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THE NUTRITIVE VALUE OF FOUR ARABLE FARM BY-PRODUCTS COMMONLY FED TO DAIRY CATTLE BY SMALL-SCALE FARMERS IN KENYA
I. ORGANIC STRUCTURAL COMPONENTS AND IN VITRO DIGESTIBILITY

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Studies on organic structural components of four arable by-products were conducted in a preliminary trial to determine cell wall constituents (Neutral detergent fibre,NDF), cell contents (Neutral detergent solubles, NDS), hemicellulose, cellulose and lignin, and to compare the chemical composition and quality of the by-products. The NDF of maize stalks (60.9%), maize cobs (86.7%) and sugar cane tops (63.3%) were higher ($P < 0.05$) than the NDF of sugar cane stalks (40.6%).

Dry matter digestibility (DMD) from in vitro digestible NDF and NDS was higher ($P < 0.05$) in maize stalks and sugar cane stalks than in maize cobs and sugar cane tops. In vivo DMD of by-products was accurately predicted from Van Soest in vitro DMD ($P < 0.05$, 0.001 and small RSD values).

In vitro DMD obtained by the two-stage technique compared favourably with the Van Soest in vitro DMD. The two techniques could be utilized successfully under Kitale conditions to predict nutritive quality of high fibre roughages.

Two stage dry and organic matter digestibility of maize stalks and sugar cane stalks was greater ($P < 0.05$) than for maize cobs and sugar cane tops. Sugarcane rind had lower digestibility than sugarcane pith. The rind had a depressing effect on the digestibility of sugar cane stalks. Rate of in vitro DM and OM disappearance established that time taken for each by-product to get digested was a critical factor that affect utilization by animals.

Key Words: By-product, in vitro, digestibility, chemical composition

In Kenya, substantial advances have been made in breeding and in management of dairy animals. Regrettably, not much improvement in their nutrition has been achieved countrywide. Kirkwood (1958,59) and Foot(1965) established that the major cause for the low production parameters in livestock in Kenya is inadequate feeding and in particular the failure to meet production requirements.

Chudleigh (1974) showed seasonal flucuations in milk production on small-scale farms which were associated with an erratic plane of nutrition. During the dry season the mean percentage drop in milk production was in the range from 19.1 to 25.0% over the wet season. Supplementary feeding can be used to maintain a sustained milk production during the dry season when there is hardly any pasture on small-scale farms, but the supplements generally used are often expensive and/or in short supply.

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Arable farm by-products are readily available under present farming systems (Chudleigh 1974; Stotz 1977). They are, in fact, considered wastes in most cases and are rarely used for livestock feeding. The high tonnage of available farm by-products in this country justifies a study of their potential for livestock production both within the large-scale farming communities and more so within the small-scale farming areas. However, the majority of high fibrous arable farm by-products are, at their very best, maintenance supplements mainly due to their high fibre and low protein levels (Laksesvela and Said 1970).

The strategy adopted in the study of some of these arable farm by-products has been in three phases. First a study of the organic structural components was conducted. It was followed by a study of their in vitro digestibility of dry matter and organic matter, culminating in a feeding trial to measure their utilization in vivo.

Materials and Methods

The trial was conducted at the National Agricultural Research Station, (N.A.R.S.) Kitale, Kenya. Experimental by-products were maize stalks, maize cobs sugarcane stalks and sugarcane tops. The by-products were obtained from Government Research Stations (N.A.R.S., Kitale and National Sugar Research Station, Kibos, Kenya) where 60 kg P_2O_5/ha during planting, 90 kg N/ha top dressing, weed control and necessary cultural practices had been applied to the maize and sugarcane during their growing phase.

The by-products were harvested manually and chopped by a stationary forage harvester to sizes of 2 - 3 cm. Sub-samples were drawn from each feed spread on a polythene sheet according to the procedure described by Goering and Van Soest (1970).

Composite samples were dried at 65°C for 48 hours in forced draught ovens. The dry samples were milled in a Christy and Norris hammer (0.8 mm mesh size). A final sample of about 500 g for each by-products was stored in airtight plastic bags ready for analysis.

Organic Structural Components and Digestibility of by-products: The by-products were analysed for neutral detergent fibre (NDF) neutral detergent solubles (NDS), acid detergent fibre (ADF) and acid detergent lignin (ADL) according to the methods of Van Soest (1963), Van Soest and Moore (1965), Van Soest et al (1966) and Van Soest and Wine (1967). Artifact lignin correction was carried out as described by Georing and Van Soest (1967), Van Soest (1965) and Georing and Van Soest (1970).

In vitro dry matter digestibility of the by-products was estimated by Van Soest's in vitro procedure according to Van Soest (1967). True digestibility of neutral detergent fibre or cell wall constituents was estimated by means of Van Soest et al (1966) in vitro procedure. Digestibility of neutral detergent solubles and bacterial and endogenous excretion were treated as constants (98 and 12.9%, respectively).

Prediction equations were established using the organic structural components of the by-products.

Dry matter digestibility (DM), organic matter digestibility on organ

ic matter basis (OMD) and organic matter digestibility on dry matter basis (DOMD or D-value) were determined by a two-stage in vitro digestibility technique (Tilley and Terry 1963 and 1968). Rumen liquor was obtained from fistulated sheep which were maintained on good quality hay of Rhodes grass (*Chloris gayana*).

Regression and correlation analyses were done by using the in vitro dry matter digestibility results obtained from the summative relationship (Van Soest 1967) and in vivo digestibility data. The in vivo DMD obtained from an in vivo digestibility trial in which two wether sheep were fed on each by-product. Preliminary period in this trial was seven days followed by 14 days collection period.

Rate of in vitro dry matter and organic matter disappearance: The rate of in vitro dry matter and organic matter disappearance for all experimental by-products was carried out by looking at in vitro digestibility (Tilley and Terry 1963) at various time intervals: 0, 12, 36, 48, 60 and 72 hours (incubation in the rumen liquor), followed by a 48 hour pepsin digestion for each digestion time.

In vivo digestibility: The in vivo digestibility measurements were made as described in paper II of this series of Kevelenge et al (1983).

Statistical analyses: Statistical analyses were done according to standard procedures outlined by Snedecor and Cohran (1967), Goulden(1956) and Steel and Torrie (1960).

Means were compared using Duncan's New Multiple-Range Test (Steel and Torrie, 1960) only when ANOVA revealed significant differences amongst means. Regressions and correlations were tested by a t-test (Steel and Torrie 1960; Snedecor and Cochran 1967).

Results

Sugarcane stalks had a significantly ($P < 0.05$) lower NDF and ADF fractions than the other by-products as shown in Tabla 1. Cellulose fractions ranged from 22.6% (sugarcane stalks) to 41.8% (maize cobs) while the hemicellulose fractions varied from 13.1% to 39.1%. All by-products were highly lignified, with ADL values ranging from 4.4 to 5.8 percent.

Dry matter digestibility calculated from in vitro digestibility of neutral detergent fibre (NDF) and neutral detergent solubles (NDS) was as shown in Table 2. The results showed that the DMD of maize stalks and sugarcane stalks were higher ($P < 0.05$) than that of other two by-products. Maize cobs had the lowest DMD.

The dry matter and organic matter digestibility values of the by-products by the two-stage in vitro procedure are presented in Table 3. Maize stalks and sugarcane stalks had comparatively higher dry matter and organic matter digestibility than maize cobs and sugarcane tops. The digestibility of sugarcane stalks was much lower than was expected, mainly due to the presence of the rind. DMD in derinded sugarcane stalks was 82.5% compared to the whole underinded sugarcane (65.9%). The rind with a mean DMD of 40.9% had a depressing effect on the DMD of whole sugarcane stalks.

Table 1:

Organic structural components of by-products (means of six replicate samples)

Item	Diets			
	Maize stalks	Maize cobs	Sugarcane stalks	Sugarcane tops
Organic structural composition of dry matter, %				
Neutral detergent fibre (N D F)	60.9	86.7	40.6	63.3
Neutral detergent solubles (N D S)	39.1	13.3	59.4	36.7
Acid detergent fibre (A D F)	36.3	47.6	27.5	43.1
Cellulose	31.9	41.8	22.6	38.1
Hemicellulose	24.6	39.1	13.1	20.2
Acid detergent lignin (A D L)	4.4	5.8	4.9	5.0

Similar trends were observed in OMD and DOMD. The low OMD compared to DMD values were attributed to the ash contents of the by-products. The effect was more pronounced in sugarcane tops diet than in any of the other three by-products.

The depressing effect of the rind on the organic matter digestibility of whole underinded sugarcane stalks was still conspicuous, although the organic matter digestibility of underinded sugarcane stalks was higher ($P < 0.05$) than that of maize stalks, maize cobs and sugarcane tops. Sugarcane pith, DMD (82.5%), OMD (82.5%) and DOMD (79.5%) was more digestible than any of the other by-products.

The regressions of in vivo DMD on in vitro DMD were linear and significant for both in vitro methods (Table 4).

The main objective of the rate of in vitro dry and organic matter disappearance trial was to study the rate of digestion of each by-product with time of incubation. The disappearance of DMD, OMD and DOMD followed

Table 2:

Summative average dry matter digestibility estimated from digestibility of neutral detergent fibre (NDF) and neutral detergent solubles (NDS) fractions of the by-products[1]

Experimental diet	NDF			NDS			TOTAL (True digestibility) (%)	Endogenous and bacterial matter as % of intake	Apparent digestibility (%)
	% in DM	True digestion coefficient (%)	Digestible amount	% in DM	True digestion coefficient (%)	Digestible amount			
Maize stalks	60.9	69.9	42.6	39.1	98	38.3	80.9	- 12.9	68.0[a]
Maize cobs	86.7	48.4	42.0	13.3	98	13.0	55.0	- 12.9	42.1[c]
Sugarcane stalks	40.6	55.7	22.6	59.6	98	58.2	80.8	- 12.9	67.9[a]
Sugarcane tops	63.3	50.2	31.8	36.7	98	36.0	67.8	- 12.9	54.9[b]

SE of treatment mean = ± 3.9%

[abc] Means in the same column with different superscripts were significantly different ($P < 0.05$)

[1] Means represent data from ten replicate samples except NDS true digestion and endogenous and bacterial matter

Table 3:

Two-stage in vitro digestibility of the by-products[1]

Experimental Diets	In vitro digestibility		
	DMD %	OMD %	DOMD (D-Value) %
Maize stalks	66.5	64.8	60.1
Maize cobs	58.8	58.3	57.3
Sugarcane stalks (Rind + Pith)[2]	65.9	65.1	63.3
Sugarcane rind	40.9	38.3	36.1
Sugarcane pith	82.5	82.5	79.5
Sugarcane tops	54.0	52.9	47.7

[1] Means represent data from six replicate samples

[2] Results on sugarcane and pith were separately included in the table to contrast the various factors that affect the digestibility of whole sugarcane diet (rind and pith together)

Table 4:

Regressions relating Van Soest and Tilley and Terry in vitro dry matter digestibility to in vivo dry matter digestibility (DMD)

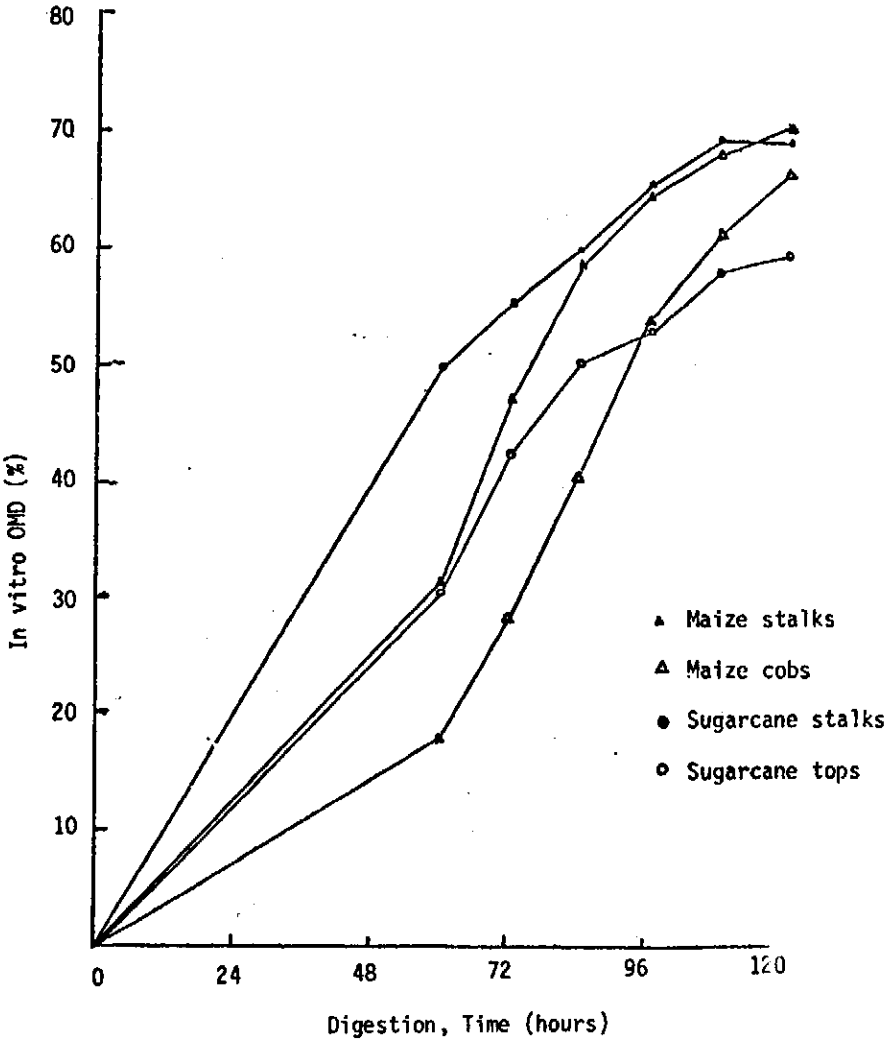
Reference	(n)	Correlation coefficient (r)	Regression	Residual standard deviation (RSD)
Van Soest in vitro	40	0.97***	DMD = 2.8 + 0.96 VDMD	± 1.1
Tilley & Terry in vitro	40	0.91*	DMD = 22.95 + 0.6 VDMD	± 2.0
	40	0.98*	OMD = 26.52 + 0.57 VOMD	± 0.9

* $P < 0.05$ *** $P < 0.001$

a similar pattern indicating that sugarcane stalks was easily digested in the initial hours of incubation in the rumen liquor, followed by maize stalks, sugarcane tops and maize cobs.

At 120 hours (72 hours incubation in rumen liquor and 48 hours acid pepsin digestion), all by-products reached a plateau. The rate of disappearance of OMD is shown in Figure 1. This graph indicates that dispite

Figure 1:
Rate of in vitro organic matter disappearance



the rapid digestibility of sugarcane stalks initially, the same rate of digestion was not maintained throughout the digestion period. On the other hand, maize stalks and maize cobs, whose initial digestibility was lower than sugarcane stalks, were digested at an increasing rate until eventually digestion was the same level with sugarcane stalks. Digestion of sugarcane tops progressed at a decreasing rate, such that by 120 hours sugarcane tops digestion was much lower than the rest of the by-products.

Discussion

The acid detergent fibre (ADF) analysis (Van Soest 1963) was included in the trial to evaluate the quality of the fibre for ruminants, as suggested by Van Soest and Moore (1965). However, there was little varia

tion in lignin content between the by-products.

Analysis of the NDF (cell wall constituents, mainly cellulose and lignin) and NDS (cell contents) contents of the by-products can be used to assess their nutritive value. The cell contents are assumed to be 98% digestible, while the cell wall constituents have variable but lower digestibilities (Table 2). Sugarcane stalks had a lower NDF content than the other 3 by-products, but with a lower digestibility coeficient than for the NDF of maize stalks; these 2 by-products had similar overall digestibility coefficients.

Combinations of NDF, NDS, ADF and ADL have been reported to give accurate results in predicting in vivo DMD (Van Soest and Moore 1965), but accurate prediction using these parameters was not possible for these by-products. Such predictions do not take account of other factors which influence digestibility, such as the maturity and species of forage, the digestibility of individual organic structural components, and the effects of plant silica in reducing digestibilities (Jones and Handreck 1965; Van Soest and Jones 1968; Smith et al 1971).

These factors are accounted for in vitro measurement of digestibility and digestibility results by the two-stage in vitro technique were in close agreement with results obtained by Van Soest in vitro digestibility technique (Tables 2 and 4). The observation that DMD, OMD and D-value of maize stalks and sugarcane stalks were significant different ($P < 0.05$) from maize cobs and sugarcane tops confirmed that the former two by products were higher in digestibility than the latter, hence could also be higher in their nutritive value. The in vitro DMD results obtained by the Van Soest (1967) procedure could be used to accurately predict in vitro DMD as shown by the linear relationship (Table 4) with low RSD values.

The rate of dry matter and organic matter disappearance in the rumen liquor revealed that in vitro digestibility of these by-products was strongly associated with incubation time. A specific time was required before each by-product was fully soaked to facilitate digestion by microorganisms. This was more so in the case of maize cobs which had the lowest digestibility in the initial hours of rumen liquor incubation.

The relationship between in vitro digestibility and time, suggested that the by-products could have been utilized more efficiently if some physical or chemical treatment had been performed prior to feeding them to animals. Physical or chemical treatment could have reduced the length of time taken in digesting the by-products. Treatment of by-products would be more effective, particularly of maize cobs, which required relatively longer retention time than maize stalks, sugarcane stalks and sugarcane tops before achieving the same level of digestibility. Any treatment of these by-products could facilitate a faster digestibility by rumen microorganisms than was observed in this trial.

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