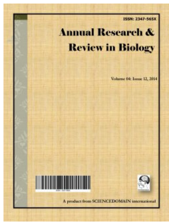

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Nutrients *In situ* Degradability of Almond Hulls and Cucumber Wastes from Greenhouse

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Authors' contributions

This work was carried out in collaboration between both authors. Author JMAO designed the study, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Author JA performed the statistical analysis and managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Information about degradability of nutrients, effective degradability (ED) values and digestion kinetics of agricultural wastes is important for feed manufacturing industry and farmers performing feed mixing practices who currently rely on nutritive values published by research institutions. Almond hull (AH) and cucumber plant (CW) were evaluated for ruminal dry matter (DM), crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) degradation kinetics.
Methodology: Duplicate bags containing 3 g ground raw material each were incubated in the rumen of two ruminally cannulated Assaf rams for 4, 8, 16, 24, 48 and 72 h. Rate and extent of ruminal degradation were estimated.
Results: Significant effects of byproduct type were observed in rapidly soluble and potentially degradable fractions, and degradation rates of DM, CP, ADF and NDF. The rapidly soluble DM, CP, ADF and NDF fractions were 16.10, 15.2, 10.64 and 14.06% for CW, and 7.21, 6.64, 6.00 and 5.62% for AH. The potentially degradable DM, CP, ADF and NDF fractions, respectively, were 55.82, 62.30, 49.40 and 55.09% for CW, and 47.61, 44.26, 46.34 and 48.53% for AH. The DM, CP,

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ADF and NDF disappearance in CW were higher (P < 0.05) compared to those in AH. Similarly, the effective degradability (ED) of DM, CP, ADF and NDF in AH were higher compared to AH (P < 0.05).

Conclusion: The new data presented in this study could be useful for the purposes of ration formulation and ruminants' performance. Considering these findings, one can propose using both byproducts, together or separately as part of ruminant rations. It can be introduced in these rations as part of roughage (wheat and barley straw). CW can be incorporated in ruminant rations as part of better quality roughage (legume hay).

Keywords: Almond hulls; cucumber wastes; In situ degradability.

1. INTRODUCTION

Middle East is characterized dry land farming. Depending on the regional rainfall, the availability of forages and cereal crops is highly seasonal. The importance of roughage as a feed resource is decreasing at the expense of cereals and agro-industrial byproducts [1-4]. Food crops leave a variety of residues (straws) that are utilized for animal feeding. Poor quality roughage comprises the only part of the diet for ruminant animals in most Middle East countries, for a considerable part of the year.

Such residues can supply a substantial part of the maintenance requirements of small ruminants in the Asian region [3,4].

Crop residues, particularly cereal straws and few agro-industrial byproducts such as almond hulls (AH), cucumber wastes (CW), olive cake, citrus pulp, sesame oil cake, bakery wastes, fruits and vegetable wastes have gained in importance due to the increasing demand of livestock feeds and to completive prices resulting from removal of feed subsidies.

Difficulty in using most of these byproducts as fresh material for long times is constrain for their wider use. The low nutritive value and the imbalanced nutrient profile of these byproducts is another reason, which limits their use as components of small ruminant diets.

AH and greenhouse wastes (GHW) has been evaluated in rations for poultry [5], small ruminants [3,6,7] and dairy cows [8]. Similarly, olive cake has been used in poultry [2], fattening lambs [1,4]. Information about its degradability of nutrients, effective degradability (ED) values and digestion kinetics of agricultural wastes is important for feed manufacturing industry and farmers performing feed mixing practices who currently rely on nutritive values published by research institutions. Unfortunately, the accuracy of ration formulation depends on the assumption that all wastes are represented by these limited published values. This study was undertaken to evaluate the nutritive value of almond hulls (AH) and cucumber wastes from greenhouse (CW) by means of chemical composition and ruminal degradability, fractional rates of digestion and effective degradability of DM, CP, ADF and NDF.

2. MATERIALS AND METHODS

2.1 Preparation of the Raw Ingredients

Almond hulls (AH) and green house cucumber wastes (CW) were obtained from local farms located near to the experimental site at faculty of agriculture farm, Tulkarm, Palestine.

2.2 *In situ* Study

Two 2-yr old Assaf rams were used in this study. Rams were fitted with rumen cannulas with a 4 cm internal diameter. One of the rams was later removed from the study due to health problems. A mixture of vetch hay and concentrate (60% concentrate (18% crude protein) and 40% hay) was offered to meet 1.25 × maintenance requirements. Hay contained 910, 90, 330, 450, 70 and 20 g/kg of DM, CP, ADF, NDF, ash, and fat, respectively. Chemical composition of the concentrate was 880, 160, 120, 340, 60, 30, 18 and 6 g/kg of DM, CP, ADF, NDF, ash, crude fat, Ca, and P, respectively. Concentrate contained vitamins A, D3 and E at levels of 50000, 700, 30 IU/kg, respectively.

The AH and CW were obtained from nearby sources, CW is a mixtures of leaves, stems and some fruits during summer after finishing a greenhouse cultivation period. AH was bought from an almond fruit crushing factory, Tulkarm city, Palestine. Raw ingredients (*i,e.* AH, CW) were dried and ground to pass through a 2 mm screen. Three-gram samples were weighed into nylon bags (8 cm × 16 cm) with 40–45 µ pore size. Prior to *in situ* degradability procedure, proximate analyses were performed on doublicates (3 g) according to the Association of Official Analytical Chemists, AOAC [9]. Two samples from each ingredient (*i.e*, AH, CW) were incubated in the rumen of each of the two remaining rams for 4, 8, 16, 24, 48 and 72 hr. After incubation, the bags were removed from the rumen and rinsed with cold tap water, until the rinsing water ran clear, then dried at 65℃ for 48 h in an oven and weighed as described by Ørskov [10] and Janicki and Stallings [11]. Ruminal disappearance (*D*) at each incubation time was calculated as the difference between the residues and original samples.

2.3 Chemical Analysis

Following AOAC [9] procedures, samples were analyzed for DM (100℃ in air-forced oven for 24 h; method 967.03), ash (550℃ in ashing furnace for 6 h; method 942), CP (Kjeldahl procedure), TECATOR, Box 70, Hoganas, Sweden). Additionally, samples were analyzed for neutral detergent fiber (aNDF; with heat stable-amylase and sodium sulfite) and acid detergent fiber (ADF; ANKOM 2000 fiber analyzer, ANKOM Technology Corporation, Fairport, NY, USA) according to Van Soest et al. [12]. Values for aNDF and ADF are expressed inclusive of residual ash.

2.4 Statistical Analysis

The amounts of DM, CP, ADF and NDF in the residues, expressed as percentages of original samples, were determined for each bag. Two observations from each ram were obtained for each raw material and occupation time. Ruminal kinetics parameters were estimated using PROC NLIN procedure of SAS, [13] fitting the exponential model of Ørskov and McDonald [14].

$$D = a + b\,(1 - e^{-ct}) \quad (1)$$

Where D is rumen disappearance at time t, a is the rapidly soluble fraction, b *is* the potentially degradable (fermentable) fraction, and c the constant rate of degradation of b (percentage per hour).

Effective degradability (ED) of nutrient components was calculated applying the equation of Ørskov and Mc Donald [14]:

$$\mathrm{ED} = a + [(bc)/(c+k)] \quad (2)$$

Where a, b, c, t are the same as defined in (1) and k is the rumen outflow rate of 2, 5 and 8% h^{-1}.

The data obtained (degradation characteristics, effective degradability and disappearance rates) were subjected to statistical analyses using PROC MIXED procedure of SAS [13]. Because of the inherent differences between rams, each ram was considered as a block (randomized complete block design with two replicates per treatment). Treatment (type of by product) was fitted as a fixed factor while block (animal) and block*treatment were fitted as random factors according to the following model:

$$y_{ijl} = \mu + \tau_i + \beta_j + \tau\beta_{ij} + \varepsilon_{ijl} \quad (3)$$

Where y_{ijl} is observation l in treatment i and block j, μ is the overall mean, τ_i is the effect of treatment i, β_j is the effect of block j, $\tau\beta_{ij}$ is the interaction effect of treatment i and block j, and ε_{ijl} is random error with mean 0 and variance σ^2.

3. RESULTS

Proximate analyses of AH and CW are presented in Table 1. The CP of AH evaluated in this study was 34.0 g/ kg DM. The rapidly soluble fraction '*a*' of DM was higher (P<0.05) in CW (16.10%) compared to AH (7.20%), Table 2. The insoluble but rumen degradable fraction of DM, 'b' was lower (P<0.05) in AH (47.60%) compared to that in CW (55.80%). CW had higher (P<0.05) amount of potentially degradable DM (a + b) than AH (72.00% and 54.80%). The same trends were found for CP, ADF, and NDF where CW had consistently higher values (P < 0.05) of a, b, and a + b (Tables 3-5).

Table 1. Chemical composition[1] of cucumber wastes (CW) and almond hulls (AH), g/ kg DM

Nutrient	CW	AH
Dry matter	540.0	890.0
Crude protein	151.0	34.0
aNDF	253.0	830.0
ADF	198.0	660.0
Ash	70.0	69.0

[1]These values are the means of two samples.
aNDF = Neutral detergent fiber; ADF = Acid detergent fiber

The effective degradability of DM, CP, ADF and NDF in AH and CW are given in Tables (2-5). The data have been calculated using rumen outflow rates of 3, 5 and 8 h^{-1}. There were differences (P<0.05) between AH and CW in effective degradability of DM, CP, ADF and NDF (ED of CW was higher than that of AH for all tested nutrients).

Disappearance rates (%) of DM, CP, ADF and NDF for AH and CW at different rumen incubation times are presented in Tables (2- 5). CW had higher ($P<0.05$) disappearance rates of DM, CP, ADF and NDF at all incubation times. At 72 h of incubation, disappearance rates of all tested nutrients were consistently above 50% for CW and below 50% for AH.

Table 2. Degradation characteristics and disappearance of dry matter (DM) in cucumber wastes (CW) and almond hulls (AH)

	CW	AH	SEM[6]
Degradation characteristics			
a[1]%	16.1[a]	7.2[b]	0.11
b[2]%	55.8[a]	47.5[b]	0.24
c[3]	0.01[b]	0.02[a]	0.009
a+b[4%]	61.9[a]	54.7[b]	0.34
Effective degradability (ED)[5]			
k=0.02	48.2[a]	36.6[b]	0.46
k=0.05	35.7[a]	25.9[b]	0.41
k=0.08	31.0[a]	20.9[b]	0.33
Disappearance (%)			
24hrs	47.3[a]	34.9[b]	0.52
48hrs	57.1[a]	46.4[b]	0.60
72hrs	64.2[a]	49.2[b]	0.46

CW= Cucumber waste; AH= Almond hulls
[1,2,3,4] constants in the equation $D = a + b(1-e^{-ct})$, where P is level of degradation at time "t", "a", readily soluble fraction; "b", insoluble fraction but degradable in rumen; "c", rate of degradation of "b" per hour; "a + b", potentially degradable fraction.[5] ED: effective degradability calculated with outflow rates of 2, 5 and 8%, [6] Standard error of the mean.
[a,b] Values within a row with different superscripts differ significantly at $P < 0.05$

Table 3. Degradation characteristics and disappearance of crude protein (CP) in cucumber wastes (CW) and almond hulls (AH)

	CW	AH	SEM[6]
Degradation characteristics			
a[1]%	15.3[a]	6.6[b]	0.14
b[2]%	62.3[a]	44.2[b]	0.41
c[3]	0.03[a]	0.01[b]	0.006
a+b[4]	77.6[a]	50.8[b]	0.47
Effective degradability (ED)[5]			
k=0.02	55.7[a]	28.7[b]	0.40
k=0.05	41.8[a]	19.2[b]	0.33
k=0.08	35.0[a]	15.4[b]	0.26
Disappearance (%)			
24hrs	55.7[a]	25.6[b]	0.63
48hrs	67.4[a]	33.9[b]	0.79
72hrs	72.7[a]	40.3[b]	0.43

CW= Cucumber waste; AH= Almond hulls
[1,2,3,4] constants in the equation $D = a + b(1-e^{-ct})$, where P is level of degradation at time "t", "a", readily soluble fraction; "b", insoluble fraction but degradable in rumen; "c", rate of degradation of "b" per hour; "a+b", potentially degradable fraction.[5] ED: effective degradability calculated with outflow rates of 2, 5 and 8%, [6] Standard error of the mean.
[a,b] Values within a row with different superscripts differ significantly at $P<0.05$

Table 4. Degradation characteristics and disappearance of acid detergent fiber (ADF) in cucumber wastes (CW) and almond hulls (AH)

	CW	AH	SEM[6]
Degradation characteristics			
a[1]%	10.6[a]	6.0[b]	0.17
b[2]%	49.2[a]	46.3[b]	0.44
c[3]	0.03[b]	0.03[a]	0.009
a+b[4%]	59.8[a]	52.3[b]	0.60
Effective degradability (ED)[5]			
k=0.02	40.4[a]	34.5[b]	0.32
k=0.05	29.5[a]	24.0[b]	0.20
k=0.08	24.4[a]	19.2[b]	0.17
Disappearance (%)			
24hrs	40.2[a]	32.8[b]	0.55
48hrs	47.8[a]	42.4[b]	0.36
72hrs	54.9[a]	47.3[b]	0.41

CW= Cucumber waste; AH= Almond hulls
[1,2,3,4] constants in the equation $D = a + b(1-e^{-ct})$, where P is level of degradation at time "t", "a", readily soluble fraction; "b", insoluble fraction but degradable in rumen; "c", rate of degradation of "b" per hour; "a+b", potentially degradable fraction. [5] ED: effective degradability calculated with outflow rates of 2. 5 and 8%. [6] Standard error of the mean.
[a,b] Values within a row with different superscripts differ significantly at $P<0.05$

4. DISCUSSION

4.1 Chemical Composition

Laboratory analyses of CW showed comparable values to those associated with the raw ingredients [15,16]. The CP of AH evaluated in this study (34.0 g/ kg DM) was higher than in some previous reports [5,17]. Differences among studies may be related to species or genetic variation. The CP content of almond hulls usually varies in the range of 48.7 24 and 80.0 10 g/kg DM. Crude protein content of AH is below maintenance and production requirements of ruminants. It was estimated that CP requirements for sheep, goats and dairy cows were 94-150, 75-160 and 120-190 g/kg DM, respectively [18], however, its nitrogen content can be improved by cheap NPN supplementation (*i.e.* urea) then reducing the feeding of supplementary ruminal crude protein.

AH had lower CP and higher ADF and NDF values compared to CW. Yalchi et al. [17] reported that AH had lower NDF, ADF contents compared to alfalfa hay. However, a large proportion of the protein (80 to 90%) might be linked to the ADF and solubility of nitrogen was only 1.5 to 3% which is particularly low. Ventura et al.[19] showed similar NDF values of CW as values in the present research; however, the reported values for CP, ADF and ash were different. Factors such as plant maturity, cultivation management and type of soil and fertility could affect feed ingredients chemical composition.

Table 5. Degradable characteristics and disappearance of neutral detergent fiber (NDF) in cucumber wastes (CW) and almond hulls (AH)

	CW	AH	SEM[6]
Degradation characteristics			
b^1%	14.1[a]	5.6[b]	0.21
b^2%	55.0[a]	48.5[b]	0.63
c^3	0.02[b]	0.02[b]	0.001
a+b[4%]	69.1[a]	54.1[b]	0.50
Effective degradability (ED)[5]			
k=0.02	41.8[a]	34.5[b]	0.27
k=0.05	30.0[a]	23.8[b]	0.48
k=0.08	25.2[a]	18.6[b]	0.22
Disappearance (%)			
24hrs	40.7[a]	32.9[b]	0.40
48hrs	48.2[a]	41.9[b]	0.74
72hrs	57.3[a]	48.1[b]	0.57

CW= Cucumber waste; AH= Almond hulls
[1,2,3,4] constants in the equation $D = a + b\ (1-e^{-ct})$, where P is level of degradation at time "t", "a", readily soluble fraction; "b", insoluble fraction but degradable in rumen; "c", rate of degradation of "b" per hour; "a + b", potentially degradable fraction.
[5] ED: effective degradability calculated with outflow rates of 2, 5 and 8%, [6] Standard error of the mean.
[a,b] Values within a row with different superscripts differ significantly at P<0.05.

As the apparent digestibility coefficients are not sufficient to evaluate the nutritive value of a feed in ruminants, therefore it is necessary to determine the ruminal kinetics of digestion of feed nutrients. *In situ* coefficients were used to develop a system to predict feed nutritive value [10]. The high readily fermented fractions (a) of DM, CP, ADF and NDF in CW compared to those in AH could be due to the high AH levels of ADF and the non fibrous carbohydrates (*i.e.* nitrogen free extract, NFE) in CW Nocek et al. [20].

The potentially degradable fractions (b) of all tested nutrients (*i.e.* DM, CP, ADF, NDF) in CW were higher than that of AH. The high AH level of NDF and low non fibrous carbohydrates could explain this result [20].

The CW had higher degradation rates compared to AH. The nutrient composition of CW of high CP and lower ADF levels may explain the higher degradation rates observed. It was shown by previous research that degradation rates were different among types of roughage [15,17,21]. Effective degradability (ED) of DM, CP, ADF and NDF calculated at 2, 5 and 8% h^{-1} outflow rates from the rumen showed that CW had consistently higher values compared to that in AH. Effective DM and CP degradability decreased with increase in outflow rates. Yan and Agnew [22] showed that ED of DM was negatively related to NDF and ADF concentrations.

The disappearance of the tested nutrients in AH and CW by the end of 48 hrs of incubation indicated that 48 h disappearance allows a comparison or a classification of feedstuffs *in vivo* digestibility without reflecting exact values of *in vivo* digestibility. This information provides an insight into the level of rumen undegradable DM post incubation for 72 h.

Many experiments have shown that non-structural carbohydrates from some feed ingredients (cassava, barley and corn) have a positive effect on fiber digestion as fiber digestibility is increased using these carbohydrate sources [21].

5. CONCLUSIONS

Extensive differences in ruminal degradation kinetics of DM, CP, ADF and NDF were determined between AH and CW. The new data presented in this study could be useful for the purposes of ration formulation and ruminants' performance. Considering these findings, one can propose using both by-products, together or separately as part of ruminant rations. It can be introduced in these rations as part of roughage (wheat and barley straw). CW can be incorporated in ruminant rations as part of better quality roughage (legume hay). However, lower incorporation levels to replace corn or barley can be practiced Adoption this option provides the fattening industry with an inexpensive nonconventional feed ingredient and reducing the environmental pollution caused by wastes disposal.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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