



THE DETERMINATION OF NUTRITIVE VALUE OF FRUIT AND VEGETABLE WASTES USING DIFFERENT MATHEMATICAL MODELS

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AUTHOR'S CONTRIBUTION

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Background: This study was carried out in order to determine the nutritive value of fruit and vegetable wastes using in situ technique. The objective of this study was to determine *in situ* CP degradability of fruit and vegetable wastes using nylon bag technique and survey to use this feed as animal feedstuffs.

Methods: Two fistulated wethers (35±1.8 kg) were used in the nylon bag method. The crude protein and dry matter disappearance were measured at 0, 4, 6, 8, 12, 16, 24, 48, 72 and 96 h. CP (Crude Protein) degradability of carrot wastes at 96h was 64.56 that were higher than the vegetable waste and that showed significant differences ($p<0.05$). Dry matter degradability of vegetable wastes at 96h was 68.58 % that was the highest and shown significant differences ($p<0.05$).

Results: Results of this study were showed that model 4 for carrot wastes and model 2 for vegetable wastes were the best-fitted models. The output of this model showed that model 2 was the best model for measuring a Dry matter of carrot wastes and model 1 was better for measuring a Dry matter of other vegetable wastes.

Conclusion: Fruit and vegetable wastes showed high ruminal degradation of CP (Crude Protein) as same as other economical feedstuffs, and these can be used instead of other feedstuffs. It should also be noted that models 3 and 4 did not achieve convergence in vegetable wastes.

Keywords: Carrot wastes; vegetable wastes; nylon bag and mathematical models.

1. INTRODUCTION

Most of the developing countries have been fighting to provide adequate feed to their livestock, because of inadequate production of conventional ingredients for livestock feeding. So the scarcity of feed sources often imposes a major challenge in livestock production in these countries [1] The challenge can be alleviated by the use of unconventional feedstuffs in

animal feeding depending on their nutrient content, availability and acceptability to animals; and provided it is economical compared to the conventional feed ingredients.

To compensate for feed shortages and to reduce feeding costs, attempts have been made to use agricultural and food industry by-products as feed ingredients. In developing countries, the utilisation of

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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 [2]. This will not only decrease the demand for cereal grains used as feeds, allowing the grain to be used by humans but may also solve the economic and ecological problems of fruit and vegetable residue (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.

In situ procedures, often based on or similar to the basic studies conducted by Ørskov and McDonald [3], are well accepted in many countries for estimating the degree of ruminal CP (Crude Protein) degradation of feedstuffs [4,5,6,7,8]. *In situ* measures can be used to obtain estimates of Undegraded Dietary Protein (UDP) values of feedstuffs within a relatively short period of time but still, this method requires cannulated animals and there is a continuing need for simpler laboratory methods to estimate the protein value of feeds. There is a revived intensive discussion about the accuracy and relevance of the measurement of soluble CP (Crude Protein) fractions to predict the rumen CP (Crude Protein) degradation of feedstuffs. The solvent used must simulate solubilization and degradation in the rumen as closely as possible. The protein degradation in the rumen depends not only on the soluble and insoluble proteins but also on the extent of the slowly digestible and indigestible proteins. Many different procedures to determine soluble and insoluble nitrogen or CP (Crude Protein) in feedstuffs have been published [9,10] and [11,12], yet no single method has so far been accepted as being reliably accurate for predicting the rumen CP (Crude Protein) degradation in feedstuffs.

The objective of this study was to determine *in situ* CP degradability of fruit and vegetable wastes using nylon bag technique and survey to use this feed as animal feedstuffs.

2. MATERIALS AND METHODS

2.1 *In situ* Degradation

In situ methods were done based on the procedures followed by Nocek et al method [13] and reviewed

by Palangi et al. [14], the ground samples (5g) were placed in Dacron bags (5.5×10 cm; 47-µm pore size) and were closed using glue. Each feed sample was incubated in 4 replicates (2 replicates for each weather) in the rumen. The incubation times were 0, 4, 6, 8, 12, 16, 24, 48, 72 and 96 h. Nylon bags were suspended in the rumen in a polyester mesh bag (25×40 cm; 3mm pore size) and were removed from the rumen at the same time so that all bags could be washed simultaneously. The nylon bags were then removed from the mesh bag and washed until the rinse water remained clear. Samples were then dried in an oven at 55°C until a constant weight was achieved before determination of DM (Dry Matter) and CP (Crude Protein) disappearance.

2.2 Mathematical Models

Two diminishing returns and two sigmoid models were used to describe the ruminal degradation of the DM (Dry Matter) and CP (Crude Protein) of fruit and vegetable wastes. The models, I and II, are Simple negative exponential curve models (monomolecular, Mitscherlich, or first-order kinetics model) without and with a lag phase [3]. Model III is Gompertz curve, asymmetrical about an inflexion point M, which can be calculated from $K = \exp(cm)$ [15]. Model IV is Generalized Mitscherlich, a generalisation of the model I (results in the model I for $d = 0$), with the addition of a square root time dependence component [16].

2.3 Statistical Analysis

The output of ruminal CP (Crude Protein) degradation of fruit and vegetable wastes were analysed using SAS (1999).

3. RESULTS AND DISCUSSION

3.1 Dry Matter

3.1.1 *In situ* ruminal degradability

The degradability parameters of Dry Matter are shown in Table 1. Carrot wastes showed high values for the soluble fraction of Dry Matter compared to the vegetable wastes. However, at 96h the vegetable waste disappearance (68.58) is higher than carrot samples (64.14) and there were significant differences ($p < 0.05$).

Table 1. *In situ* DM (Dry Matter) degradability

Feeds	Incubation time (h)									
	0	4	8	12	16	24	36	48	72	96
Carrot wastes	22.12 ^a	22.78 ^a	25.54 ^a	28.28 ^a	31.79 ^b	39.17 ^b	49.46 ^a	53.41 ^a	58.36	64.14 ^b
Vegetable wastes	18.16 ^b	20.65 ^b	23.36 ^b	26.45 ^b	39.04 ^a	42.05 ^a	43.82 ^b	46.20 ^b	57.58	68.58 ^a
Standard Error Means	0.176	0.221	0.305	0.342	0.758	0.401	0.435	0.519	0.316	0.372

Table 2. The degradability parameters of CP

Feeds	Incubation time (h)									
	0	4	8	12	16	24	36	48	72	96
Carrot wastes	13.31 ^a	12.12 ^a	16.80 ^a	21.20 ^a	25.65 ^b	36.69 ^a	39.81	46.65	61.39 ^a	64.56
Vegetable wastes	9.99 ^b	10.48 ^b	12.42 ^b	17.56 ^b	30.43 ^a	33.60 ^b	37.84	43.80	54.82 ^b	62.31
SEM	0.213	0.480	0.340	0.300	0.644	0.744	0.856	0.950	0.761	1.643

^{a,b} Values within a row with different superscripts differ significantly at $P < 0.05$.

Table 3. Measurement of DM degradation characteristics of fruit and vegetable wastes using different mathematical models

Model	a	b	c	L	d	k	SSM	CSST	R-Square
Carrot wastes									
1	19.11	53.15	0.020	-	-	-	6553.90	6661.40	0.9839
2	22.44	44.65	0.027	6.39	-	-	6621.90	6661.40	0.9941
3	21.39	41.68	0.053	-	-	0.058	6617.60	6661.40	0.9934
4	23.48	44.01	0.020	9.00	0.086	-	6612.40	6661.40	0.9926
Vegetable wastes									
1	18.42	60.95	0.015	-	-	-	7086.90	7449.80	0.9513
2	18.15	61.22	0.015	-0.27	-	-	7086.90	7449.80	0.9513
3	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-

1- Ørskov and Mc Donald (1979) without leg phase, 2- Ørskov and Mc Donald (1979) with leg phase 3- France et al. (1999) and 4- Danoa et al. (2004)

a= Fastly soluble fraction b = slowly soluble fraction c= insoluble fraction L = leg phase d and k = Model Constants

Table 4. Measurement of CP (Crude Protein) degradation characteristics of fruit and vegetable wastes using different mathematical models

Model	a	b	c	L	d	k	SSM	CSST	R-Square
<i>Carrot wastes</i>									
1	10.069	71.489	0.0158	-	-	-	9813.0	10024.1	0.9789
2	12.717	63.345	0.0193	4.061	-	-	9870.3	10024.1	0.9846
3	10.998	60.317	0.0293	-	-	0.285	9826.1	10024.1	0.9802
4	12.717	76.353	0.0071	5.484	0.0723	-	9875.3	10024.1	0.9851
<i>Vegetable wastes</i>									
1	7.605	64.952	0.0184	-	-	-	9196.8	9473.4	0.9708
2	9.993	58.481	0.022	3.587	-	-	9230.7	9473.4	0.9744
3	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-

1- Ørskov and Mc Donald (1979) without leg phase, 2- Ørskov and Mc Donald (1979) with leg phase 3- France et al. (1999) and 4- Danoa et al. (2004)

a= Fastly soluble fraction b = slowly soluble fraction c= insoluble fraction L = leg phase d and k = Model Constants

3.1.2 Statistical models output

The comparison of various fitted models for dry matter degradability of Fruit and Vegetable Wastes based on the coefficient of determination (R²) showed that Model-2 was the best fit to the carrot wastes, and model 1 for vegetable wastes, respectively (Table 2). It should also be noted that models 3 and 4 did not achieve convergence in vegetable wastes.

The Dry Matter soluble and insoluble fraction for carrot wastes (19.11, 0.020) were more than the vegetable wastes (18.425, 0.0157), But the B fraction of vegetable wastes (60.959) are higher than carrot wastes (53.15).

To assess the validity of mathematical models that can describe the degradation pattern of a given feed, their behaviour, statistical performance, and biological characteristics should be evaluated. Fruit and vegetable wastes showed high ruminal degradation of Dry Matter as same as other economical feedstuffs, and there can use instead of other feedstuffs.

3.2 Crude Protein

3.2.1 *In situ* ruminal degradability

The degradability parameters of CP (Crude Protein) are shown in Table 1. Carrot wastes showed high values for the soluble fraction of CP (Crude Protein) compared to vegetable wastes.

The achieved data for CP (Crude Protein) degradation of this work was lower than Palangi et al. [14].

3.2.2 Statistical models output

The comparison of various fitted models for crude protein degradability of Fruit and Vegetable Wastes based on the coefficient of determination (R²) showed that model 4 was the best fit to the carrot wastes, and model 2 for vegetable wastes, respectively (Table 2). It may be concluded that the models with lag time were the best models for the description of degradability trends in CP of the Fruit and Vegetable Wastes.

The CP soluble and insoluble fraction for carrot wastes was more than the vegetable wastes. The found data in this experiment showed high values for insoluble fraction compared to that reported by Taghizadeh et al. [17], but its soluble fraction agrees with the finding mentioned in the study. The obtained data for CP (Crude Protein) soluble fraction was lower than that reported by Elizald et al. [18], but the

CP (Crude Protein) insoluble fraction was consistent with their data.

4. CONCLUSION

Fruit and vegetable wastes showed high ruminal degradation of CP (Crude Protein) as same as other economical feedstuffs, and these can be used instead of other feedstuffs. It should also be noted that models 3 and 4 did not achieve convergence in vegetable wastes.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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