability (*Y*) of DM at time (*t*) was obtained from an exponential curve as  $Y = A + B(1 - e^{-Ct})$  which was fitted to the experimental data by iterative regression analysis (Ørskov & McDonald 1979).

The effective degradability (ED) of DM was estimated as follows:  $ED (\%) = (A + B \times C) / (C + k)$ . In these equations, 'A' is the soluble and very rapidly degradable fraction, and 'B' is the insoluble but potentially degradable fraction which degrades at a constant fractional rate (C) per unit time (t), ED is the effective degradability, and 'k' refers to the fractional outflow rate of small particles from the rumen. Particulate outflow rate from the rumen, was set to 0.03, 0.06, and 0.09/h.

### Statistical analysis

The data of chemical composition, mineral content, phenols and antioxidant capacity of WDP were analysed using the GLM procedure of SAS Institute (2002) with effect of variety in the model as:  $Y = \mu + T_i + e$ , where *Y* = dependent variable,  $\mu$  = overall mean of *Y*, *T* = variety effect, and *e* = residual error, while data of

**Table 1.** Chemical composition of varieties wasted date palm (% DM).

Variety	CP	Fat	Ash	NDF	ADF	NFC	GE, kj/100g
Mozafati	3.73 <sup>c</sup>	0.35 <sup>c</sup>	1.81 <sup>c</sup>	7.25 <sup>bcde</sup>	3.83 <sup>e</sup>	86.86 <sup>a</sup>	1534 <sup>c</sup>
Koloteh	3.23 <sup>c</sup>	0.40 <sup>b</sup>	1.97 <sup>b</sup>	6.02 <sup>de</sup>	4.04 <sup>de</sup>	88.38 <sup>a</sup>	1498 <sup>e</sup>
Mordasang	3.57 <sup>c</sup>	0.43 <sup>b</sup>	1.65 <sup>c</sup>	8.34 <sup>b</sup>	6.06 <sup>b</sup>	86.01 <sup>a</sup>	1483 <sup>f</sup>
Estameran	4.4 <sup>b</sup>	0.23 <sup>d</sup>	1.75 <sup>c</sup>	6.02 <sup>de</sup>	4.34 <sup>cde</sup>	87.50 <sup>a</sup>	1518 <sup>d</sup>
Zahedi	3.48 <sup>c</sup>	0.17 <sup>e</sup>	1.80 <sup>c</sup>	8.02 <sup>bd</sup>	5.33 <sup>b</sup>	86.53 <sup>a</sup>	1783 <sup>a</sup>
Kharak	6.27 <sup>a</sup>	0.67 <sup>a</sup>	5.81 <sup>a</sup>	32.27 <sup>a</sup>	23.97 <sup>a</sup>	54.98 <sup>b</sup>	1603 <sup>b</sup>
SEM	0.10	0.009	0.03	0.36	0.23	0.42	7.1

Mean values within a column with no common superscript differ significantly from each other ( $p < .05$ ).

rumen DM degradability were analysed using the GLM procedure with effect of variety and heifer in the model as:  $Y = \mu + T + H + e$ , where *Y*,  $\mu$ , *T<sub>i</sub>* and *e* were the same as former model and *H* = random effect of heifer. Statistical comparison of the variety means was performed using Tukey–Kramer test.

## Results and discussion

### Chemical and mineral composition

The chemical compositions of six varieties of WDP are given in Table 1. The WDP of different varieties had relatively low CP and this value was in the range of 3.23 to 6.27%, that Kharak variety had the highest CP (6.27%) compared to other varieties ( $p < .05$ ). The protein concentration in date fruit is around 1.5–3.2%, varying with date cultivar and variety (Al-Farsi et al. 2005a; Ismail et al. 2006). Al-Harrasi et al. (2014) reported that the level of protein in 22 date varieties growing in Sultanate of Oman is ranged from 1.8 to 3.8% (Al-Harrasi et al. 2014). The result of our study showed that the concentration of CP in WDP is higher than other studies. This increase can be due to difference in climate or use of nitrogen fertilisers. WDP varieties, except for Kharak variety, had lower amounts of NDF and ADF. Kharak variety had dry and roughage texture, and as expected, its NDF was higher than that of other varieties ( $p < .05$ ). Among chemical compounds, the value of NFC in the WDP was very high (54.98 to 88.38%). The lowest value of NFC was related to Kharak variety that it was due to high level of its NDF compared to other varieties.

The gross energy values of WDP varieties ranged from 1483 to 1603(kj/100g). The high gross energy value is due to the high carbohydrate of WDP varieties. The value of gross energy in this study was similar to Oman date palm fruits (Al-Harrasi et al. 2014). Although many studies have been done on the chemical composition of date palm, according to our studies, there is no information about the chemical composition of WDP. The major difference between palm fruit and wasted date palm is due to its lower

quality for humans use and this low-quality product is regarded as wasted for different reasons such as being too hard or too soft and contamination with external materials; it seems that their chemical composition would not be so different. This study is the first report on chemical composition of WDP varieties.

Al-Dobaib et al. (2009) reported that discarded date can replace up to 30% of the grain ration of diet (corn and barley grain) for dairy goats and it was found that this replacement had no negative impact on production and composition of milk in dairy goats. These researchers suggested the use of discarded date palm in the diet of small ruminants in tropical and subtropical areas where livestock are faced to shortage of food. Recently, Khezri et al. (2016) showed that adding 18% wasted date as a source of energy in sheep diets resulted in lack of adverse effects on digestion in sheep that suggests this by-product could be used as an alternative nutrient in sheep feeding. Generally, through results obtained by chemical compounds of different varieties of WDP, it can be concluded that this by-product can be used as a source of energy and a good alternative for energy-rich components like corn and barley grain due to having high amounts of NFC (due to the presence of soluble carbohydrates).

The mineral content of six varieties of WDP is shown in Table 2. Results showed that all WDP varieties are a good source of minerals particularly K and Ca. in Kharak variety, K was significantly higher compared to other varieties ( $p < .05$ ). The date fruit has

**Table 2.** Mineral content of varieties wasted date palm (mg/100g DM).

Variety	P	Na	Fe	K	Mg	Ca
Mozafati	0.70 <sup>e</sup>	17.62 <sup>d</sup>	6.56 <sup>e</sup>	1031.33 <sup>c</sup>	66.15 <sup>d</sup>	581.37 <sup>a</sup>
Koloteh	2.77 <sup>c</sup>	31.88 <sup>a</sup>	7.91 <sup>d</sup>	955.67 <sup>d</sup>	68.13 <sup>c</sup>	120.63 <sup>e</sup>
Mordasang	8.48 <sup>a</sup>	27.60 <sup>b</sup>	8.25 <sup>c</sup>	923.00 <sup>e</sup>	86.63 <sup>b</sup>	215.50 <sup>b</sup>
Estameran	1.49 <sup>d</sup>	16.60 <sup>e</sup>	9.14 <sup>b</sup>	944.67 <sup>d</sup>	54.73 <sup>e</sup>	98.71 <sup>f</sup>
Zahedi	2.72 <sup>c</sup>	16.70 <sup>e</sup>	9.09 <sup>b</sup>	1116.33 <sup>b</sup>	67.84 <sup>c</sup>	170.43 <sup>c</sup>
Kharak	3.30 <sup>b</sup>	25.25 <sup>c</sup>	16.92 <sup>a</sup>	2509.33 <sup>a</sup>	280.23 <sup>a</sup>	163.93 <sup>d</sup>
SEM	0.03	0.11	0.03	3.73	1.31	0.32

Mean values within a column with no common superscript differ significantly from each other ( $p < .05$ ).

also been described as a major source of Fe among fruits and berries (Khan et al. 2008; Borchani et al. 2010). The results of our study are in agreement with other published reports (Ahmed et al. 1995; AlHooti et al. 1995).

Currently, a wide ratio of Ca and P is considered acceptable in dairy cattle ration. However, it is recommended that the Ca:P ratio in the dairy cattle ration should be less than 7 (NRC 2001). In the present study, Ca/P ratio in all varieties was considerably high. These results suggest that although WDP varieties had very higher Ca contents, it may not be utilised properly due to high Ca:P ratio, caused by the lower P content. When WDP varieties make a significant part of the animal ration, supplementation of P will be required for proper utilisation of Ca and P.

### Total phenolic compounds, flavonoids and antioxidant capacity

The TPC of WDP varied from 2.96 to 9.43% sample. The highest TPC was obtained in Kharak date and the lowest TPC was found in Koloteh date. Also, Kharak date has the highest content of TT, TF and CT compared to other varieties ( $p < .05$ ) (Table 3).

Biglari et al. (2008) reported that the TPC of various types of date from Iran varied from 2.89 to 141.35 mg gallic acid equivalents (GAE)/100g sample. These results are similar to our study (Biglari et al. 2008). Al-Farsi et al. reported TPC values were between 172 and 246 mg gallic acid equivalents 100g fresh weight of Omani dates (Al-Farsi et al. 2007). Al-Harrasi et al. (2014) reported that the TPC of ten Algerian date contents ranged from 226 to 955 mg GAE/100g (167 to 709 mg GAE/100g of fresh weight) that were closer to the TPC value of Kharak date (Al-Harrasi et al. 2014).

Phenolic compounds such as tannins can play both negative and positive role depending on their type and amount. Low and moderate levels less than 4% of tannins in the diet favour nitrogen retention in

**Table 3.** Total phenolic, total tannin, condensed tannin, total flavonoid content and antioxidant capacity of varieties wasted date palm (mg/100g DM).

Variety	TPC	TT	CT	TF, mg CEQ/100 g	Antioxidant activity	
					FRAP, $\mu\text{mol}/100\text{g}$	DPPH
Mozafati	3.417 <sup>e</sup>	1.787 <sup>c</sup>	0.47 <sup>b</sup>	1.62 <sup>b</sup>	14.16 <sup>c</sup>	51.97 <sup>d</sup>
Koloteh	2.967 <sup>e</sup>	1.460 <sup>c</sup>	0.41 <sup>b</sup>	1.30 <sup>b</sup>	13.90 <sup>c</sup>	52.17 <sup>d</sup>
Mordasang	4.363 <sup>d</sup>	1.637 <sup>c</sup>	0.39 <sup>b</sup>	2.09 <sup>b</sup>	18.81 <sup>c</sup>	56.21 <sup>c</sup>
Estameran	5.043 <sup>c</sup>	2.827 <sup>b</sup>	0.46 <sup>b</sup>	2.22 <sup>b</sup>	30.01 <sup>b</sup>	62.08 <sup>b</sup>
Zahedi	5.657 <sup>b</sup>	2.577 <sup>b</sup>	0.47 <sup>b</sup>	2.51 <sup>b</sup>	29.43 <sup>b</sup>	72.23 <sup>b</sup>
Kharak	9.437 <sup>a</sup>	4.620 <sup>a</sup>	0.76 <sup>a</sup>	54.78 <sup>a</sup>	164.29 <sup>a</sup>	89.10 <sup>a</sup>
SEM	0.10	0.09	0.02	0.40	1.42	0.61

Mean values within a column with no common superscript differ significantly from each other ( $p < .05$ ).

TPC: total phenolic compound; TT: total tannin; CT: condensed tannin; TF: total flavonoids.

ruminant animals and thereby improve the growth and the production rate of milk, but the high levels of tannins can cause the proteins pass gastrointestinal tract, resulting in negative impact on the animal. Since, the level of tannins in the varieties of date palm is moderate, it seems that using WDP does not effect on animal's performance (Hove et al. 2001).

To measure the antioxidant activity of the different varieties of WDP, two methods of FRAP and DPPH were used. In both methods, Kharak variety had higher antioxidant activity than other varieties ( $p < .05$ ) though other varieties also had significant antioxidant activity (Table 3). Antioxidant activity of date palm fruit has been reported by many investigators (Mohamed & Al-Okbi 2005; Al-Farsi & Lee 2008); and the antioxidant activity of date is attributed to phytochemical compounds such as phenolic acids, flavonoids, anthocyanins, etc. (El-Shami et al. 1992; Yeh et al. 2009). Rock et al. (2009) showed that Medjool and Hallawi date cultivars could inhibit DPPH radicals by 44 and 39%, respectively, at a concentration of  $10 \mu\text{g/mL}^{-1}$  which is thought to be due to high levels of flavonoids and tannins present in ethyl acetate extract (Rock et al. 2009).

The results of this experiment are in line with results of Biglari et al. (2008) who reported that Kharak variety had higher antioxidant activity than other varieties due to having a higher level of phenolic compounds (Biglari et al. 2008). Recently, the interest in using natural antioxidants in livestock production has increased because they are considered to be safer than synthetic antioxidants and have greater practical potential for consumer's acceptability, palatability, stability, and shelf-life of animal products (Kang et al. 2008; Naveena et al. 2008). As a result, the search for natural antioxidants, especially in plants, has notably

increased in recent years. Waste products obtained from the processing of fruit and vegetables offer a practical and economic source of antioxidants that could be included in ruminant's diet instead of synthetic antioxidants.

Leaves, roots, skin and seed of many plants, such as grapes, pomegranate, green tea and date palm have antioxidant activity and this antioxidant activity is caused by compounds such as phenols, Flavonoids, vitamins, etc. (Naveena et al. 2008; Rababah et al. 2011; Amany et al. 2012; Emami et al. 2015b). Emami et al. (2015b) reported that pomegranate seed pulp by-products increase the oxidative stability of goats' meat due to having phenolic compounds (3.92% TPC) and therefore the antioxidant activity ( $782.1 \mu\text{mol Fe}^{2+}/\text{L}$ ) (Emami et al. 2015b). Santos et al. (2014) reported that the use of silage of remains of grapes that have compounds with antioxidant activity ( $19.5 \text{ mg GAE/g TPC}$ ) leads to absorption of these compounds in the digestive tract and transfer them to cows' milk. As a result, it leads to improved and increased antioxidant activity of milk (Santos et al. 2014). Therefore, according to the results, since the varieties of date palm, especially Kharak variety, showed high-antioxidant activity; using it in the ruminant nutrition might act as natural antioxidants in animal's products (meat and milk), however, *in vivo* research is needed to prove this issue.

### In situ degradability of DM

Dry matter disappearance at different incubation times are given in Table 4. In this experiment DM disappearance of all WDP samples from nylon bag incubated in rumen increased with increasing incubation time. At all times of incubation, Kharak variety had the lowest

**Table 4.** Dry matter rumen degradability and its coefficient of varieties wasted date palm.

	Wasted date palm						SEM
	Mozafati	Koloteh	Mordasang	Estameran	Zahedi	Kharak	
Incubation times, h							
2	0.41 <sup>c</sup>	0.41 <sup>c</sup>	0.45 <sup>ab</sup>	0.44 <sup>bc</sup>	0.48 <sup>a</sup>	0.26 <sup>d</sup>	0.01
4	0.51 <sup>c</sup>	0.55 <sup>b</sup>	0.53 <sup>bc</sup>	0.53 <sup>bc</sup>	0.60 <sup>a</sup>	0.31 <sup>d</sup>	0.01
8	0.58 <sup>b</sup>	0.59 <sup>b</sup>	0.57 <sup>b</sup>	0.60 <sup>b</sup>	0.65 <sup>a</sup>	0.37 <sup>c</sup>	0.01
12	0.061 <sup>c</sup>	0.63 <sup>bc</sup>	0.61 <sup>c</sup>	0.66 <sup>b</sup>	0.71 <sup>a</sup>	0.41 <sup>d</sup>	0.01
24	0.69 <sup>c</sup>	0.69 <sup>c</sup>	0.68 <sup>c</sup>	0.72 <sup>b</sup>	0.76 <sup>a</sup>	0.48 <sup>d</sup>	0.007
48	0.82 <sup>b</sup>	0.78 <sup>c</sup>	0.76 <sup>c</sup>	0.87 <sup>a</sup>	0.84 <sup>b</sup>	0.55 <sup>d</sup>	0.008
Estimated parameters							
a, g/g DM	0.35 <sup>a</sup>	0.35 <sup>a</sup>	0.35 <sup>a</sup>	0.36 <sup>a</sup>	0.34 <sup>a</sup>	0.18 <sup>b</sup>	0.01
b, g/g DM	0.41 <sup>b</sup>	0.39 <sup>b</sup>	0.38 <sup>b</sup>	0.47 <sup>a</sup>	0.45 <sup>a</sup>	0.34 <sup>c</sup>	0.01
c, h <sup>-1</sup>	0.07 <sup>c</sup>	0.13 <sup>ab</sup>	0.12 <sup>ab</sup>	0.08 <sup>bc</sup>	0.15 <sup>a</sup>	0.10 <sup>bc</sup>	0.01
D (a + b)	0.76 <sup>b</sup>	0.74 <sup>b</sup>	0.73 <sup>b</sup>	0.84 <sup>a</sup>	0.80 <sup>a</sup>	0.53 <sup>c</sup>	0.02
ED, 0.03/h	0.59 <sup>b</sup>	0.67 <sup>ab</sup>	0.65 <sup>ab</sup>	0.71 <sup>ab</sup>	0.73 <sup>a</sup>	0.45 <sup>c</sup>	0.04
ED, 0.03/h	0.54 <sup>b</sup>	0.62 <sup>ab</sup>	0.60 <sup>ab</sup>	0.64 <sup>ab</sup>	0.67 <sup>a</sup>	0.40 <sup>c</sup>	0.04
ED, 0.09/h	0.50 <sup>b</sup>	0.58 <sup>ab</sup>	0.56 <sup>ab</sup>	0.59 <sup>ab</sup>	0.63 <sup>a</sup>	0.37 <sup>c</sup>	0.03

Mean values within a row with no common superscript differ significantly from each other ( $p < .05$ ).

a: the water soluble fraction; b: the potentially degradable (insoluble) fraction; c: the degradation rate constant of b; ED: effective degradability.

degradation of DM. Degradation of rapidly degradable fraction (a) was significantly lower in the Kharak variety compared to that in other varieties (18%). There was no significant difference between other varieties. The value of insoluble but potentially degradable fraction (b) was highest in varieties of Zahedi and Estameran, lowest in Kharak variety and at moderate level in other varieties. Dayani et al. (2012) reported fraction (a) in pulp date palm by-products as 34.8%. Additionally, these studies also reported that the value of fraction (a) and fraction (b) in the pulp date is more than its value in pit and Lerd (Dayani et al. 2012). There is no information available including the kinetic digestion and disappearance of WDP varieties in the rumen, so there are no comparisons to be made with. Low level of fraction (a) in the Kharak variety can be due to the high amount of the NDF than other varieties that would lead to a reduction in the optional value of feed consumption in animals (Van Soest 1994). Pascual et al. (2000) noted that dry matter intake of sheep fed diets contained date Lerd that was lower than other date by-products, which is consistent with the low level of fraction (a). The high fractions (a + b) of the WDP varieties (except Kharak) show the presence of soluble nutrients that are expected to be instantaneously utilised by the rumen microbes (Ahmad Khan et al. 2015). Not only the total degradation, but also the rate of degradation, measured by the *in situ* nylon bag technique, is important for estimation of nutrient supply to ruminants. The degradation rate is also strongly related to digestible DM intake (Belachew et al. 2013). Thus, interspecies variations in DM degradability could result in differential intakes of the tree leaves when fed in large quantities. Considering fraction (a) and higher degradation of various varieties of WDP, except for Kharak, at initial times of incubation, it can be concluded that WDP can be replaced in the diet of ruminants as a part that had higher dry matter degradation with a part of diet such as corn and barley grain, that in turn leads to reduced consumed feed costs.

## Conclusions

Based on the results of this experiment, it can be concluded that WDP at various varieties can be used as a part of ruminant's diet. Considering chemical composition, all varieties except for Kharak variety have higher values of NFC. This higher value of NFC quickly increases the degradable fraction and leads to higher degradation of dry matter at initial times of incubation. Kharak variety although has lower values of NFC and higher values of CP and NDF compared to other

varieties, this variety had higher values of phenolic compounds and as result higher antioxidant activity compared to other varieties. Therefore, it seems that using this variety leads to improvement in the quality of animal products such as increasing the antioxidant activity of their milk and meat. Our results show that in addition to the data on chemical composition, information on the *in situ* ruminal degradation characteristic of WDP varieties are important for an accurate and efficient utilisation of the WDP varieties in livestock ration. Considering the higher value of WDP production, it can be used as an alternative in the diet of ruminants, especially in arid and semi-arid areas of Persian Gulf. However, the level of using them requires *in vivo* experiments.

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## Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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