Maejo Int. J. Sci. Technol. **2009**, *3*(03), 371-378

Maejo International Journal of Science and Technology

ISSN 1905-7873

Available online at www.mijst.mju.ac.th

Full Paper

Nutritive value and nutrient digestibility of ensiled mango by-products

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Received: 8 April 2009 / Accepted: 5 October 2009 / Published: 6 October 2009

Abstract: Mango canning by-products (seed and peel) together with ensiled mango peel were subjected to analysis of dry matter (DM), ash, crude protein (CP), crude fibre (CF), ether extract (EE), nitrogen-free extract (NFE), gross energy (GE), neutral detergent fibre (NDF) and acid detergent fibre (ADF). In vitro digestibility of DM (IVDMD), ADF (IVADFD) and NDF (IVNDFD) was determined after digesting the by-products in buffered rumen fluid for 24 or 48 h in an incubator. CP content in peel, seed and peel silage is 4.68, 4.19 and 5.27% respectively. As expected, mango seed has a higher fibre content than mango peel and peel silage as indicated by NDF (53.01 vs 25.87 and 27.56% respectively) and ADF (31.02 vs 19.14 and 17.68% respectively). However, mango seed also has greater GE than mango peel and peel silage (4,070 vs 3,827 and 3,984 kcal/g DM respectively), probably due partly to its high fat content.

Four head of male native cattle were used to determine nutrient digestibility of ensiled mango by-products by randomly allowing them to receive ensiled mango peel with rice straw (EMPR) and different levels of Leucaena leaves. Treatments consisted of: 1) ensiled mango peel + rice straw (90:10); 2) ensiled mango peel + rice straw + Leucaena leaves (85:10:5); 3) ensiled mango peel + rice straw + Leucaena leaves (80:10:10); and 4) ensiled mango peel + rice straw + Leucaena leaves (75:10:15). Addition of Leucaena leaves to silage increased apparent digestibility of DM (53.84, 55.43, 59.04 and 58.69% for the four formulations above respectively), probably because of increasing amounts of CP from Leucaena leaves, resulting in greater digestibility of NDF (39.11, 44.47, 47.12 and 43.32% for the four formulations above respectively). Total digestible nutrients (TDN) and digestible energy (DE) showed the same trends as apparent digestibility of DM.

Key words: mango by-products, mango peel, mango seed, apparent digestibility, energy value

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Introduction

Mango is considered as one of the most delicious fruits in Thailand. Its harvesting time is between January and May, which is in the dry season when green forage is in shortage. Mango is an excellent source of vitamin A and C, as well as a good source of potassium, beta-carotene and fibre. Normally, it is produced for human consumption as raw or ripe mango products. During the processing of ripe mango, its peel and seed are generated as waste, which is approximately 40-50 % of the total fruit weight. Mango peel is a good source of dietary fibre and its chemical composition may be comparable to that of citrus fibre. The peel has a high value of antioxidant activity and glucose retardation index while its aroma and flavour is pleasant [1]. The peel is thus palatable to cattle but very few farmers use it for animal feed because of the high moisture and acidity content.

During the processing of ripe mango, the waste (peel and seed) is a problem for canning factories. Its disposal may appreciably increase environmental pollution due to its rapid decay, thus becoming a good source of house fly multiplication. However, Omole et al. [2], Govinda Naik et al. [3] and Naveen et al. [4] reported that fruit waste and by-products may be used as alternative feed in livestock rations either as dry product or as silage. Therefore, the ensiling of mango by-products especially mango peel may be an economical way to reduce the problem of waste disposal from mango production as well as increase their utilisation as animal feed.

To produce good silage from mango peel, it would be desirable to mix it with dry materials such as rice straw to adjust moisture and with Leucaena leaves to increase protein content for proper fermentation of the ensiled products. This study was conducted to determine the nutritive value of mango by-products and evaluate the digestible nutrients of ensiled mango by-products with rice straw and Leucaena leaves (Figure 1). The feed could possibly be used to set up a feeding strategy for Thai native beef cattle fed with low quality roughage.

Materials and Methods

Composition

Ripe mango (*Mangifera indica*) by-products were obtained from a cannery plant in Sarapee district, Chiang Mai province. The by-products were dried on the truck overnight before ensiling and sampling for analysis. Peel and seed were hand- separated and the separated products were mixed thoroughly. Random samples of peel and seed were taken for analysis of dry matter (DM), ash, crude protein (CP), crude fibre (CF), ether extract (EE), nitrogen free extract (NFE) and gross energy (GE) according to the methods described in AOAC [5]. Organic matter (OM) was calculated from DM (OM =DM – ash). The analysis of neutral detergent fibre (NDF) and acid detergent fibre (ADF) was carried out according to the methods of Goering and Van Soest [6].

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mango peel


mango seed


EMPR+0%LL
(peel : rice straw =90:10)


EMPR+5%LL
(peel : rice straw : LL=85:10:5)


EMPR+10%LL
(peel : rice straw: LL=80:10:10)


EMPR+15%LL
(peel : rice straw: LL=75:10:15)

Figure 1. By-products from mango and ensiled mango by-products

In vitro digestibility

In vitro digestibility of DM (IVDMD), NDF (IVNDFD) and ADF (IVADFD) of mango peel, mango seed and mango peel silage was determined using ANCOM^{II} Daisy Incubators (ANKOM Technology, Macedon, NY). Samples were ground (1mm) and incubated in buffered rumen fluid for 24 h and 48 h. Rumen fluid was obtained from 2 fistulated native bulls before ad libitum feeding with guinea grass. The experimental design was Completely Randomised Design.

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Apparent digestibility

Four head of male native beef cattle at four years of age with average body weight of 236 ± 13.3 kg were randomly allocated to one of the four dietary treatments according to Latin Square Design. The treatments consisted of (1) 90:10 ensiled mango peel + rice straw (EMPR, 90:10), (2) 85:10:5 ensiled mango peel + rice straw + Leucaena leaves (EMPR+5%LL=85:10:5), (3) 80:10:10 ensiled mango peel + rice straw + Leucaena leaves (EMPR+10%LL= 80:10:10), and (4) 75:10:15 ensiled mango peel + rice straw + Leucaena leaves (EMPR+15%LL= 75:10:15). The diets were fed to the animal twice daily at 2.0 % of the body weight (DM basis). Water and mineral blocks were freely available throughout the experimental periods. Total collection method was assigned for the determination of apparent total tract digestibility of nutrients. The experiment was conducted at Maejo University during July - October 2008.

The experiment consisted of four periods with each digestibility period lasting 19 days and preliminary period taking place in the first 14 days while collection period was in the last 5 days. Feed intake was recorded daily throughout the entire experiment. Dietary DM intake was calculated on DM basis. Feed, feces and leftover feed were individually collected and used for the calculation of nutrient digestibility. Total digestible nutrients (TDN) were calculated using the equation: TDN = digestible CP + digestible CF + digestible NFE + digestible EE × 2.25 [7]. Gross energy of feed and feces was determined using an adiabatic bomb calorimetre (IKA calorimetre system C 5000). Digestible energy was then calculated. The data were analysed according to 4x4 Latin Square Design [8]. The significant differences between treatments were analysed based on Duncan's new multiple range test [9].

Results and Discussion

Composition

The composition of ripe mango by-products are shown in Table 1. The dry matter content of mango peel was lower than that of mango seed. At present the price (0.20 Baht per kg) of mango by-products may be economical as a source of roughage, even though their CP content is low. Crude protein content of mango peel in this experiment (4.68%) was lower than the value reported by Ojokoh (8.64%) [10], but higher than that reported by Naveen et al. (3.9%) [4] and Buwjoom and Maneewan.(3.18%) [11]. This might be due to differences in varieties, cultivation and method of by-product collection. However, mango peel in this experiment was higher in CP and NFE (4.68 and 76.13% of DM) but lower in CF and ADF (10.10 and 19.14 % of DM), when compared to mango seed. Mango seed was higher in GE and CF, mainly because the kernel is usually a good source of starch, fat and protein. This agreed with Elegbede et al [12] who reported that mango kernel was high in fat and starch (12.8 and 32.8% respectively).

Table 1. Composition of ripe mango by-products

By-product	DM (%)	% of DM						GE (kcal/g DM)
		CP	CF	EE	NFE	NDF	ADF	
Mango peel	20.10	4.68	10.10	1.21	76.13	25.87	19.14	3,827
Mango seed	23.88	4.19	30.84	2.72	47.79	53.01	31.20	4,070
Ensiled mango peel	18.27	5.27	9.02	1.63	75.87	27.56	17.68	3,984

Ensiled mango peel was highest in CP but lower in CF and ADF. This might be due to the fact that during fermentation process carbohydrates including cellulose, pectin, lignocellulose, starch and sugar are broken down by microorganisms to produce microbial biomass, and therefore the fibre content decreased but CP content increased. Results from this experiment agreed with those of Ojokoh [10], who reported that fermentation of mango peel increased protein content of the fermented product while there was a decrease in fibre content.

In vitro digestibility

Compared with mango seed, mango peel and mango peel silage were higher in IVDMD, IVNDFD and IVADFD at 24 h and 48 h (Tables 2-3). However, the in vitro digestibility of DM, ADF and NDF in mango seed suggests that it might be acceptable for feeding ruminants if it was ground, as performed for this laboratory analysis. The high NDF (53.01%, Table 1) of the hard outer shell is compensated by the highly digestible, high energy content inside the shell. Feeding trials are needed to determine if ground mango seed is acceptable as ruminant feed. Also, methods for separation of the seed shell from the kernel should be investigated.

Table 2. In vitro DM and fibre digestibility (%) of mango by-products at 24 h

Item	IVDMD**	IVNDFD**	IVADFD*
Mango peel	$69.28^{A} \pm 2.3$	$40.63^{B} \pm 1.8$	$37.88^{a} \pm 2.2$
Mango seed	$55.77^{B} \pm 1.9$	$36.24^{C} \pm 1.6$	$30.14^{b} \pm 1.7$
Mango peel silage	$74.11^{A} \pm 2.1$	$48.33^{A} \pm 2.1$	$40.17^{a} \pm 2.1$

* Means with different superscripts significantly differ (P<0.05).
** Means with different superscripts highly differ (P<0.01).

Table 3. In vitro DM and fibre digestibility (%) of mango by-products at 48 h

Item	IVDMD**	IVNDFD**	IVADFD*
Mango peel	$75.95^{B} \pm 3.2$	$48.51^{A} \pm 1.8$	$41.29^{a} \pm 1.6$
Mango seed	$45.12^{C} \pm 2.1$	$40.27^{B} \pm 1.3$	$34.06^{b} \pm 1.1$
Mango peel silage	$79.89^{A} \pm 1.4$	$52.71^{A} \pm 1.6$	$43.54^{a} \pm 1.4$

* Means with different superscripts significantly differ (P<0.05).
** Means with different superscripts highly differ (P<0.01).

Apparent digestibility

From Table 4, it can be seen that increasing Leucaena leaves in the silage tended to increase DM, CP, EE, CF and GE but NFE tended to decrease with increasing Leucaena leaves in the silage. The positive effect of Leucaena leaves was due to the nutritive value of this legume, which is high in protein, DM and GE [13,14]. Furthermore, the physical characteristics of ensiled mango peel and rice straw with or without Leucaena leaves were good although their DM was slightly lower than the optimal range for good ensiling products. This should be due to the high moisture content in the peel as well as to its sugar being converted to lactic acid by lactic acid bacteria. The physical characteristics of rice straw were better after the ensiling process. Its structure was softer with a light yellow colour and lactic acid odour from the fermentation process.

Table 4. Composition of ensiled mango peel + rice straw with or without Leucaena leaves

Item	DM (%)	% of DM						GE (kcal/g DM)
		CP	CF	EE	NFE	NDF	ADF	
EMPR(90:10:0)	18.76	4.91	29.25	1.96	55.49	46.22	31.28	3,632
EMPR+LL(85:10:5)	19.24	5.97	32.19	2.49	49.62	52.64	33.54	3,733
EMPR+LL(80:10:10)	20.42	6.88	33.16	2.68	48.74	52.88	35.43	3,818
EMPR+LL(75:10:15)	21.65	8.47	34.22	2.91	45.26	53.23	36.36	3,869

Table 5 shows that the values for the apparent digestibility of the nutrients (DM, OM, CP, CF, EE, NFE and ADF) in EMPR with different amounts of Leucaena leaves were higher than those in EMPR alone. The apparent digestibility figures for CP, CF and NFE were highly different (P<0.01) while those for EE, NDF and ADF were significantly different (P<0.05). No significant difference was found on the apparent digestibility of DM and OM (P>0.05). Supplementation of Leucaena leaves in the silage thus increased the apparent digestibility, which agrees with results of Geerts et al. [15], who found that nutrient digestibility of the diet increased with increasing crude protein content but decreased with increasing fibre content.

Table 5. Apparent digestibility of ensiled mango peel + rice straw with or without Leucaena leaves

Nutrient / Apparent digestibility, %	EMPR	EMPR + 5%LL	EMPR +10%LL	EMPR +15%LL
DM	53.84 ± 4.6	55.43 ± 2.3	59.04 ± 3.5	58.69 ± 2.8
OM	56.81 ± 3.3	58.56 ± 2.1	61.30 ± 3.1	60.18 ± 3.4
CP**	39.44^{C} ± 2.0	45.18^{B} ± 4.4	56.55^{A} ± 5.1	54.32^{A} ± 2.2
CF**	41.64^{C} ± 3.6	46.86^{B} ± 3.2	50.41^{A} ± 4.3	50.06^{A} ± 2.9
EE*	46.51^{b} ± 2.2	52.10^{a} ± 0.9	53.21^{a} ± 4.5	53.36^{a} ± 4.6
NFE**	47.25^{C} ± 3.5	58.15^{A} ± 3.6	59.30^{A} ± 1.8	54.67^{B} ± 5.1
NDF*	39.11^{b} ± 3.5	44.47^{a} ± 1.8	47.12^{a} ± 4.4	43.32^{a} ± 4.0
ADF*	29.82^{c} ± 4.3	37.37^{a} ± 2.0	36.61^{a} ± 5.3	34.04^{b} ± 5.3

* Means with different superscripts significantly differ (P<0.05).
** Means with different superscripts highly differ (P<0.01).

Calculation of total digestible nutrients (TDN) from digestibility of nutrients shows that EMPR with different percentages of Leucaena leaves had higher average values of TDN than that of EMPR alone (Table 6) and thus the former can be used as roughage source for ruminants especially in the dry season. The variation of DE of the silages followed the same pattern as that of TDN.

Table 6. Total digestible nutrients (TDN) and digestible energy (DE) of ensiled mango peel + rice straw (EMPR) with or without Leucaena leaves

Item	TDN (% DM)	DE (Mcal / kg DM)
EMPR	45.63 ± 4.0	1.91 ± 0.5
EMPR + 5%LL	53.45 ± 3.2	2.08 ± 0.4
EMPR + 10%LL	56.53 ± 2.7	2.33 ± 0.6
EMPR + 15%LL	54.67 ± 3.6	2.16 ± 0.4

Conclusions

Mango by-products (peel and seed) from canning plants are found to be low in CP and DM content, while mango peel silage is higher in CP but lower in CF and ADF than fresh mango peel. The digestibility of nutrients (DM, OM, CP, CF, NFE, NDF and ADF) of ensiled mango peel with rice straw increases with increasing admixture of Leucaena leaves. Calculation of TDN from digestibility of nutrients shows that ensiled mango peel with different levels of Leucaena leaves has a higher average value of TDN than silage without Leucaena leaves.

In vitro digestibility shows that all forms of mango peel by-products can be used as cattle feed. Further study in cattle is needed to determine if ground mango seed is also acceptable as feed as in vitro results suggest.

Acknowledgement

This study was supported by a grant from the "Establishment of a Feeding Standard of Beef Cattle and Feedstuff Database for the Indochinese Peninsula Research Fund" of Japan International Research Centre for Agricultural Sciences.

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