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# Post-Harvest Studies and Quality of Yams - A review

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There have been few studies on factors affecting yam tuber quality. Tuber quality can be approached from several points of view: nutritional value, changes in organoleptic and physico-chemical characteristics during storage and food preparation or the differing responses of the various yam cultivars to these factors. This paper reviews the literature on these aspects of yam quality and reports on work carried out in Guadeloupe to characterize the response of different yam species to storage and cooking. The studies bring out the differing behaviour among and within *Dioscorea* species and the need to take into account post-harvest behaviour when selecting cultivars for a particular food or processing use.

**Keywords:** Yams; *Dioscorea* spp.; Post-harvest; Tuber quality; Storage losses; Processing

## Introduction

The main use of the genus *Dioscorea* is for food. A few species have pharmaceutical use and small amounts of yam food waste are used in animal feed. Among the nearly one hundred edible *Dioscorea* species, which are the true yams (Martin, Degras, 1978), the main cultivated ones have provided the needs of millions of people in the tropics for many centuries, in the following respects:

- high food production per unit area
- good balance of nutritive elements
- significant contribution to socio-cultural traditions.

If we consider the research carried out during the last decades, it has not been demonstrated that yams could perform as well as other staples like cassava, cereals or even sweet potatoes in these respects.

The possibility of attaining high yields still exists, but two constraints may account for today's situation. The economics of the production system and the relevance of post-harvest management systems have not been sufficiently studied. Post-harvest losses are known to account for between 25 and 50 per cent of the gross yield lost to the consumer. Improvements in cultivation cannot compensate for such large losses. Studies and experiments are not lacking in this area, but are far less numerous than conventional field research. They have never considered the whole process from harvest to final consumption. This paper is a modest attempt at providing a comprehensive approach to maintaining the qualitative value of yams after harvest.

Several aspects of the process of post-harvest utilisation of yam have been documented by several authors. We shall review these and also include original data from research conducted at INRA with the assistance of collaborators in the Caribbean and elsewhere.

## Post-harvest losses

### Losses during storage

Most yams are stored for several months before use. The consequent loss of weight is well documented (Coursey, 1967, 1981, Degras, 1986). Roughly ten per cent of harvest weight is lost per month, which amounts to between 50 and 60 per cent after a six month storage period, the maximum duration for most yam farmers. However, storage for as long as one year has been reported. (Malinowski, 1977).

As Treche and Guion (1979) have pointed out (Table 1), loss of edible portion may not be as great as loss of fresh weight and is also influenced by the cultivar. Losses are also increased by other factors, such as damage from wounds and bruises, nematodes, beetles or caterpillar attacks, and diseases.

Table 1. Effects of storage on nutritional potential of yam in the Cameroon (after Treche and Guion, 1979).

	Fresh		After 7 weeks		After 19 weeks	
	D. cayenensis	D. rotundata	D. cayenensis	D. rotundata	D. cayenensis	D. rotundata
Gross weight (g)	1000	1000	765	879	430	611
Peel lost (g)	28	20	37	25	49	37
Edible dry matter (g)	170	279	151	256	92	184

D. cayenensis = cv Batibo; D. rotundata = cv Oshei, both of Cameroon

### Reduction of Post Harvest Losses

To reduce storage losses, various attempts have been made to improve traditional storage methods, such as structural changes to the Nigerian yam barns (Wilson 1979) and replacement of yam houses in the Ivory Coast with storage pits (Sauphanor, 1986) and cribs in Guadeloupe. These changes have been combined with the use of pesticides. However, traditional use of wood ash is still effective although according to Nwankiti (1983), the choice of the wood or burning material is important. Careful curing under natural conditions can assist in providing a significant reduction of pest and disease attack (Degras, 1986).

Only sophisticated physical or chemical procedures can significantly reduce the normal deterioration due to aging, by reducing the rate of metabolism. Cold storage and gamma irradiation have been proposed (Adesuyi, 1978, Demeaux, 1981). The experimental use of gibberellic acid is now being studied at IITA and NRCRI in Nigeria, at IDESSA in Ivory Coast and at INRA in Guadeloupe, following the initial studies of Wickham (1983) in Trinidad. At INRA we have shown that Gibberellic acid is effective on *D. trifida*, which normally has a short dormancy. A report from Ivory Coast indicates the possibility of using a solution of gibberellic acid for as long as a week thus reducing the cost of the dip (Dumont, personal communication).

The characteristics of different cultivars in storage is well known. However, less is known about the effect of pre-harvest crop

management practices. A review of the effect of fertilizers on the rate of subsequent post-harvest tuber loss suggested some surprising results (Degras, 1985). Recent experiments in Ivory Coast (Dumont, 1986) suggest that fertilization may increase of the level of post-harvest loss. Treche and Guion (1979) have shown that depending on the cultivar of *D. cayenensis-rotundata* and the duration of storage, greater food yield could be obtained from harvesting at either seven, eight, nine or ten months.

### Losses during food preparation

**The edible part of the tuber:** The rejection of peel during food preparation leads to losses commonly estimated at 15% - 30% of the weight at harvest. Smaller losses are found with tubers from the primary harvest of *D. cayenensis* ssp. *rotundata* from a crop harvested at five months. In some parts of Nigeria part of the peel can then be incorporated in the part consumed (M. Akoroda, personal communication). In general, the bigger the tuber, the lower is the relative loss of weight from peeling. Finally, the highest relative losses occur with very irregular shaped tubers.

Varieties of some cultivated species (*D. alata*, *D. glabra*, *D. nummularia*) and of protocultivated, or wild species, may sustain a far higher relative loss due to their tuber morphology. For example, the yam head may be large, hard and unpalatable. In this case, losses can reach half of the harvest. In contrast, many cultivars of *D. trifida*, the cush-cush yam, have long slender peduncles between the nodal complex and the storage organ. Here, the ratio of relative loss from peeling can be as low as five percent depending on the cultivar.

Cultivation techniques and ecological conditions can induce wide variations in losses through effects on tuber morphology. One of the best known examples is the variation of the "head" portion in the tuber of some *D. alata* cultivars where late planting of cv Iaiti, in August, instead of March or April, suppresses the development of the unpalatable part. The total yield is lower than with early planting, but it is still within the range of good selected cultivars (Degras, 1986).

### Yam Composition and Food Value

The chemical composition of the important yams is well known, though the variations within species and in different ecozones needs further study. For instance, analysis of sugar content among cultivars of *D. trifida* (Splittstoesser, 1976) and *D. alata* (Bell and Fourier, 1981) provide evidence of a non-sweet cush-cush and of sweet *D. alata* cultivars. Before considering the balance among nutritional elements in yams, it is worth considering the toxicity or poor digestibility factors in some edible yams.

Nutritional acceptability factors range from actual toxicity of some edible yams (e.g. *D. bulbifera*, *D. dumetorum*, *D. hispida*) to the poor digestibility of some *D. alata* cultivars. Such problems can be avoided by choosing the cultivar or by a tedious detoxification process. However, studies done by Martin (1980) suggest that ordinary diets which include yams could contain some toxic components. Traces of an anti-amylase factor could account for the rather low digestibility of yam, when compared to cassava. However, even with the "toxic" species, *D. dumetorum*, non-toxic cultivars exist. Moreover Szylit et al. (1977) have proved that the starch of this species is as digestible as that of cassava. We are not aware of any extensive evaluation of the range of digestibility within a yam species. Such

research, as well as the evaluation of the range of toxic components (Eka, 1985) could provide explanations for the different intake levels and traditions of usage which exist.

We have cited already the work of Splittstoesser (1976) showing variation in the levels of sugars among species. He also showed in this paper the inter- and intra-specific variation in amino acid levels within five yam species.

The main nutritive component in yam is starch (50 - 80% of dry matter (D.M.)), which also shows considerable intraspecific variation, not only as proportion of the dry matter content, but also in its structure. The size of starch grains is closely related to the proportion of amylose and amylopectin. In *D. esculenta* such grain size ranges from 1 to 15 microns (Delpuech et al., 1978). The activity of the amylase enzyme during storage of *D. esculenta* also shows considerable intraspecific variation (Houvet et al., 1982). Size of grain and type of starch affect starch digestibility.

Few studies measure losses of nutrients occurring during cooking. Coursey and Aidoo (1966) studied the loss of ascorbic acid and observed losses of 5 to 35 percent depending on cooking method. The results of Splittstoesser (1976) for the loss of amino-acids during cooking presented in Table 2 compare both inter- and intraspecific differences. Losses of free amino acids can more than double depending on cultivar. The only complete study of the variation in nutritional components during culinary preparation (Bell and Favier, 1981) considers four yam species, but, unfortunately it lacks clear varietal references for *D. cayenensis* and *D. rotundata*. Figure 1 shows the different preparations and the resulting variations in protein, fiber, ash and thiamine content for *D. rotundata*. No change in the carbohydrate content was found. The effect of high levels of yam consumption on human health has been studied only indirectly (Martin, 1980).

**Table 2** Protein content and amino-acid changes resulting from cooking (Data from Splittstoesser, 1976)

Species	Protein (Nx6.25 % D.M.)	Amino-acid content							
		Before cooking				After cooking			
		Protein % protein	Total a.a. %	Free		Total a.a. %	Lost		
				%	%		%	%	
D.M.	D.M.	Total	D.M.	Total	D.M.	Total	Free		
<hr/>									
D. alata:									
cv Forastero	7.3	77	6.6	1.0	15.0	6.1	7.6	50	
cv Florido	10.5	78	9.8	1.6	16.3	9.5	3.1	19	
D. esculenta:									
cv Papa	8.2	68	7.6	2.0	26.1	7.3	4.0	15	
cv Spindle	8.8	82	7.9	0.7	8.9	7.6	3.8	43	
D. rotundata:									
cv guinea blanco	8.1	83	7.2	0.5	6.9	6.9	4.2	60	
D. trifida:									
cv Cousse-couche violette	6.7	76	6.1	1.0	16.4	5.8	5.0	30	
cv IKRA 25	7.6	78	7.2	1.3	18.1	6.9	4.2	23	

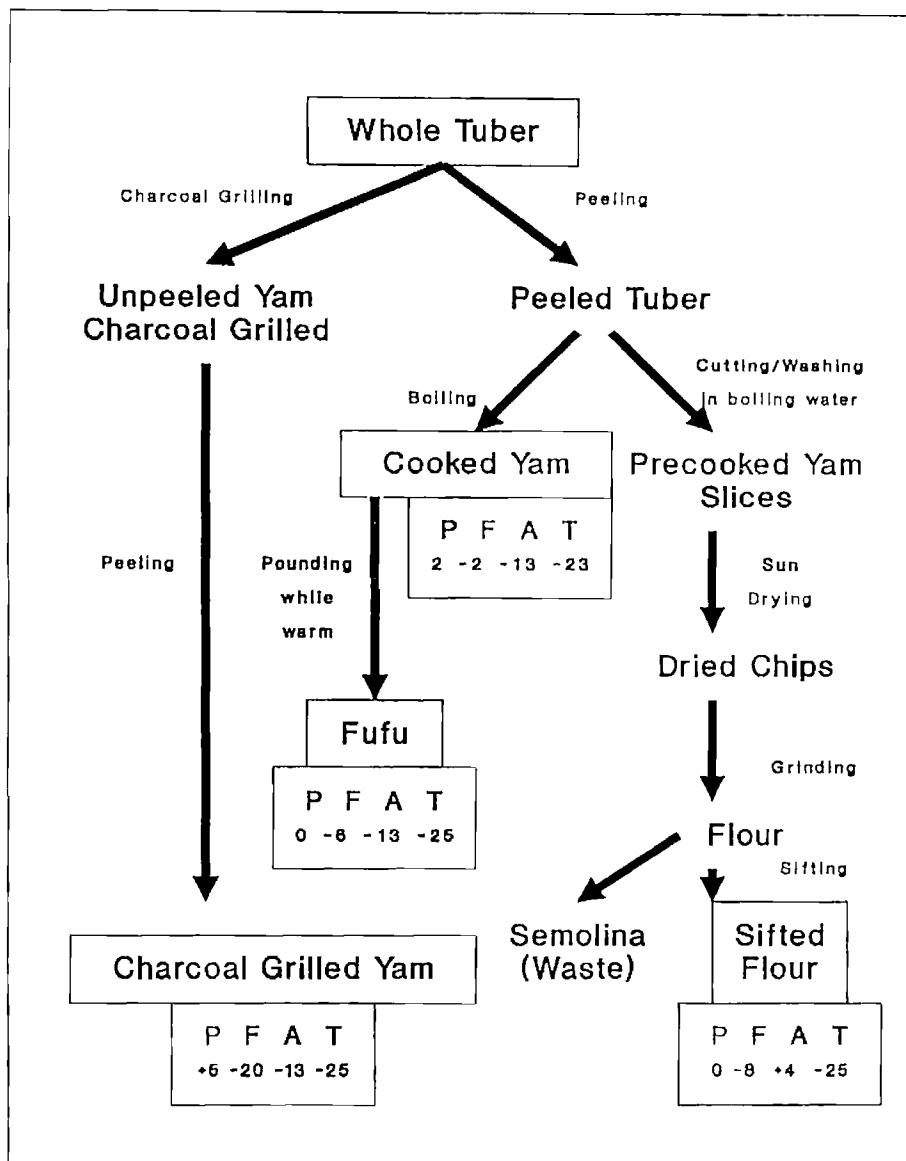


Figure 1 Changes in white yam (*D. rotundata*) composition after processing into various products after Treche and Guion (1970). Protein (P), Fat (F), Ash (A) and Thiamine (T) changes are given as % DM change from original whole tuber

## Evaluation of Cooking Quality

The chemical composition of a food resource does not itself determine attractiveness. Through their preparation processes, foods which are not eaten raw become more attractive. Identifying the factors responsible for this attractiveness is possible through sensory analysis of organoleptic characteristics and sometimes through physico-chemical analysis. Analyses can establish "objective" measures for easier selection of required varieties or for testing the conformity of industrial products to consumer preferences. They also provide socio-cultural data.

The relatively short time since the beginning of experimental selection of yams accounts for the absence of a methodology for determining culinary attributes and characteristics. From preliminary observations over several years and the very limited literature (Martin, 1976; Martin and Ruberte, 1976) we attempted to describe two series of yams for their culinary attributes.

### Culinary attributes of two series of yams

One of the main objectives of the study was to establish some basis for varietal characterisation and clonal selection among progenies. Varietal specification was tested with our *D. alata* germplasm collection and clonal selection feasibility was tested with *D. cayenensis-rotundata* material.

**Material:** Tests were begun on 61 cultivars of *D. alata* (local or introduced) in February, two weeks after harvest. Sixteen of these were still available in June after five months of storage.

Seventy clones of progenies of *D. cayenensis-rotundata* selected from 800 sexual seeds of IITA polycrosses received in 1983, were harvested after full plant senescence in February 1987 and observed the same month. Fifteen clones were also harvested at an early edible stage as a first harvest at five to six months after planting. A second sampling was made two or three months later, according to the traditional system. At the time of testing, the samples harvested early had had four to five months of storage, whereas the later harvested samples or those harvested only once were stored for only a few weeks. Only one tuber of each series of clones was available for study.

**Observations and Methods:** Weight, length and health of each tuber were noted. After peeling, three slices, one centimeter thick, were cut from top, middle and bottom sections of each tuber. Skin irritation by rubbing on arm, flesh granulation (cell starch and vessel arrangement) and flesh colour were noted for each section. Samples were placed in individually covered petriboxes, without directly adding water, and cooked for eleven minutes in a micro-wave oven provided with a free water surface. Cooking degree and flesh colour were noted, as well as consistency, sweetness and bitterness.

Specific gravity, pH and glucose (using colorimetric paper) were tested for most samples and chemical analysis for sugar was performed on a limited number of samples.

## Results

***D. alata* cultivars:** The observations made on the 61 cultivars tested after two weeks of storage as well as the tests on 6 cultivars with five months storage are still being analyzed. The only important



result so far is that the traditional cultivars (Pacala group) and good new selections (Belep, Plimbite) can be identified from our assessment, as having medium to weak flesh granulation, no skin irritation, maintenance of pure white flesh after cooking, firm to friable consistency and a score (scale of 0 to 3) of not more than 1 for sweetness and 0 for bitterness.

***D. cayenensis-rotundata* progenies:** The full analyses are not yet completed, but some preliminary results can be selected for discussion.

**Skin irritation:** Middle sections from 30% of clones were non-irritant, while 15% were very irritating in the sample of 70 single harvest clones. Good correspondence was found between early and late harvested material.

**Flesh granulation:** Very coarse granulation as seen in some *D. alata* types was not observed in middle sections of the tubers. Of the 70 late harvested clones, 63% was only slightly granulated. The distribution was similar for both systems of harvest.

**Cooking quality:** About 80 per cent of the middle tuber sections cooked well under the uniform time used. Insufficient or excessive cooking was sometimes associated with infected material.

**Flesh colour:** Table 3 presents data concerning the colour changes occurring to tuber slices of *D. rotundata* clones during cooking. From the data presented it is possible to conclude that:

- The number of colour combinations is increased by cooking
- Colour combinations are likely to be more diverse from late harvested material than from early harvested material
- The greyish component is always increased by cooking
- The dominance of the white component is obvious in early harvested material after cooking, but is not so clear after cooking late harvested material.

**Flesh consistency:** Flesh consistency of middle sections varied from pasty (21%) to firm (50%) or very firm (10%) and friable (10%). Some pasty samples appeared to be associated with infection of the tuber.

**Sweetness:** On a scale of 0 to 3 (3 = cush-cush yam standard) middle sections ranged from 0 to 2.0 with similar frequencies for 0.5 (27%), 1.0 (25%), and 1.5 (24%).

**Bitterness:** On a scale of 0 to 3 (3 = quite unpalatable) tuber sections ranged from 0 to 2.5 with 20% at 0 level and 44% at 0.5.

## Discussion - Conclusion

It is noteworthy that, apart from flesh coloration, which was studied for all three tuber sections, the harvesting systems did not appear to affect tuber quality. It may be that flesh colour is more susceptible than other characters to the duration of storage. If so, the longer storage time after the early harvest would reduce white colour levels. The data of Martin and Ruberte (1976) partly support this view. If the colour difference is due to the younger stage of the early harvested tubers having less developed off-colours, this could account for the traditional use of this material.

**Table 3** Coloration of yam slices of *D. rotundata* progenies before and after cooking

Sample	Harvest Date	Frequencies (%) of the Basic Coloration among the Samples								Number of Combinations of the Basic colorations	
		White		Yellow		Purple		Greyish		B	A
		B	A	B	A	B	A	B	A		
Same 15 Clones	Early	98	61	21	30	33	19	2	42	7	14
	Late	85	65	21	53	40	31	31	63	11	14
70 Clones	Late	91	57	46	44	44	16	28	71	17	25

1) B = before, A = after cooking

More characteristics should be considered, especially aroma at cooking. Osinowo (1985) found only slight differences between the aroma of *D. alata* and *D. rotundata*, but differences between cv. Taiti and other *D. alata* cultivars, as well as among the progenies was evident. A more experienced taste panel would have been required to weight the different odour profiles of our yams using the terms such as "sweet, cooked vegetable, aromatic, fragrant, earthy, nutlike, herbal" quoted by Osinowo (1985).

Also, there is need to asses more accurately the correlation between micro-wave oven and conventional cooking methods and to correlate the results of this year with those of future harvests.

As has been said, physico-chemical tests are at too much of an exploratory level for extensive comment. pH appeared somewhat reliable as a clonal character, while specific gravity and glucose levels did not appear to be reliable.

The usefulness of these characteristics of yam quality will be evident in view of developing the quality of yam food required by the consumer by selection or through technological transformation. For instance, "fufu" is the main way of consuming yam in West Africa and *D. rotundata* is obviously more adapted to traditional culinary recipes. In the Caribbean "fufu" is quite unknown and in many places white *D. alata* cultivars cut in big pieces and cooked in salted water remain the standard, while in Jamaica, yellow yam (*D. cayenensis*) is highly favoured.

These culinary differences require the maintenance of a reasonable level of cultivar diversity. A recent survey conducted in Martinique among 200 homesteads (Palcy, 1987) indicates a desire for a cultivar combining the qualities of the best *D. alata*, *D. rotundata* and *D. trifida* cultivars.

### Quality of Yam and Industrial Processing

Experience in the Caribbean, Africa and Asia has shown that yam can be processed either at the village level or in industrial scale plants using technology developed for white potato, to provide modern processed yam products suitable for urban consumption. Such products are "instant yam" and yam chips. Since it soon became obvious that choice of cultivar was important (Martin, Ruberte, 1972), more

attention has been paid recently to the effect of cultivar on the quality of "instant yam". At the beginning, only the quality of the different species was stressed, particularly in Barbados, where *D. alata*, *D. cayenensis-rotundata* as well as *D. trifida* were thought good, while *D. esculenta* was not (Sammy, 1983). There was perhaps little local experience with consumption of the product to provide guidance. The failure in the past of many attempts to produce "instant fufu" in West Africa is clearly related to lack of concern with varietal factors in the industrial processing (Dumont and Hahn, personal communication). Okpokiri's data (Okpokiri, 1982) clearly shows the differences between *D. rotundata* cultivars. Recent changes have led to promising products in Ivory Coast and Nigeria.

The successful use of yam mixed with wheat flour, in foods like bread or pastries, has also proved to be dependent on use of suitable varieties (Martin, Ruberte, 1975).

Even products which differ from usual standards can be promoted through publicity or adapted to the new requirements of our changing world. For instance, the low cost, mechanized production of cv. Florido in Ivory Coast could provide suitable material for an industrial "fufu" which could become established, despite its less classical taste, among poor consumers in the urban areas. The use of unpeeled yam as proposed by Akoroda (1987) may be similarly accepted.

The importance of technological and economic policies in determining the future development of yam utilization should also be recognised.

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