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Research Article

Assessing the nutritive value of fruit and vegetable residues as ruminant feed

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Abstract: This study was carried out to assess the nutritive value of summer fruits and vegetable residues (FVR) as ruminant feed. Samples of FVR were collected from the central terminal of Karaj in different summer months and homogenized before being analyzed for chemical composition. In situ degradability was determined, as were in vitro and in vivo digestibility. The results of chemical composition analysis for a period of 3 months showed significant differences in terms of dry matter (DM), Pb, and Mn contents. The higher Mn content was more than the allowance level established for livestock feeding. Although the in vitro digestibility coefficients were not significantly different, in situ degradability showed lower values for DM in August. This can be attributed to a higher ash content resulting in lower in vivo digestibility (56.22%). The findings indicate that there may be problems if FVR is used as a single and intact ruminant feed; however, FVR may still be regarded as a cheap source of feed after treatment.

Key words: Nutritive value, fruits and vegetable residues, in situ, in vitro, in vivo

Introduction

In many parts of the world, the development of animal production is limited due to low rainfall and a shortage of feed resources. Meanwhile, considerable amounts of various agricultural by-products that could be used as animal feed are lost each year. In order to compensate for feed shortages and to reduce feeding costs, attempts have been made to use agricultural and food industrial by-products as feed ingredients. In developing countries, the utilization of agricultural and food industry residues for animal feeding could be considered a solution. Recently, high feed costs and accessibility limitations have forced livestock breeders to use agricultural and food processing by-products and residues as animal feed (1). This will not only decrease the demand for cereal grains used as feed, allowing the grain to be used by humans, but may also solve the economic and ecological problems of FVR and waste disposal. Fruit and vegetable production is a very important part of the total agricultural crops produced in Iran; 3-5 million tons of fruits and vegetables are lost annually, however, because of shortages in processing and preservation facilities in this country (2). Studies carried out by the Tehran Municipal Recycling Organization estimate a daily production of 200-250 tons of FVR, which forms between 20% and 40% of the total municipal waste in this capital

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city (3). The large amount of this residue currently being generated every year constitutes a potential pollutant and daily disposal of the residues will increase the organization's costs. On the other hand, some research has shown the benefits of utilizing food industry residues in ruminant feeding (1,4). In fact, vegetable residues can be used in fresh, dried, or ensiled forms for animal feeding (5). Shamma and Asefi (3) used dried FVR in feedlot rations for male Holsteins and observed a lower feed:gain ratio (7.648 vs. 6.231) and higher weight gain (13%) for the group receiving their proposed feed compared with that of the control group. These researchers reported dry matter, crude protein, and ash for FVR as high as 93.5%, 13.2%, and 9.4%, respectively. However, to find out the optimum processing and utilization of such residues as animal feed, the seasonal availability and nutritive value of these by-products should be identified.

The objective of the present study was to investigate the chemical composition, digestibility, and degradability of FVR and to determine the variation of nutritive values among summer months.

Materials and methods

The Karaj Fruit and Vegetable Central Market, one of the largest fruit and vegetable markets in Alborz Province, was selected for sampling purposes. Once a week for a period of 12 weeks during the summer of 2008, 20 sub-samples were procured from different sites of residue bulks to obtain a 5-kg sample. The residues contained half fruit and half vegetable residues. These residues had constant ingredients, but differed in ratios. In order to solve this problem, as ratios could not be exactly determined because of previous degeneration, all of the samples were pooled to create homogeneous samples. After the separation of exogenous materials, the samples were homogenized and oven dried at 60 °C for 3 days in a ventilated oven. The dry samples were hammer-milled (2-5 cm) and used for in vitro and in situ studies.

Chemical composition, including crude protein (CP), crude fiber (CF), and ether extract (EE), was determined according to AOAC methods (6). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin were determined according to the Van Soest detergent system (7). Minerals such as calcium (Ca), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and lead (Pb) were also determined through the use of an atomic absorption spectroscopy system (Varian, SpectrAA - 300) in accordance with AOAC official method No. 975.03 (6). Phosphorous (P) was measured with a spectroscopy Coleman Junior 2 device according to AOAC official method No. 965.17 (6). Gross energy (GE) was determined using a bomb colorimetric system (model 1261-1755) (6). In situ rumen degradability was determined in triplicate (using 3 mature Taleshi steers weighing 383 ± 28.5 kg) through the procedure described by Ørskov et al. (8). Approximately 5 g of each sample was placed in a polyester bag (45 µm mesh; SEFAR PET 1000, Switzerland) and incubated for 4, 8, 16, 24, 48, 72, and 96 h in cattle fitted with rumen cannula. Washing losses (all nylon bags were washed after incubation, see below) were measured by weighing 5 g of sample in nylon bags that were soaked in water for 1 h and washed for 30 min in a domestic washing machine. After washing the nylon bags, the insoluble residues were dried at 55 °C for 48 h. The same procedure, without the soaking step, was followed when removing the nylon bags from the rumen. The resulting data were used to fit to the first order degradation equation: $P_t = a + b\,(1 - e^{-c\,(t-l)})$ (9). This equation was fitted by FCURVE 6 software[1], where *a*, *b*, *c*, and L are the intercept of the degradation curve at zero time, the potential degradability of the component that will in time be degraded, the rate constant for the degradation of *b*, and the lag phase for t > l, respectively. The resulting constants were used to estimate the potential degradability (PD) (a + b) and effective degradability (ED) according to equation of McDonald (9):

$$ED = a + bc/(k + c) \times \exp\left(-(c + k) \times l\right),$$

where k is the outflow rate, assumed to be 0.02 h^{-1} for animals fed at maintenance level.

The in vitro digestion of samples was assessed using the 2-stage digestion procedure (10). Then, the in vitro dry matter (DM) and organic matter (OM) coefficients of digestibility were calculated.

[1] Excel facilitated NEWAY software.

FVR samples (1000 kg fresh) were collected for 12 weeks throughout the summer 2008 and oven dried at 55 °C overnight to reach 90% DM. After the sampling period was finalized, the FVR samples were mixed in a horizontal feed mixer to create a FVR mixture for the whole season. Four mature male rams were used to determine the in vivo digestibility of FVR. At the outset of the trial, the rams were weighed and then fasted for 16 h without food and water. Individual feeding was performed with only fresh FVR for 9 days as an adaptation period and for 7 days as the sampling period. The feed was delivered twice a day at the maintenance level. Feed samples and feces were then analyzed to determine the apparent digestibility coefficients and TDN.

Data obtained from the experiment were analyzed (ANOVA) as a completely randomized statistical model ($Y_{ij} = \mu + T_i + e_{ij}$) using SAS statistical software version 9.0. In this model, the effect of different summer months was studied and means were compared using Duncan's least significant range test.

Results

The chemical composition, cell wall composition, GE, and mineral content of the FVR are shown in Table 1. Although CP, CF, EE, ash, NDF, ADF, lignin, Ca, Mg, K, Na, Fe, Cu, Zn, Pb, and GE did not differ significantly (P > 0.05) in different summer months, the DM, Pb, and Mn contents

Table 1. The chemical composition and gross energy (GE) content of fruit and vegetable residues in summer months (DM basis).

Item	July	August	September	Mean	P value
Dry matter (%)	9.87^{b1} ± 0.21	12.4^{a} ± 0.18	12.61^{a} ± 0.43	11.62 ± 0.46	0.0011
Crude protein (%)	15.46 ± 0.35	14.23 ± 0.70	14.50 ± 0.23	14.73 ± 0.30	0.2315
Crude fiber (%)	12.8 ± 1.25	12.46 ± 0.81	11.46 ± 1.33	12.44 ± 0.61	0.7101
Ether extract (%)	1.7 ± 0.30	1.28 ± 0.17	1.35 ± 0.35	1.44 ± 0.16	0.5716
Ash (%)	19.36 ± 2.37	25.46 ± 0.95	22.86 ± 1.87	22.55 ± 1.27	0.1357
NDF (%)	35.80 ± 4.00	32.96 ± 3.04	29.36 ± 2.20	32.71 ± 1.84	0.4101
ADF (%)	21.26 ± 2.05	20.46 ± 0.94	19.70 ± 0.68	20.47 ± 0.72	0.7307
Lignin (%)	3.46 ± 0.71	1.28 ± 0.38	1.35 ± 1.63	3.57 ± 0.59	0.5358
GE (kcal/kg)	3426.5 ± 138.83	3240.3 ± 17.21	3259.5 ± 11.45	3308.7 ± 50.16	0.2779
Calcium (%)	1.16 ± 0.49	1.57 ± 0.28	1.50 ± 0.48	1.41 ± 0.22	0.7783
Phosphorous (%)	0.38^{a} ± 0.01	0.30^{b} ± 0.01	0.35^{a} ± 0.02	0.34 ± 0.01	0.0166
Magnesium (%)	0.05 ± 0.01	0.19 ± 0.07	0.15 ± 0.07	0.13 ± 0.04	0.3067
Potassium (%)	1.03 ± 0.15	1.29 ± 0.07	1.26 ± 0.24	1.18 ± 0.09	0.5654
Sodium (%)	0.18 ± 0.00	0.45 ± 0.02	0.20 ± 0.05	0.28 ± 0.06	0.1756
Iron (mg/kg)	1595 ± 349.0	3691 ± 133.4	3897 ± 232.7	3061 ± 546.0	0.1631
Manganese (mg/kg)	49.95^{b} ± 2.11	109.8^{a} ± 21.48	97.0^{ab} ± 13.28	85.58 ± 11.67	0.0605
Copper (mg/kg)	13.50 ± 0.61	11.9 ± 1.10	14.2 ± 1.68	13.22 ± 0.85	0.5736
Zinc (mg/kg)	59.30 ± 2.99	60.03 ± 7.10	65.9 ± 3.17	61.74 ± 2.83	0.6443
Lead (mg/kg)	1.60 ± 0.17	7.15 ± 2.57	3.75 ± 1.07	4.16 ± 1.14	0.1236

[1] Means in the same row with different superscripts differ significantly (P < 0.05).

were significantly different ($P < 0.05$). In vitro and in vivo digestibilities were not significantly different ($P > 0.05$), as illustrated in Tables 2 and 3. The in vivo dry matter digestibility was 56.22% in sheep (Table 3). This relatively low value was due to the high ash content in these residues. The mean values for DM and OM rumen degradability are given in Tables 4 and 5. The rumen DM degradability for August was significantly lower than the other 2 summer months ($P < 0.05$), but this pattern was not consistent for OM degradability, as only September samples with higher OM degradation were determined to be significantly different ($P < 0.05$). The above patterns were also seen to be applicable for the effective degradability (ED) of DM and OM too. Degradability did not show significant difference between the samples. The potential DM degradability observed to be lower in the August samples was probably a result of the higher ash content.

Table 2. The in vitro digestibility of FVR for different summer months.

Month	DMD[1] (%)	OMD (%)	DOMD (%)
July	75.16 ± 5.19	76.33 ± 4.59	61.78 ± 5.61
August	73.30 ± 2.90	77.53 ± 3.55	57.86 ± 3.34
September	72.58 ± 3.51	78.10 ± 3.98	60.38 ± 4.54
Mean	73.68 ± 2.03	77.32 ± 2.05	60.0037
P value	0.8966	0.9518	0.8340

[1] DMD - dry matter digestibility; OMD - organic matter digestibility; DOMD - digestible organic matter in dry matter.

Table 3. The coefficients of in vivo digestibility and total digestible nutrients (TDN) of FVR in sheep.

Items (Percent)	DM	OM	CP	CF	EE	NFE	GE	TDN
Mean	56.22	70.24	66.44	55.02	59.11	75.17	68.38	50.9
Standard Error	1.32	0.87	1.20	2.85	1.98	0.17	1.38	0.57

Table 4. The in situ DM degradability of FVR for different summer months.

Sampling months	Deg_{24}[1]	Deg_{48}	PD	%C	ED	Lag Time (h)
June	89.94^{a2} ± 0.34	90.49^{a} ± 0.12	90.17^{a} ± 0.41	19.97^{a} ± 1.72	85.53 ± 0.52	1.43^{a} ± 0.56
August	87.47^{b} ± 0.22	87.56^{b} ± 0.30	87.53^{b} ± 0.09	29.03^{a} ± 2.12	84.03 ± 0.07	2.00^{a} ± 0.36
September	89.69^{b} ± 0.26	90.06^{a} ± 0.17	90.17^{a} ± 0.19	33.33^{a} ± 6.93	86.26 ± 0.33	1.90^{a} ± 0.90
P value	0.0014	0.0001	0.0006	0.1608	0.0119	0.8096

[1] Deg_{24} - degradability after 24 h incubation; Deg_{48} - degradability after 48 h incubation; PD - potential degradability (a + b); %C - degradation rate as percent; ED - effective degradability when rumen outflow rate is supposed to be 0.02/h.
[2] Means in the same column with different superscripts differ significantly ($P < 0.05$).

Table 5. The in situ OM degradability of FVR for different summer months.

Sampling months	Deg_{24}[1]	Deg_{48}	PD	%C	ED	LT (h)
June	$90.15^{b2} \pm 0.23$	$88.99^{b} \pm 1.60$	$88.97^{c} \pm 0.38$	$22.93^{a} \pm 3.62$	85.00 ± 0.99	$1.47^{a} \pm 0.75$
August	$90.20^{b} \pm 0.13$	$89.99^{b} \pm 0.35$	$90.13^{b} \pm 0.12$	$28.73^{a} \pm 0.71$	85.56 ± 0.17	$2.03^{a} \pm 0.09$
September	$94.07^{a} \pm 0.48$	$94.37^{a} \pm 0.49$	$93.976^{a} \pm 0.03$	$33.13^{a} \pm 6.81$	89.56 ± 0.37	$1.97^{a} \pm 0.98$
P value	0.0002	0.0181	<0.0001	0.3377	0.0037	0.8342

[1] Deg_{24} - degradability after 24 h incubation; Deg_{48} - degradability after 48 h incubation; PD - potential degradability (a + b); %C - degradation rate as percent; ED - effective degradability when rumen outflow rate is supposed to be 0.02/h; LT - lag time (h).

[2] Means in the same column with different superscripts differ significantly ($P < 0.05$).

Discussion

Differences in the DM content of the samples could be attributed to the differing DM content of some residues from carrots, potatoes, apples, etc. or to the warm summer weather, which can decrease the moisture content of vegetables and fruits. Other researchers have reported higher DM contents. Gasa et al. reported DM content between 11.8% and 28.2% (11) and Givens and Barber reported apple pulp DM at 32.3% (12).

Teymoornejad (13) reported DM contents for FVR in winter and spring 11.2% and 10.6%, respectively. The CP content for FVR was 14.73% in summer, which was higher than the 12.63% reported by Gasa et al. (11). Fazaeli (14) reported that the CP content for citrus pulp was 5.21% to 10.6%. Ghasemi (15) reported lemon pulp CP to be 10.2% (15). In addition, Givens and Barber (12) noted that the CP of apple pulp was 6.7% and Valizadeh (16) reported a CP content of 7.3% for apple pulp (16). Teymoornejad (13) reported CP contents for FVR as being 13.9% and 14.5% in winter and spring, respectively. The high ash content (22.55%) suggests soil spoilage or the existence of mud in samples or harvesting crops. This observation was also noted by Gasa et al. (11). Manganese (Mn) contents were significantly different for each of the summer months ($P < 0.05$), with an average content of 85.58 mg/kg. This value was higher than the standard allowance for farm animals (17) and may be attributed to the high incidence of fresh herbages rich in Mn, which make up a major part of the FVR. Phosphorous contents were also significantly different for each month ($P < 0.05$) and were 0.34% on average.

Gasa et al. (11), researching residues from food industries, observed in vitro coefficients of digestibility of 48.6%, 83.9%, and 91.1% for tomato residues, apple pulp, and cauliflower, respectively. The coefficients for digestibility for apple pulp and cauliflower were higher than that obtained for FVR; however, the digestibility coefficient was lower in tomato residues than in FVR because of the high crude fiber (46.8%) found in tomato residues. In a study of apple pulp, Valizadeh et al. (16) observed in vitro digestibility coefficients of 65.9% and 69% for DM and OM, respectively.

Examining the in situ degradability of food industry wastes, Gasa et al. (11) reported rumen dry matter degradation to be 47.1%, 89.1%, and 93.8% for tomato pulp, apple pulp, and cauliflower, respectively; the same items showed results of 50.8%, 89.5%, and 93.5% with regard to OM degradability. These findings suggest that FVR is more degradable than tomato pulp and more similar to fruit degradation. Furthermore, if the ash content can be decreased, in situ degradation will increase. The high degradation of FVR could be an outcome of the high NFC content and thus the high washing loss in spite of the insignificant differences observed for different months (48.53%, 48.56%, and 52.73% for July, August, and September, respectively). The lag time for FVR in different months was not found to be significantly different. The observed lag time (1.5-2 h) was related to the fibrous nature of the FVR, where rumen microbes need time to make observable decreases in weight after attaching to feed particles.

Valizadeh (16) reported 66.3% DM digestibility for apple pulp and Ghasemi (15) reported in vivo digestibility of lemon pulp at 82.55%. Both of these results are higher than expected because of the lower ash content of those feeds. Teymoornejad (13) reported the in vivo DM digestibility of FVR to be as high as 59.43 in spring months, a result that closely resembles our own.

In vivo OM digestibility in this experiment was 70.24%, which was close to those reported by Valizadeh (16) (68.7%), and Fazaeli (14), who studied apple pulp and reported OM digestibility as 83%. Teymoornejad (13) reported 74.5% digestibility, about 5% higher than the results of the present experiment, which is probably due to the higher NDF content in summer. Examining food industry wastes such as tomato pulp, apple pulp, ensiled apple pulp, peas, and cauliflower residues, Gasa et al. (11) reported the in vivo OM digestibility of these feeds at 48.08%, 84.70%, 80.04%, 70.21%, and 79.22%, respectively. With the exception of tomato pulp, these results were seen in the degradability trial. Johnson et al. (18) examined the in vivo digestibility of FVR and found higher digestibility values (62.2%, 54.5%, 84.6%, 43.4%, and 76.6% for DM, CP, EE, CF, and NFE, respectively) because of the lower ash content and different chemical composition of the residues used in their experiment. The coefficient of CP digestibility was somewhat lower but close to that of Teymoornejad (13), probably as a result of the higher lignin bound protein occurring in summer when plants were more mature.

The digestible energy and metabolizable energy of FVR were calculated according to the data collected in the study as 2343.3 and 1921.5 kcal/kg, respectively. These findings, combined with the results from previous experiments (10,11,14,15), show that FVR can be regarded as a ruminant feed, but that some treatment may be needed to decrease its ash content in order to obtain higher digestibility and intake levels.

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