QUANTIFICATION OF AGRICULTURAL BY-PRODUCTS COMMONLY USED IN ANIMAL FEEDING

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INTRODUCTION

As the human population continues to grow unabated in the developing regions of the world and food preference changing, the demand for food including animal protein is bound to increase. However, the high human population creates a high pressure on agricultural land such that land set aside for livestock production is getting smaller. For example, in Kenya, it is estimated that the *per capita* land availability in high and medium potential areas of Kenya will be 0.51 hectares by 1985 (Said, 1980) in comparision to 0.64 hectares in 1979. Unfavourable land to human and land to animal ratios call for changes in livestock feeding systems. One such development has been the use of crop residues and by-products for animal feeding.

Although the use of agro-industrial by-products as livestock feeds has been carried out since time immemorial, the scientific studies on the systematic utilization of such products started by the turn of this century (Otis, 1904).

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Since then most studies have revolved around quantification of the available agricultural wastes and their systematic utilization by livestock (Jackson, 1971; Owen, 1976; Said, 1982). In planning the use of residues and by-products in livestock feeding, it is preconditional to have information on quantities available. Unsurprisingly therefore individual scientists (Owen, 1976, Said, 1980; Kategile, 1981; Jackson, 1971) and institutions (FAO, ILCA) have attempted to estimate the quantities of crop residues and by-products for livestock feeding.

In connection with quantification, a number of ratios have been developed in temperate and tropical countries relating crop residues to some form of yield such as grain yield in case of cereals (Owen, 1976; Said, 1980). The validity of such ratios for all situations especially for crops grown in developing countries is questionable due to a large variation in crop production practices. The use of such ratios could, therefore, either under or overestimate the residue and by-product quantities which could bear little relevance to livestock feed budgets.

This paper is intended to draw the attention of scientists on the need to verify the ratios and/or modify the ratios to validate the estimates of quantities of agricultural by-products produced. Some crop wastes are taken as examples with reference to Kenya. It is also intended to give guidelines on sampling procedures.

QUANTITY OF CROP WASTES

Proper collection of data for estimation of crop wastes is paramount. The agricultural by-products as livestock feeds should be broadly divided into two major categories namely; i) farm crop residues, and ii) industrial by-products. The farm crop residues include mainly the cereal straws for rice, wheat, oats, barley and millet, maize and sorghum; and the haulms of beans, peas and groundnuts. This category includes also the potato vines, sugarcane tops and banana stems, leaves and peels. The industrial by-products include the special farm extracted waste such as maize bran and wastes of sisal, coffee, pineapple and sugarcane. The other major groups of industrial by-products consists of rice polishings, brans from cereals, cakes from oil seeds and nuts, brewer's wastes and pyrethrum marc.

There are basically two methods of estimating quantities of crop wastes available:

1. Direct method of estimation in which samples of crop and crop residues are taken in the field and processed in the laboratory. Once the production per unit area is known and by knowing the total area under the crop a final estimation of the particular residue can be obtained.

2. Indirect method of estimation which depends on derivation of ratios relating residue or by-product extracted per unit grain or crop produced. If the total crop production figures are known a final estimate of a particular residue or by-product can be done.

The methods of collecting data vary slightly depend-on which category of wastes (residues or by-products) is being investigated.

Crop Residues - Data Collection

1. Background Preparations

   Gather basic information on the target area or area of study with regard to the following points.

   a. Geographic and demographic - area, population size and density, economic and social structure of the population etc ...

   b. Land use and agriculture - arable land, area under specific crops, yield of each crop, staple and cash crops, crop processing capacities, livestock populations, production and major uses. Present use of crop residues produced.

This information can be obtained from Ministries of Agriculture and/or Livestock Development, Central Statistical Units and Non-Governmental Organisations such as FAO. These data should be tabulated and interpreted. Table 1 gives such data

Table 1. Geographic, Demographic (Human and Livestock) and Agricultural Land use in Kenya and Tanzania

	Kenya	Tanzania
Area ('000 km^2)	580.4	945.0
Population (million)	15.3	18.0
Density (per km^2)	26.4	19.0
Arable land ('000 ha)	1,790.0	5,140.0
Pasture land ('000 ha)	-	35,000.0
Agriculture as % GNP	36.6	41.0
Cereal Production: ('000 tons)		
Small grains	415.0	305.0
Maize	2,500.0	900.0
Sorghum/Millet	350.0	220.0
Others ('000 tons)		
Sugar-cane	401.3	1,367.0
Cotton seed	18.0	116.0
Sisal	46.9	81.0
Pineapple	145.0	47.0
Pyrethrum	15.8	-
Sunflower	-	40.0
Coffee	91.0	52.0
Legumes production: ('000 tons)		
Beans	360.7	150.0
Groundnuts	117.0	75.0
Peas	-	-
Livestock Production: ('000 head)		
Cattle	10,247.0	12,900.0
Sheep	6,500.0	3,000.0
Goats	8,500.0	4,700.0
Camels	607.0	-

on Kenya and Tanzania which is typical of most developing countries. There are four basic problems with these data:

(i) The information is in most cases scanty and incomplete.

(ii) In case of food staples such as cereals and pulses, the production estimates sometimes overlook the produce consumed on the farm.

(iii) For major cash crops such as sugarcane, the crop acreage is usually based on large scale farms neglecting the small scale acreage.

(iv) These data are available a year or two after the crop is long gone. In terms of feed budgeting or inventorizing, the estimated production figures can only be used in an extrapolative manner. This speculative use of the data can hardly be relied on.

These kinds of limits in the target area or national statistical data affect directly any form of estimates of crop residues and by-products available.

2. Zoning and Stratification

a. Make a quick inspection of the area before sampling and decide on how and where to take samples.

b. Divide the target area into climatic zones in which a particular crop is grown. In Kenya, for example there are a number of maize growing zones in which different maize varieties are grown. Zoning in essence eliminates biases due to variety and climate.

c. Appraise visually the crop stand in terms of plant population (sparse to dense) and quality of crop (poor to good) before selecting sampling sites - plots within a field and fields within a growing zone.

3. Sampling

a. Select sampling sites that reflect the real situation of the crop using zoning and stratification procedures mentioned in 2a, b and c.

b. Take samples that are adquately representative. Sample not less than three(3) plots per hectare and not less than ten(10) fields from each growing zone.

c. Apply sampling methods that are acceptable internationally. For crops planted in rows apply the agronomically acceptable methods of sampling that take into account critical factors such as fertility and nutrient uptake gradients. For crops that are broadcast such as millet and those that tiller like sweet potatoes, apply the quadrant method commonly used in pasture studies for estimation of yield.

Crop By-products - Data Collection

1. Background Preparations

a) Make contacts with relevant ministries, industries and institutions on the existing and planned processing industries. Information is likely to be obtained from the following: Ministry of Agriculture and/or Livestock; Ministry of Industry; Chamber of Commerce, Crop Authorities and/or Boards (coffee, sugar, sisal, cereals, cotton, etc); Central Statistical Units; and other organizations. Information sought should include; names of factories, number of factories; respective processing capabilities (types of crops to be processed and quantities); processing technologies involved; actual quantities of raw materials obtained and produced over a period of time (5 to 10 years); types of by-products produced; actual quantities of by-products produced annually; theoretical extraction rates of plants; actual extraction rates obtained over a number of years; factors affecting extraction rates; disposal of processed by-products; and future plans.

b) Make appointments for the visits and interviews with officials of the ministries, institutions and factories. One might be able to gather information from central bodies in one country but the same may not be true in others.

2. Sampling

a) Make a quick inspection of the factory and stores before taking samples to make a decision on what to sample and from which place will a sample be drawn.

b) Samples of seeds and free flowing feeds from bags should be as representative as possible using a sampling spear or by opening them and removing a small portion. The number of bags from which samples should be taken depends on the size of the lot.

Table 2. Percentage of bags to be sampled as influenced by size of batch

Size	Percentage of bags to be sampled
2-20 bags	20%
21-60 "	10%
61-200 "	7%
201-500 "	5%
501-1000 bags	4%
More than 1000 bags	3%

Samples of less than 100 kg consisting as little as one bag should be sampled so as to produce as representative a sample as possible, weighing at least 0.75 kg.

Similar materials stored in bulk require samples taken in accordance with the size of the lot as indicated below:

Table 3. Number of samples to be taken from bulk lots

Size	Number of samples
Less than 1 ton	4
1 - 2 tons	6
3 - 5 "	10
6 - 10 "	15
11 - 25 "	25
26 - 50 "	40
51 - 100 tons	60
For each additional 1 ton in excess of 100 tons	2

Very lumpy materials such as oilcakes require a slightly different sampling procedure, in which pieces are selected from different parts of the whole quantity as follows:

Table 4. Number of pieces (samples) to be taken from lumpy materials

Size of lot	Number of pieces
Less than 2 tons	5
2 - 5 tons	10
6 - 50 "	15
51 - 100 "	25
For each additional 20 tons in excess of 100 tons	2

Precautionary note: examine the samples collected thoroughly for evidence of wetting, presence of contaminants such as stones, dirt and storage pests. The presence of these should be recorded. Samples with high moisture contents are liable to spoilage.

c) Liquids in drums e.g. molasses, should be sampled in accordance with the plan for bagged materials. Bulk tanker containers of molasses can be sampled by taking portions from top, middle and bottom of tank.

d) Samples from effluent e.g. sisal waste should be drawn from the channel at intervals of 15 minutes for two hours and bulked and reduced in size. It may be necessary to draw two types of samples vis. with water, without free draining water.

e) To ascertain that samples drawn on that particular day are representative, one should get information on the operationa conditions of the processing plant at the time when the materials sampled were produced.

4. In view of the fact that different varieties of crops (e.g. maize, rice) mature at different times of the growing/harvesting seasons, it is important to sample in coincidence with the specific varietal harvest periods.

Handling of Samples

a) Separate residue from crop, i.e. straw from grain, and remove any contaminants. Weigh the crop and residue separately.

b) Composite samples of crop and residue separately. The compositing should be restricted to the sampling fields, in case of crop residues; and to batch basis in case of crop by-products.

c) Subsample the composite samples using acceptable techniques especially taking into account the minimum representative fraction of not less than 2 kg, in case of solid samples and 1.0 to 2.0 litre, in case liquid samples.

d) Determine dry matter content on all subsamples using the standard procedures (A.O. A.C., 1980).

e) Express all yields on a dry matter basis and calculate ratios using these yield figures.

Problems in Estimation of Quantity

When estimating the quantities of crop residues and by-products a number of problems are encountered.

a) Laboratory facilities - in order to make reasonable accurate estimates, good laboratory facilities for determining, among other things, dry matter content should be available. Access to such facilities in remote areas is impossible.

b) Co-operation - small scale farmers tend to be suspicious and very unwilling to co-operate in such surveys. This biases sampling as most of it is done on Government stations and large scale farms.

c) Difficult estimates - for crops that go into ratoons such as sorghum and sugarcane the estimates of crop residues for the first crop and the subsequent ratoon crops should be different. The national figures of acreage under the crop do not usually differentiate this. And for perennial crops that produce crop residues throughout the year, such as sweet potatoes planted on the flat as in Kenya, the crop residue yields are difficult to estimate.

d) Availability of crop wastes

Total estimates of crop residues and by-products are of very little value in terms of animal feeding. Estimates of available wastes should be done using correction factors for 1) alternative uses 2) imports and exports 3) consumer preferences, among other things. For example in Kenya, consumer preferences determine the amounts of maize bran and rice polishings available for animal feeding. Instalat-ion of efficient machinery has affected the availability of sisal and pineapple waste. The use of pyrethrum marc for making mosquito coils; maize stovers and cobs for feul; rice straw for coffee mulching and molasses for the manufacture of alcohol and feul, have all drastically reduced the availability of the respective crop residues and by-products for livestock feeding.

Expression of quantities

All estimates of crop residues and by-products should be expressed on dry matter basis. This has many advantages some which are:-

a) Relationship with animal feed requirements. This helps in feed budgeting.

b) It also gives more accurate comparative data which would be important in ranking sources of residues and by-products for livestock feeding.

There is a common tendency especially by big industrial concerns and some agronomists to express residues and by-product quantities in terms of fresh weight. This is misleading. For instance, Kenya Canners Limited reported a pinneapple waste recovery rate of 15.6%. From the pinneapple production figures at the factory, this worked out to 25,000 metric tons of waste annually. When the waste was analysed, the dry matter content was only 25%. So the available livestock feed from this source was only 6,250 metric tons annually. This situation is very true especially where wet processing is practised.

All estimates of crop wastes should be matched to livestock units on a national level first. But because crop residues are not necessarily produced in areas with relatively high livestock concentration, and this coupled with the problem of transportation of crop wastes, the amounts of crop residues and by-products available per livestock unit should be calculated for each major livestock producing area. This is the most important piece of information.

Some Residue and By-Product Ratios of Crops Grown in Kenya

The few ratios given in Tables 5 and 6 are derived from a study currently going on in Kenya on inventoring crop residues and by-products. The study is not completed yet, hence the obvious gaps in the presented data. The data was collected using the methodology described earlier in this paper.

Table 5 gives ratios of stovers to grain for maize in Kenya which varied from 1.0:1.0 to 3.6:1.0. This variation was caused mainly by variety of maize, climatic factors and agronomic practices among other factors. These figures also differed from those commonly used in estimation of maize stores production (Owen, 1976; Said, 1982; Butterworth, 1984; Urio, 1984; Kategile, 1981). There are other factors which could affect residue to crop ratios such as method of harvesting, contamination and field losses during harvesting sampling plots.

Table 6 shows some extraction rates of some crop by-products commonly found in Kenya. Extraction rates tend to be affected by a number of factors such variety, method of extraction, type and operation of machinery and stage of processing. It is important to note that the extraction rates are lower when expressed on a dry matter basis.

Table 7 highlights the problem of using different conversion ratios in estimating crop residues. The variation in maize, sorghum and millet stovers production estimates calls for serious systematic verification of the commonly used conversion factors from various workers and institutions.

Table 5. Some Factors that affect Crop Residue Yields - The Maize Case Study

Location	Variety	Year	Season	Fertilizer Applied (Kg/ha)		Stover[1]: Grain Ratio
				Nitrogen	Phosphorus	
Kabete	H511	1981	Long rains	37.5	37.5	1.8:1.0
Kabete	H512	1983	" "	0	100	1.0:1.0
Kabete	H512	"	" "	100	0	1.0:1.0
Kabete	Katumani composite	1983	Short rains	0	0	2.1:1.0
Embu	H512	1981	Long rains	37.5	37.5	3.6:1.0
Embu	H512	1982	Long rains	37.5	37.5	2.7·1.0

[1] Stover included the stem, the leaves and husks and the ratios are based on dry matter content.

Table 6. Some Factors That Affect Crop By-product Yields

Crop/By-product	Variety	Method of Extraction	Type of Machinery	% recovery	
				As is	DM basis
Maize (bran)	-	Physical	Batch	18.1	16.3
			Automated	15.9	14.0
Rice (bran)	-	Physical	"	10.0	8.9
Pyrethrum (marc)	-	Chemical	"	~~67.0~~ 93.0	~~58.4~~ 80.9
Pineapple (waste)	-	Physical	"	15.6	3.9
Coffee (pulp)	Arabica	Physical	Batch	44.0	29.0
Sorghum (bran)	White	"	"	15.0	-
	Red	"	"	20.0	-
	High tannin	"	"	25.0	-

Table 7. Comparative Estimates of Crop Residues and By-Products Produced in Kenya and Tanzania Using Different Conversion Ratios[1] ('000 metric tons)

Country	Kenya		Tanzania		
Authors (Year) / Crop Residue	Butterworth (1984)	Said (1982)	Butterworth (1984)	Kategile (1981)	Urio (1984)
Maize Stover	3000	5000	1200	2000	3098
Wheat Straw	212	187	70	78	41
Rice Straw	40	39	200	131	379
Sorghum/Millet Stover	1399	676	6214	621	3429

[1] Butterworth used conversion ratios developed by Powell in West Africa (residue: grain) maize 1.6, millet, 4.5, sorghum 3.7, wheat and rice 1.0); Kategile and Said used Owen's "temperate" ratios (residue: grain, maize 2.0, millet and sorghum 4.0, wheat and rice 1.0) and Urio used "Tanzanian" ratios (residue: grain, maize 2.0, millet and sorghum 3.7, wheat and rice 1.0)