Feed value evolution of whole discarded fruits and peels of two Moroccan *Opuntia ficus-indica* Mill. accessions

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Abstract

The use of crop and agro-industrial by-products in animal feeding is an alternative to fill the fodder deficit in low rainfall areas. The aim of the present study was to investigate the chemical composition and the in vitro dry matter digestibility (IVDMD) of whole discarded cactus fruits (WDCF) and their fruit peels (FP) for two accessions (spiny and spineless) during the three months when they are available. Forty samples were harvested from each accession once a month from an eight-year-old field. Each sample composed of ten WDCF. The results showed a significant effect (p<0.05) of the accession and the month for most studied parameters. For the three months combined, the average proportion of peel to whole fruit (FP/WDCF) was highest for the spiny accession compared to the spineless accession (50.4 vs. 46.1% dry matter (DM)). During the harvesting periods and for the two accessions, the DM averaged 16.9 and 16.3%; crude protein (CP) were 5.3 and 3.9% DM, respectively, for WDCF and FP. The neutral detergent fiber (NDF) was 24.9 and 11.5%; IVDMD was 77.7 and 90.7%; while the phosphorus (P) content was 0.09 and 0.07%, respectively, for WDCF and FP. With the harvesting period, for both products and the two accessions, the DM, Ash, CP and IVDMD decreased, while the three fiber components (NDF, ADF and ADL) increased. The nutritive value of the spiny accession collected in September had the highest value. Both WDCF and FP are supplementing the diets of ruminant cereal straw, while ensuring adequate protein and fiber in diets.

Keywords: arid zones, cactus pear by-products, nutritive value changes, ruminant feeding

INTRODUCTION

Ruminants are a major component of the agricultural sector in Morocco, especially in the western part of the country. The climate in this region is characterized by low rainfall with longer dry season. It hosts a large number of animals estimated at about 2.38 million heads, dominated by sheep which represents 81.40%, followed by cattle with 13.40% and goats with 5.20% (MAPMDREF, 2019). Livestock of this region produces 30% of the national red meat yield. Typically, feeding of ruminants is based on pastures and cereal by-products (stubble and straw). However, it must be highlighted that the rangelands in this region are degraded due to overgrazing and climatic change that also affect the availability of cereals. Consequently, the quantity and the quality of feed decline, resulting in lower intakes negatively impacting the ruminant productivity.

Therefore, the use of appropriate alternative feed supplements should be encouraged to provide animals in harsh conditions with major nutrients to balance diets and reduce their cost. Cactus seems to be a good alternative for roughage in some regions of Morocco during summer and fall. It can easily grow even on the poorest land showing high tolerance to drought (Pimienta-Barrios, 1994). It is widely cropped in the west and south of Morocco, and both cladodes and discarded fruit are used tofeed ruminants (Araba et al., 2013). The annual production of prickly pear for human consumption is estimated at more than one million tons, of which 40-50% is lost because of their deterioration under high temperature (Bendaou and

Ait Omar, 2013). These damaged fruits are referred to as whole discarded cactus fruits (WDCF). These fruits remain on the cactus plants for 2 to 3 months after the fruit harvesting period from June to August.

Many previous studies have been interested to the evaluate cactus pads in ruminant feed while very few targeted WDCF. The rational use of discarded cactus pear fruit in ruminant feed requires a knowledge of their nutritive value. The latter depends on genetic characteristics of the species or clones (Nefzaoui and Ben Salem, 2001), harvesting season (Felker, 2001) and growing conditions such as soil fertility and climate (Gonzalez, 1989).This study was undertaken to assess chemical composition and in vitro dry matter digestibility of WDCF and their peels (FP) of two accessions (spiny (S) and spineless (SS)) during the three months of fruit availability.

MATERIALS AND METHODS

Forty samples were collected from an eight-year-old *Opuntia ficus-indica* field including two accessions (spiny (S) and spineless (SS)) for September, October, and November. Each sample consisted on ten fruits. In the laboratory, half of the samples was left complete (WDCF) and the other half was fragmented into fruit peel (FP), juice and cactus seeds (SD). Samples were weighed and dried in a draft oven at 50°C for 4 to 7 days until it reached a constant weight. Dried samples were ground to pass through a 1-mm sieve and stored for analysis. Ash was determined by incinerating the samples in a muffle furnace at 550°C for 4 h. Total nitrogen (N) was analyzed with the Kjeldahl method (method 984.13; AOAC, 1995), modified by using a solution of boric acid (40 g L^{-1}) to receive free ammonia during distillation and a standard acid solution [sulfuric acid (0.005 N)] for titration. Crude protein (CP) was calculated as N×6.25. Chemical analysis of all samples used the method of Van Soest et al. (1991) for neutral detergent fiber (NDF), and Goering and Van Soest (1970) for acid detergent fiber (ADF) and acid detergent lignin (ADL). The NDF was determined directly and corrected by its ash content, whereas ADF and ADL were extracted successively and corrected by ash content of the ADL residue. An Ankom 200 Fiber Analyzer (ANKOM Tech. Corp., Fairport, NY) was used to determine NDF and ADF. The ADL was determined on ADF using 72% sulphuric acid to solubilize cellulose. In vitro dry matter digestibility (IVDMD) was obtained by pepsin-cellulase digestibility method (Tilley and Terry, 1963). Phosphorus (P) content was obtained by spectrophotometry (method 962.02; AOAC, 1995).

Analysis of variance was used to test for differences in percent DM, Ash, CP, NDF, ADF, ADL, P and IVDMD between accessions and month of harvest. The least significant differences test was used to compare the samples means. Differences were accepted when $P<0.05$. On the other hand, months were regressed separately on each nutritional parameter using data from the 30 replicates (n=30). Least square method was used for obtaining estimates of parameters in linear regression models.

RESULTS AND DISCUSSION

Physical appreciation

For both accessions and for the three months combined, the average proportions of peel to whole fruit (FP/WDCF), pulp to WDCF (PP/WDCF) and seeds to pulp (SD/PP) were 48.2, 51.8 and 17.5% respectively. Our results were similar for the FP/WDCF (48%) and were higher for the SD/PP proportion (12%) than those found by Kaanane (2000). However, FP/WDCF and SD/PP were highest for spiny accession (Table 1).

There was a significant ($P<0.05$) positive linear relationship between peel % (FP/WDCF) and harvesting month for each accession. The spineless accession had the highest FP/WDCF increase rate with advancing months (4.84 vs. 2.85). Mokoboki et al. (2005) reported that peel % was influenced by the rainfall pattern during the growth season when fruit tended to store water in peel.

Table 1. Importance of morphological components of whole discarded cactus fruits (WDCF).

	FP/WDCF (%)	PP/WDCF (%)	SD/PP (%)
Spiny	50.4^{a}±3.3	49.6^{c}±3.4	18.5^{e}±2.1
Spineless	46.1^{b}±4.3	53.9^{d}±4.3	16.6^{f}±1.5
Mean	48.25	51.75	17.55

Means in column followed by different letters of each product are significantly different at P<0.05.

FP = fruit peel; PP = pulp; SD = juice and cactus seeds.

Chemical composition and IVDMD

Significant differences were recorded for the two accessions and between months. The spiny accession showed a significant higher (p<0.05) value for all parameters studied and during the three months except for P content (Table 2). This finding was comparable to that of Rothman et al. (2013) who found that the cactus pear quality depends on genetic characteristics and on harvesting season.

Table 2. Chemical composition and IVDMD of two accessions for all months combined.

Accession		DM (%)	CP (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	Ash (%DM)	P (%)	IVDMD (%)
WDCF	Spiny	17.8^{a}	5.9^{a}	26.3^{a}	21.4^{a}	7.2^{a}	5.9^{a}	0.09^{a}	78.3^{a}
	Spineless	16.1^{b}	4.7^{b}	23.6^{b}	19.1^{b}	6.5^{b}	5.3^{b}	0.1^{a}	77^{b}
	Mean	16.9	5.3	24.9	20.3	6.9	5.5	0.09	77.7
FP	Spiny	17.3^{c}	4.2^{c}	12^{c}	10.2^{c}	1.6^{c}	9.5^{c}	0.08^{c}	92.2^{c}
	Spineless	15.3^{d}	3.6^{d}	11.01^{d}	8.6^{d}	1.3^{d}	9.3^{d}	0.07^{c}	89.1^{d}
	Mean	16.3	3.9	11.5	9.4	1.5	9.4	0.07	90.7

Means in column followed by different letters of each product are significantly different at P<0.05.

1. Dry matter (DM).

Dry matter (DM) content for accessions and months pooled for WDCF and PF averaged 16.9 and 16.3%. This value was in the range (15%) of value reported by Kaanane (2000) for cactus pear for human consumption (harvest between June and August). By contrast, lower DM content (8%) was found by Tegegne (2001) for Ethiopian cactus fruit.

There was a significant negative linear relationship (P<0.05) between DM and months for WDCF and FP. The decrease rates were higher for spiny products accession (-1.87 and -2.47) than the spineless products accession (-0.84and -1.02) (Figure 1).The decrease in DM content was probably due to the rainfall during these months, which was consistent with the forage results observed by Silva et al. (2017). However, Sibaoueih and Boujghagh (2010) noted an increase in DM of cactus pads between June, September and December.

2. Ash.

Ash content of FP was higher than WDCF for the two studied accessions. It averaged 9.4 and 5.5% DM, respectively, for FP and WDCF. Considerably lower ash content (1%) of cactus fruit was reported by Tegegne (2001) while Salmaoui (2010) found higher ash content in Moroccan cactus fruit peel about 16.7% DM. The ash of all products decreased significantly with the advancement of harvest month with medium regression coefficients ranging from 0.56 to 0.78 (Table 3). The P content of WDCF for both accessions exceeded that found earlier which was between 0.015 to 0.032% MS, while that of FP was like that found by Gebremeskel et al. (2017). Phosphorus also decreased with the harvest month for WDCF of spineless accession. Nefzaoui and Ben Salem (2001) reported that the trend of evolution of ash in cladodes was not clear and seemed to be high in spring, while Sarti (2000) found that this parameter was neither influenced by the harvest period nor by the accession for cactus pads.

Table 3. Linear-regression equations of each parameter on harvesting month for each accession and each product.

Parameter	Accession	Product	Harvesting months			Regression parameters		Data statistics	
			1	2	3	Intercept	Slope	R^2	p-value
Ash	Spiny	WDCF	6.75	6	5.25	7.5	-0.75	0.72	0.026
		PF	9.99	9.45	8.9	10.54	-0.54	0.58	0.031
	Spineless	WDCF	5.53	5.33	5.14	5.53	-0.19	0.78	0.024
		PF	9.87	9.26	8.64	10.49	-0.6	0.56	0.036
NDF	Spiny	WDCF	21.69	26.31	30.92	17.08	4.6	0.88	0.041
		PF	0.95	11.98	13.01	9.92	1.3	0.7	0.035
	Spineless	WDCF	18.08	23.62	29.16	12.54	5.5	0.94	0.037
		PF	9.39	11.01	12.64	8.76	1.6	0.69	0.043
ADL	Spiny	WDCF	5.67	7.25	8.83	4.09	1.6	0.88	0.029
		PF	1.18	1.65	2.13	0.71	0.5	0.7	0.027
	Spineless	WDCF	4.63	6.53	8.42	2.74	1.9	0.9	0.030
		PF	0.89	1.28	1.68	0.49	0.4	0.45	0.035

Regression equation: y = a+b*x, where y = ash or NDF or ADL, a = intercept, b = slope and x = month in fraction of year.

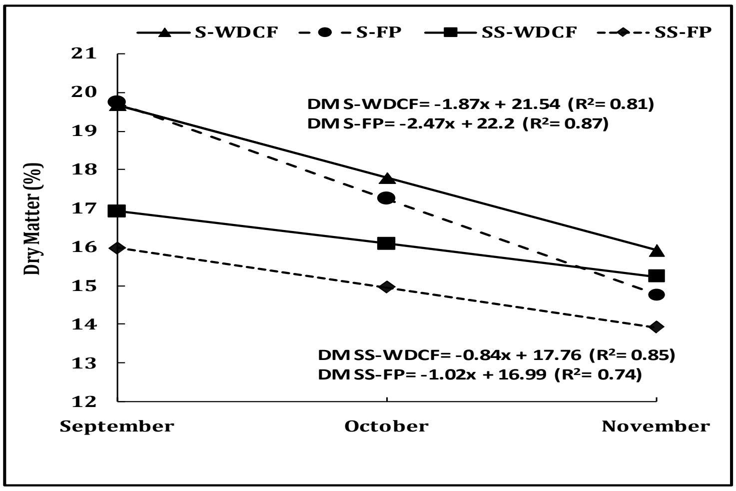

Figure 1. Changes in DM during harvesting months.

3. Crude protein (CP).

Mean CP content of WDCF (5.3% DM) was higher than in the FP (3.9% DM) for the two accessions and months combined. The spiny products showed a higher CP content than spineless products. Higher CP contents of FP were reported by Gebremeskel et al. (2017) for Ethiopian ecotypes ranging from 7 to 7.7% DM and by Salmaoui (2010) (6.56% DM) for Moroccan ecotypes. Tegegne (2001) found a low CP content of cactus fruits (1 to 2%) while Dubeux et al. (2019) revealed a high CP content (8.1%) of cactus fruits in Madagascar.

Crude protein content for the four products studied were below the minimum requirement (7% DM) recommended by Van Soest (1994) to maintain a suitable ruminal environment for microbial growth.

There was a significant negative linear relationship between CP and harvesting month ($P<0.05$) (Figure 2). The greatest decrease rate in CP content with harvesting month was exhibited by WDCF (-1.41), while PF were found to have the lowest decrease rate (-0.9).This trend was consistent with those reported by several works for cactus pads (Guevara Juan et al., 2004) and for harvested forages (Coblentz et al., 1998).

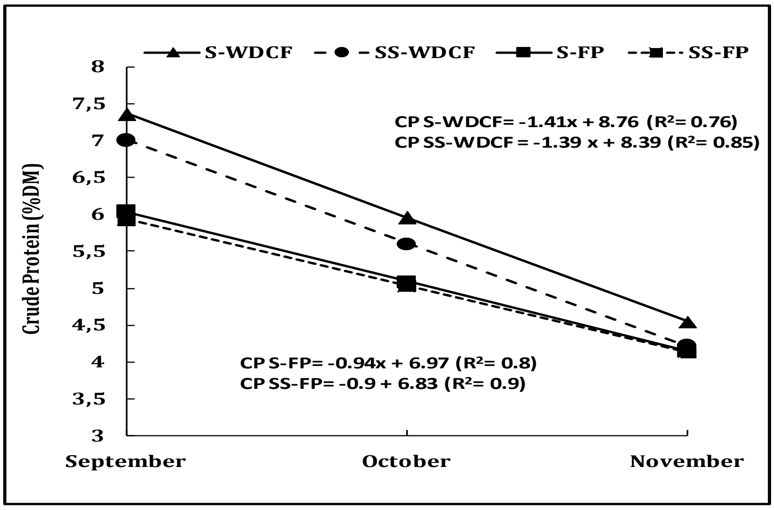

Figure 2. Changes in CP during harvesting months.

Fiber components (NDF, ADF and ADL)

Significant variations were found in cell wall contents (NDF, ADF and ADL) between accessions and products (WDCF and FP). The NDF content in FP was half that in WDCF for both accessions (Table 2). The NDF content in WDCF for the two accessions and months combined averaged 24.9% DM. Dubeux et al. (2019) found higher NDF content in cactus fruits (67.5%) as well as Sibaoueih and Boujghagh (2010) who reported NDF values from 37.9 to 45.5% for cladodes aged 6 to 18 months.

Average ADF contents were 20.3 and 9.4% DM, respectively, for WDCF and FP. The ADF content of WDCF was nearly double that of FP for both accessions and months combined. Tegegne (2001) found lowest crude fiber content (10.39% DM) for cactus pear. For WDCF our accessions exhibited a higher ADF than those for cladodes in other studies: 11-15% DM (Yousfi and Ben Salem, 2010) and 14.7% DM (Guevara Juan et al., 2004).

The ADL content pooled for accessions and months were 6.9 and 1.5% DM, respectively, for WDCF and FP.

There was a significant positive linear relationship between NDF content and month (Table 3). The slopes are higher for the Spineless accession 5.5 vs. 4.6 and 1.6 vs. 1.3 for WDCF and FP, respectively. The ADF and ADL also increased significantly with the harvest month (Figure 3; Table 3). This pattern of the three fiber parameters was like that of cactus pads (Guevara Juan et al., 2004) and harvested forages (Horrocks and Valentine, 1999).

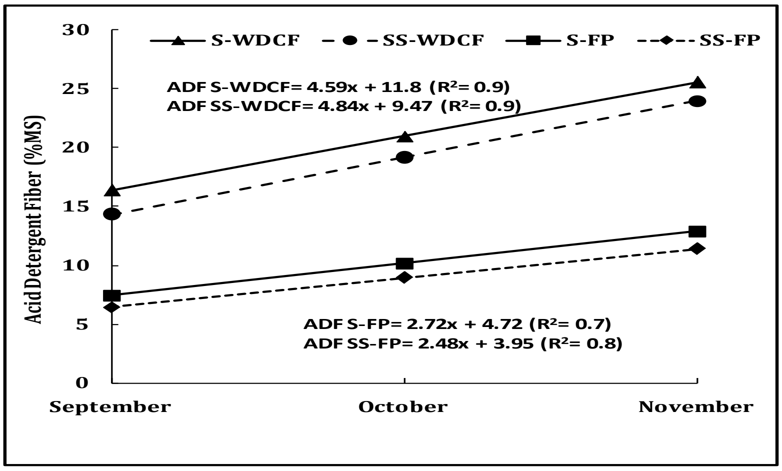

Figure 3. Changes in ADF during harvesting months.

In vitro dry matter digestibility (IVDMD)

The digestibility of FP for the two accessions was higher than for WDCF (90.7 vs. 77.7%). The peel digestibility was higher than that reported (75.6%) by Gebremeskel et al. (2017), while WDCF digestibility was lower (82.92%) than that found by Tegegne (2001). The spiny products were more digestible than spineless products. All the IVDMD values in our work were higher than the IVDMD for cladodes (62%) reported by Felker (2001).

There was a significant ($p<0.05$) negative linear relationship between percent IVDMD and months for each product (Figure 4). This negative regression was also recorded by Tegegne (2001) for cactus pads.

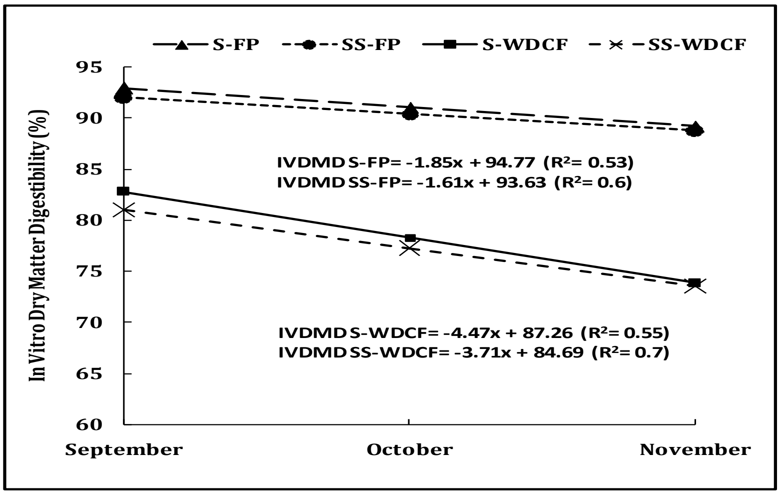

Figure 4. Changes in IVDMD during harvesting months.

CONCLUSIONS

It must be concluded that whole discarded *Opuntia ficus-indica* fruit (WDCF) and peels (FP) have a high potential as ruminant feed due to high energy content. Both whole fruits and peels are rich in ash and water, low in CP and cell wall components and have a high digestibility.

Three fiber components (NDF, ADF and ADL) tended to increase whereas DM, ash, CP and IVDMD showed a tendency to decline during the harvesting month. As the spiny accession contains a slightly higher CP content and as the highest in September, spiny products harvested during this month can be recommended if it is necessary to prioritize accessions and months.

The use of these products in ruminant feeding may require a supplementation, especially protein and/or fiber to obtain better results in terms of animal production.

Further studies still needed to elucidate the incorporating rates in ruminant diets and to find an adequate storing method for these wet products.

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