CROP POST HARVEST PROGRAMME

Project Title: Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana

R No: R6505; ZB No: ZB0016

FINAL TECHNICAL REPORT

1 January 1996 – 31 March 2000

Project Leader: Dr Roger D. Bancroft

Project Leader's Institution: Natural Resources Institute
at the University of Greenwich

Contents

Tables

Figures

Abbreviations

ADB	Agricultural Development Bank
DSC	Department of Agricultural Economic University of Ghana at Legon
DNFS	Department of Nutrition and Food Science, University of Ghana at Legon
EL	Ecological Laboratory, University of Ghana at Legon
FRI	Food Research Institute
FSD	Food Systems Department
GFDC	Ghana Food Distribution Corporation
GPRTU	Ghana Private Road Transport Union
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
IFAD	International Fund for Agricultural Development
MSEG	Marketing Systems Economics Group, NRI
MTADS	Medium Term Agricultural Development Strategy
MoFA	Ministry of Food and Agriculture, Ghana
NARS	National Agricultural Research Strategy
NRI	Natural Resources Institute, University of Greenwich
PPMED	Policy Planning Monitoring and Evaluation Department
RNRRS	Renewable Natural Resources Research Strategy

Acknowledgements

The author would like to acknowledge the role of the Crop Post Harvest Programme (as mediated by Natural Resources International) and the Renewable Natural Resources Research Strategy of the UK's Department for International Development for providing the opportunity and the necessary funding to conduct the research project reported here.

The implementation of the project in Ghana could not have been accomplished without the good will of the senior management of the Agricultural Engineering Services Department of the Ministry of Agriculture in Accra and the support of the Regional and District Directors of the Regions of Ashanti, Brong Ahafo, Northern and Volta; the Food Research Institute in Accra, and the Department of Agricultural Economics, Department of Nutrition and Food Science and the Ecological Laboratory – all of the University of Ghana at Legon.

To all those involved in the production and marketing of yam tubers who so generously gave of their time to participate in our surveys and to work along side the project team during our field-work – a very great thank you.

Finally, a sincere and heartfelt thank you to Mr David Crentsil, Counterpart Project Manager, and the Project Team in Ghana:
Mr Acheampong, Mr Asempah, Mr Danso, Dr Gallat, Mr Gogoe,
Mr Motte, Mr Noamesi and Mrs Zewedie-Bosuner, and Mr Collinson, Ms. Gray, Mr Jeffries and Mr Thompson at the NRI. It is only through your unstinting hard work and dodged perseverance that the project achieved its objectives.

Contact Address

Dr Roger David Bancroft
Senior Researcher (Post-Harvest Horticulturist, Technologist and Root Crop Specialist)
Natural Resources Institute at the University of Greenwich
Central Avenue, Chatham Maritime
Kent, ME4 4TB, United Kingdom
Tel: 01634 883733
Fax: 01634 880066/77
e-mail: r.bancroft@gre.ac.uk

Project Title: Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana

R No: R6505; ZB No: ZB0016

Keywords

Yam, *Dioscorea* spp., roots and tubers, West Africa, Ghana, post-harvest, handling, grading, curing, storage, yam-barn, transport, marketing, market characterisation, rots, disease, losses, quality, socio-economics

Executive Summary

Of a global yam production of 30.3 million metric tonnes per year some 95-96 % originates from the 'Yam-Belt' of West Africa where possibly 60 million people are involved in its production and marketing. In general resource-poor peasant farmers are responsible for the cultivation of yams for whom the crop represents both food security and an important source of monetary income. Population growth, urbanisation and the further development of local, regional and overseas markets suggest that the demand for yams will increase. If producers and traders were able to respond effectively to these marketing opportunities, the contribution to rural livelihoods made by the yam trade would expand, and the income generating potential of the crop would be more fully realised.

In 1994 the National Agricultural Research Strategy Plan for Ghana identified yam as a priority crop for research and development and particularly identified the need to reduce losses which were estimated at some 20% of production. In response, this project sought to examine the yam marketing systems within Ghana, determine the nature, causes and implications of losses and attempt to formulate and test appropriate technologies or protocols to reduce them.

The project revealed an intricate and keenly competitive traditional marketing system linking scattered farmsteads through a hierarchy of local markets to the more distant urban centres and markets in neighbouring states and overseas. Loss assessment studies indicate that the most significant consequence of the shortcomings in the contemporary marketing systems is the premature degradation of tubers by rots resulting in either partial or absolute biological loss of between 2 and 50% and price discounting often of the order of 35-80%. Also of significance is the observation that of all apparently 'healthy' yams sampled from the markets some 20-38% harbour chronic internal rots.

As the general level of development in the yam producing areas precludes the use of fungicides or refrigerated cool stores, the pre-storage 'curing' of yams has been advocated as a means of forestalling decay and moisture loss in tubers. There is scant evidence to suggest that this process has ever been deployed effectively on a large scale in West Africa. Observations made during project suggest that traditional curing techniques are generally too haphazard to make any significant impact on the shelf-life potential of yams and often hasten the onset of sprouting whereas, the rigid adherence to specific curing and post-harvest protocols have the potential to significantly reduce the weight of rots recovered from tuber samples after three and

four months storage. Laboratory research has sought to correlate the perishability of different varieties of tubers with a series of physiological indices. Associations are found to exist. It remains to be determined how this information may be practically exploited to select yam cultivars of different perishabilities for different retail markets.

The main conclusion of studies undertaken in Ghana is that, to effect any significant diminution and control of the losses identified in the marketing chain in the foreseeable future, specific traditional post-harvest handling and marketing practices will need to be radically altered with the focus of change directed at the producers and the exporters in particular.

1. Background

1.1 Constraints that impact on the post-harvest exploitation of yam tubers

1. Yam has potential to contribute significantly to the alleviation of food security concerns in West Africa. However in Ghana it has been noted that high production costs and post-harvest losses have increased prices to the extent that many indigenous consumers have turned increasingly to the consumption of cassava as a substitute (Tetteh and Saakwa 1991). To date, the relatively little research that has been conducted on yams has attempted to address the most obvious production problems associated with the crop and has considered methods of propagation, production strategies and measures against pre-harvest diseases (Tetteh and Saakwa 1991, and references therein), fewer studies have considered the improvement of the post-harvest system overall and the investigation of the marketing system has largely been ignored.

2. In the past, due to the lack of hard data, it has been exceptionally difficult to establish a reasonable estimate for the percentage post-harvest losses that may be sustained by a yam crop. Research undertaken in Ghana (Mück 1994) estimated that after storage of 2 to 6 months the general losses of root and tuber crops was of the order of 10 to 50 %. Alhassan (1994), also reporting from Ghana, cites post-harvest losses of yam and cassava at 30% of the total crop. Various authorities have all proposed different levels of loss for yams (Table 1) and, in common with other perishable commodities, published figures have often cited a potential range of values. It is, however, difficult to determine the validity of such generalised data when the basis of such calculations is omitted.

Table 1. A sample of estimates for the post-harvest loss of yams

Published Percentage Loss of Yam	*Authority*
5%	Anon (1986), Greeley (1991) and Lipton (1972),
10-15% in 3 months	Coursey (1967)
25%	Ihekoronge and Ngobby (1985) and FAO (1985)
40%	Waitt (1961)
30-50%	FAO (1975)
50% in 6 months	Coursey (1967)

3. The need to improve the post-harvest storage, handling and transportation of yams is underlined by the results of surveys conducted in Ghana by both the Natural Resources Institute (NRI) and by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). A survey covering on-farm losses in the Brong Ahafo and Northern Regions of Ghana conducted in 1994 by GTZ (GTZ 1995, S. Gallat, *pers. comm.*) estimated that the combined on-farm losses for fresh yam and cassava ranged from 4-25%. At that time such biological wastage equated to a mean financial loss of

194,000 Cedis (approximately 160 US$ equivalents) per farmer per season with individual financial losses ranging from 35,000 to 534,000 Cedis (approximately 28 US$ to 430 US$) per farmer per season. A further survey carried out by GTZ in 1995 focused specifically on yam, indicated an average biological loss of 18% over a typical storage period of 16 weeks (GTZ 1995, S. Gallat *pers. comm.*). When considering the available information that seeks to quantify and describe the post-harvest losses of yams very little data has been published that addresses the socio-economic components of the system. One recent study conducted by in Nigeria (Okoh in press, 1996) does suggest that post-harvest losses of the order of 12.4% (3.2% of tubers absolutely wasted and 9.2 % of tubers unfit for commercial sale) could equate to a loss of 10.45% of the expected gross revenue for the farmers affected.

4. Following storage on-farm, surveys undertaken during collaborative work between NRI and Ghanaian National Programmes have indicated the large quantities of yams are transported considerable distances from the areas of production to urban centres, and to ports for export (Kleih *et al.*, 1994). Observations suggest that considerable losses also occur during the process of transport and marketing, but there are few reliable data on the extent of these losses, or the nature of the constraints that inhibit the further development of these systems. To determine the economic viability of introducing different forms of technical interventions into existing indigenous yam production and marketing systems more studies are required to determine the economics realities faced by the producers and traders.

5. Yam itself is a very diverse crop covering many species of *Dioscorea* (Degras L. 1993). Edible yams contribute significantly to the diet of communities in many regions across Asia, Africa, South and Central America, the Caribbean and the Pacific, however, intensive yam cultivation is presently focused in what has become known as the 'Yam Zone'. This incorporates the West African states of Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria and Togo. Of the total annual global production of yam some 95-96 % is believed to originate from West Africa (FAO, 1994, and Onwueme & Charles, 1994). Estimates of the annual production of yams in Ghana in particular are disparate, but according to the FAO, 1 million tonnes of yam was produced in 1994. Six species are currently grown widely in West Africa: *Dioscorea rotundata* (White yam), *D. alata* (Water yam), *D. esculenta* (Chinese yam), *D. cayenensis* (Yellow yam), *D. bulbifera* (Aerial yam) and *D. dumetorum* (Trifoliate yam). Of these, White yam is the most important, constituting 80% of the total production, followed by Water yam and Chinese yam. In addition some wild species are also harvested for food. The storability of yams varies considerably between species, and between varieties. It has been observed that the White yams are much more perishable than Water yams. For White yams, although the basis is not understood, the most popular varieties tend to be those that are the most perishable. For example one of the most popular varieties, *Pona*, stores for a maximum of three months compared to 6-12 months for most other varieties (Kleih *et al.*, 1994).

6. Post-harvest biological losses of yams result both directly and indirectly from a combination of physical (Dumont, R. 1995), physiological and pathogenic causes The inherent high moisture and carbohydrate content of the tubers together with their bulky nature and high rates of respiration render them mechanically weak and prone to physical damage, attack by insect pests, animals and colonisation by micro-organisms and physiological deterioration. Losses, although increasingly evident

after harvest, often result from damage and infections that have their genesis in the field or at the time of harvest. Damage to the surface tissues of yam tubers whether by feeding insects (*Morse et al.*, 1999) and rodents, by mechanical damage at harvest and during subsequent handling or by the action of nematodes may all pre-dispose the host tissues to premature physiological deterioration and infection by fungal and bacterial agents.

7. Conventional wisdom suggests that the major causes of post-harvest loss are weight loss, rotting, insect infestation (Ezeh, 1995 and IITA, 1995) and sprouting. Weight loss occurs through a combination of respiration, water loss by seepage and evapo-transpiration. The latter being particularly accentuated by sprouting.

8. Changes in respiration rates with temperature and time following harvest have been studied (e.g. Passam *et al.*, 1976), but varietal differences have not been examined in detail and remain essentially under-exploited and poorly understood. The promotion of wound healing by curing has been shown to reduce water loss (Gonzales de Rivera, 1972; Martin, 1974; Passam *et al*, 1976; Thompson, 1972, and Thompson *et al.*, 1973). The optimal environmental conditions to promote curing have been studied by a number of investigators (see Akoroda, 1995; Been *et al.* 1974 & 1976, and Cooke *et al.*, 1988) but with mixed results. Again, varietal differences have not been studied extensively and the commercial exploitation of curing in the post-harvest sector appears to be minimal and haphazard. Weight loss by transpiration can be slowed by reducing ventilation, but the concomitant rise in relative humidity may increase losses due to rotting. Sprouts developed from tubers are another factor that particularly accentuates losses on-farm. Yam tubers do not respond to the most commonly used sprout-suppressants (Thompson & Bancroft, 1996; Campbell *et al.* 1962, and Hayward & Walker, 1961), giberellic acid has, however, been shown to be effective, and has been the subject of a number of studies (e.g. Cooke *et al.* 1988 and references therein, Nnodu and Alozie 1992). Unfortunately, there is scant evidence to suggest that this chemical can be used economically in those communities that would benefit most from its sprout suppressant properties.

9. Post-harvest rots are associated with much of the observed losses of commercial yams on-farm and during marketing. Major fungal and bacterial pathogens associated with commonly observed infections have been reported for several regions and in various contexts (Adeniji, 1970; Anon, 1986; Green and Simons 1994; Mishra *et al.* 1989; Noon, 1978, and Thompson *et al.* 1977), however, relatively little is known about which rots bring about what forms of quality depreciation and when, and there appears to have been almost no research undertaken to determine how the epidemiology of these diseases may be manipulated to reduce the incidence and/or severity of infection in the commercial post-harvest sector.

10. A body of work has developed describing methods for improving storage. This includes studies on the use of different designs for conventional ambient yam-storage barns (Adesuyi, 1973; Ezeike, 1985; Ezeike, *et al.*, 1989; Girardin, O. *et al.*, 1996; Henckes *et al.*, 1995; Nwankiti *et al*., 1988, and Thompson & Bancroft, 1996), the use of fungicides (Thompson & Bancroft, 1996) and the possible use of refrigeration to extend the storage life of yams (Cooke *et al.*, 1988). In the latter case, although yams are susceptible to chilling injury below 15°C, it is technically feasible to extend storage in this way, especially if fungicides are also used. Most of these

studies are characterised by their academic interest. Unfortunately few report the successful transmission of their findings into the commercial reality of yam production and trading.

1.2 Genesis of Project

11. The National Agricultural Research Strategy (NARS) Plan, and the Medium Term Agricultural Development Strategy (MTADS) of the Government of Ghana (1994) identified yam as a priority crop for research and development and particularly identified the need to reduce losses which the Ministry of Food and Agriculture (MoFA) officially estimated as some 20% of production. The survey work (cited above) undertaken by the NRI and GTZ added case study examples to support this proposition and led to the recommendation that research should be carried out into the storage and marketing of fresh yam if any help was to be forthcoming to the industry in the foreseeable future. Visits by NRI staff to research centres in Ghana, Côte d'Ivoire and Nigeria (1996) determined that although some research initiatives had been pursued with regards the on-farm storage of yams almost no research work had been or was being conducted on the problems of marketing yams in the West African Region. To respond to the concerns of the NARS in Ghana and apparent lack of knowledge regarding the problems that appeared to beset the commercial exploitation of fresh yams, therefore, the Project was designed to examine the structure and workings of the traditional yam marketing systems within Ghana, determine the nature, causes and implications of losses of fresh tubers and as a consequence develop, test and, if possible, promote appropriate technologies, protocols and pragmatic interventions that had the potential of improving the efficiency of the marketing chain.

Note: References cited in this section may be found in Appendix A.

2. Project Purpose

12. The work undertaken by the Project 'Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana' was specifically focused on the RNRRS Programme Purpose No. 3 'Non-grain starch staple handling, marketing and credit systems improved'. The commodity base was 'Yam' with a geographic focus in Ghana but with relevance to other countries in the West African 'Yam Belt'. In order to develop and promote post-harvest technologies and methodologies with the potential to impact on the constraints identified in the yam marketing system, the Project was designed to undertake the following:

a) Characterise the modes of operation of the principal marketing systems in Ghana;

b) Determine the probable cause, nature and extent of biological and economic losses in tubers during their transportation and marketing from the farm-gate to the traditional retail market;

c) Investigate appropriate technical solutions, and recommend more effective handling and marketing strategies for the marketing of fresh tubers, and

d) Correlate the physiological characteristics of different varieties of yams to their potential perishability.

3. Research Activities

3.1 Context of Research Activities

13. Work towards the realisation of the Project Purpose is best appreciated by reference to the series of ‘Outputs’ and research ‘Activities’ defined in the original Project Memorandum. A synopsis of these is presented in Appendix B. The various textural descriptions of the fieldwork undertaken and the research team’s findings pertinent to each output and defined activity area are also referenced in Appendix B. The authors of these latter documents, their titles and date of genesis may be found in the Appendix C.

14. In broad terms the various constituent activities of the project-necessitated inputs from three different subject areas, namely:

a) Socio-Economics
b) Post-Harvest Biology, and
c) Post-Harvest Physiology.

15. Table 2 records the location and schedule of activities undertaken in pursuit of the socio-economic and post-harvest biology components of the project. This work continued from the initiation of the project in February 1996 to March 1999. The post-harvest physiological studies were extended until March 2000. Table 3 summarises the parameters which formed the focus of these investigations.

16. Much of the work carried out during the first 18 months of the Project sought to identify and document the essential social-economic structure that supports the yam trade and how biological and economic losses of yam influence the income of traders. The socio-economic work was undertaken by staff of the NRI, Marketing Systems Economics Group (MSEG), Department of Agricultural Economic (DAE), University of Ghana at Legon and the Ministry of Food and Agriculture (MoFA) in Ghana. In particular this team worked on Output 1 and Activities 1.1; 1.2 and 1.3. Inputs from this team were also required for the economic component of Activity 2.1.

17. The Post-Harvest Biology component of the project dealt primarily with the assessment of biological losses within the marketing system and how environmental factors and post-harvest handling protocols influenced the observed biological loss of fresh yam tubers. This work formed the basis of Outputs 2 and 4. The concomitant Activities 2.1; 2.2; 4.1; 4.2 and 4.3 and were carried out by staff of the NRI, Food Systems Department (FSD) and MoFA.

18. Output 3 required access to laboratory facilities and input from post-harvest physiologists. The Food Research Institute (FRI) in Accra was commissioned to undertake this component of the project and a staff member from the FRI pursued Activities 3.1, 3.2 and 3.3. This work was undertaken both at the NRI in the UK and also at the Department of Nutrition and Food Science (DNFS) and the Ecological Laboratory (EL), University of Ghana at Legon. Supervisory inputs were made by staff from all three of these facilities.

19. From the time when the Project was first conceptualised until its termination, at all stages the research undertaken in relation to Outputs 1, 2 and 4 was conducted in partnership with the collaborative institutes and directly with representatives from or groupings of the various target audiences (i.e. yam producers, traders and their Market Associations).

20. Two post-graduate students from the University of Ghana at Legon became members of the project team during the course of the fieldwork. Where appropriate training and supervision was provided by both staff of the NRI and MoFA. One student used his observations in the field as a basis for his M.Phil. thesis. The second student, who is also a member of staff of the FRI, conducted research pertinent to his Ph.D. with material generated by the Project and with assistance and supervision by staff of the NRI and University of Greenwich. This latter student also received training at the NRI in the UK for a period of 12 months.

3.2 Methodologies adopted by the Socio-Economic Team

3.2.1 Market System Characterisation & Identification of Principal Agents active within the Yam Marketing Systems

21. Research to characterise the nature and identify the agents working within the existing Ghanaian yam marketing system was begun in February 1996. The main body of this work was completed within a year, however, where opportunity and resources permitted additional information was gathered throughout the course of the project by conducting surveys in key study areas (refer to Table 2).

22. On account of the qualitative nature of the data and the emphasis on understanding the processes and relationships of the marketing systems and in order to encourage the maximum level of participation, these studies made use of an informal 'Participatory Rural Appraisal' survey methods. It was considered that in the time frames often available a more formal approach would have proved too inflexible and would have probably misrepresented or understated the complexities of the systems of interest.

23. Individual and group interviews were carried out with representatives at all stages of the marketing chain. Key informants identified and interviewed included producers, producer/traders, rural and urban market traders, market administrators and truck operators. Respondents were selected on arrival at the village or market in collaboration with village elders or market associations. Discussions were held on a wide range of topics including production and supply of yams, seasonality, flows along the marketing chain, transport, finance arrangements, losses and problems faced in the storage and marketing of yams.

24. Secondary information of relevance to the yam marketing systems study was also used to compliment the primary data collected. This information was derived from the following sources: the Dept. of Policy, Planning, Monitoring and Evaluation (PPMED) of MoFA, Ghana, the Statistical Service, the Ministry of Transport and Communications, University of Science and Technology, Kumasi.

3.2.2 Interface between Yam Quality and Economic Value

25. An understanding of how product quality affects market price is a pre-requisite for technical interventions designed to improve product value. In 1997, NRI staff and officers from MoFA conducted two quantitative surveys of yam trading in Techiman market. The aim was to establish the importance of financial losses caused by poor yam quality and to measure the relationships between price and a series of quality defect variables.

26. A full description of the survey design, methodology and results appear in Gray *et al.*, 1997b. The first survey spanned five weeks in June and July 1997 and collected data on nine quality variables and price. Data gathering was categorised according to two types of trader (wholesaler and retailer) and two types of yam (one white and one water variety). In total, 120 heaps of yams were surveyed.

27. The data analysis of the first survey produced inconclusive results. At the beginning of the yam trading season the quality of the surveyed yams was too uniform to allow statistical techniques to tease out the relationships between the quality variables and price. Type of trader and the variety of yam emerged as the only reliable predictors of price. The analysis was unable to conclude that the quality variables either did or did not have an impact, merely that quality problems were not prevalent in Techiman market during the survey period. To improve the chances of finding quality price relationships in future studies, Gray recommended a shortening of the survey period to reduce the price impact of changes in daily and weekly market conditions, and to delay data collection until later in the season to capture greater quality variations that may occur at another times of the year.

28. A second survey was, therefore undertaken in November 1997. Details of the methodology adopted during this second attempt are summarised in Appendix D. The quality variables monitored were as follows:

- Tuber rotting
- Tuber breakage
- Surface damage (grazes, gashes, bruising, cuts)
- Termite damage
- Nematode damage
- Cooked spots
- Sprouting
- Tubers cut by trader due to rot
- Ageing

29. The second survey adopted similar analytical methodology to that used by Gray. An examination of scatter plots of price against each of the quality variables revealed which variables could be excluded from the analysis due to zero or minimal variation and also gave an early indication of potential relationships between variables. Collinearity between the explanatory variables was judged to be a significant potential problem and so a correlation matrix to indicate where linear relationships may exist was established. A series of multiple regressions on price were then calculated, using only one quality variable per regression to minimise the effects of collinearity. In each regression, a dummy variable described the type of trader (wholesaler or retailer) and a time trend was incorporated to account for the week in which each yam heap was surveyed. Tests for normality and constant residual variance were conducted for each equation.

3.2.3 Spatial Price Linkages in Ghanaian Yam Markets

30. A key issue in the marketing of agricultural produce is price variability. Both in-season and year-to-year price variability in spatially separated markets provides an indication of the efficiency with which the market system may react to changing economic conditions. Spatial market integration refers to co-movements of prices, and more generally, to the smooth transmission of price signals and information across spatially separated markets. Excessive price variability suggests the inefficient transmission of market price intelligence. A study commissioned by the Project and conducted by the DAE sought to answer the following:

1. To what extent may Ghanaian yam markets be considered as spatially linked?
2. To determine whether spatial linkages had improved over time.
3. To what extent are yam markets integrated? and
4. Whether market integration was demand driven or 'supply-pushed'?

31. Data used in the study was derived from the monthly observation of yam prices at the wholesale market level of 11 towns and cities in Ghana collected by the PPMED. Correlation coefficients and co-integration methods were employed in the analysis. This was augmented by field observations using semi-structured questionnaires.

3.3 Methodologies adopted by the Post-Harvest Biology Team

3.3.1 Generic Quality Assessment Protocol

32. Literature available in the public domain that cite forms of biological depreciation of yam tubers provide little precise information as to the qualitative nature or quantitative extent of the factors responsible. It was therefore necessary for the project team to devise *de novo* a scoring system that sought to make good this deficiency. The indices that were ultimately chosen and used on a routine basis to describe the biological quality of any given yam tuber under inspection are exemplified by the data record sheet illustrated in Appendix E.

33. This quality assessment system was used throughout the course of the project. Specifically the biological condition of both 'sound' and 'unsound' yams was routinely recorded during the monitoring of the:

1. yam consignments handled by various types of traders and retailers in the various markets surveyed;

2. yams used during the on-farm handling and storage trial devised to assess certain modified post-harvest protocols, and

3. yams used during inter-market transportation trials devised to assess the impact of external factors on yam quality.

3.3.2 Quality Depreciation in the Market Place

34. To assess the biological status of yams flowing through typical market locations yam samples were routinely recovered from separate wholesale and retail consignments. As resources permitted, return visits to the same markets were made over a period of days, weeks and months in order to collect information on the biological quality of yams being traded over time. Depending on the prevailing trading conditions assessments were undertaken on the range of white yam varieties available in the market on any particular day. Random samples were drawn from all grades of material from those attracting premium prices (Grade 1) to those that had been discarded (Grade 6). The number of roots sampled per consignment varied from 4 to 35 depending on the number of tubers per consignment. In each instance notes were taken of the known history of the different consignments, their trading value and, for each tuber sampled, both their external and internal physical attributes. Overall each tuber was assessed for over 40 different indices (See Appendix E).

3.3.3 Assessment of Modified Post-Harvest Protocols

35. An on farm trial designed to contrast the storage and shelf-life potential of yams exposed to different post-harvest handling and storage protocols was established for the duration of a single yam storage season. The experiment was conducted at Fiaso, a village in the Techiman District of the Brong Ahafo Region. Two varieties of yam were monitored – 'Pona' (often regarded as the most popular variety and market standard) and 'Lili'. Figure 1 summarises the methodology adopted in the execution of the trial. Once established the quality assessment protocol already described was used to monitor the condition of yams recovered from the yam barn over the period September 1998 to January 1999.

36. Essentially this trial sought to determine the impact of two levels of post-harvest treatment on the biological quality of stored yam tubers. The first level of treatments, 'post-harvest conditioning treatments', contrasted a typical pit-storage regime with the strict application of a lime slurry to the proximal and distal end of each yam tubers followed by 'curing' in a straw lined clamp at high humidity and at ambient temperature for a period of 12 days. The subsequent and second level of treatments focused on the longer-term storage of yams for the majority of a typical storage season. During this time different sub-sets of yams were maintained either in traditional pits; held on shelves in a yam barn; coated with a sucrose-ester post-harvest coating and held in a yam barn, or treated with a 2% preparation of the fungicide thiabendazole after curing and held in plastic bags. The latter were employed to impose some for of modified gas atmosphere on the tubers during storage. To ensure such gas atmospheres did not result in anoxia of

the stored tubers, the plastic bags were alternatively sealed for two weeks and then opened for two weeks for the duration of the trial.

3.3.4 Impact of Environmental Factors on Quality

37. In a bid to collect data that might provide insights as to which levels of temperature, relative humidity and physical damage were associated with the biological quality of yam tubers. Temperature and relative humidity data loggers were deployed to monitor the conditions pertaining during the establishment of the storage trial summarised above.

38. Attempts were also made to determine what happened to the biological quality and saleability of yams derived from the storage trial following their bulk transportation to distant markets. In practice the quality of sub-sets of yams derived from the storage trial were monitored at various points during multi-leg journeys from their site of storage to a distant market. The transportation, duration and handling practices adopted during these journeys were typical to that which yam tubers are routine exposed. The methodology adopted during these studies is summarised in Figure 2.

3.4 Methodologies adopted by the Post-Harvest Physiology Team

39. The physiological research component of the project sought to measure and monitor a series of key physio-chemical variables considered characteristic of the biological status of yam tubers over time and to correlate such changes with the 'storage potential' (perishability) of a selection of yam varieties. Preliminary studies were undertaken with five different varieties of White yam derived from local markets. Ultimately, protocols were restricted to observing the behaviour of the varieties: Pona, Dorbari and Chinchito harvested from known sources and destructively analysed at prescribed intervals throughout an entire storage season whilst being held in an improved yam barn structure for the duration of an entire storage season. Table 3 provides a summary of the range of indices monitored and the methodologies adopted. Data was collected on five occasions over the storage period, on each occasion four tubers for each of the three-named yam varieties was analysed.

Table 3. Summary of methodologies used to monitor physiological indices of tubers recovered from an improved yam barn during the course of the 1999-2000 yam storage season.

Category of Indices	**Indices**	**Notes**	**Methodology**
Physiological	Oxygen uptake	At each assessment interval, replicate yam tubers were monitored at 8 hourly intervals for 5 days in closed gas systems.	Gas concentrations measured by use of gas chromatogram
	Carbon dioxide evolution		
Physical	Tuber weight, volume (density), dry matter content and texture	Texture measured from homogenised tissue sample of 250g dispersed in 500g deionised water.	Texture measured by 'falling number viscometry' according to the ICC (International Association of Cereal Chemistry) Standard Procedure No. 107 (1988)
Chemical	Starch	Glucose equivalence of starch content measures by absorbance of spectrophotometer at 340nm.	Enzymatic Assay Kit SA-20 (Sigma, 1997)
	Glucose	Glucose content measures by absorbance of spectrophotometer at 340nm.	Enzymatic Assay Kit GHAK-20 (Sigma, 1997)
	Protein	Colorimetric complex measured absorbance of spectrophotometer at 562nm.	Bicinchoninic Acid Protein Assay Kit TPRO-562 (Sigma, 1987)
Biochemical	Amylase		Hui (1992)
	Lysozyme		Hui (1992)
	Cresolase		Hui (1992)
	Catecholase		Hui (1992)
Other	Wound healing potential		
	Susceptibility to rot		
	Storage duration		

4. Outputs

4.1 Outputs Targeted

40. The defined outputs sought by the project were as follows:

1) Major in-country marketing systems characterised and the relationship between produce quality and economic value of fresh yam determined.

2) Situations where significant losses (physical and economic) occur, identified, quantified and characterised.

3) Genetic, physiological and environmental factors associated with yam perishability established.

4) Improved handling strategies developed and tested.

4.2 Summary of Significant Results

41. The project revealed an extensive, intricate and keenly competitive traditional marketing system linking scattered farmsteads in the producing areas through a hierarchy of local markets to the more distant urban centres (Gray, 1996, Gray & Crentsil 1997, Gray *et al.*, 1996, 1997a and 1997b) and ultimately markets in neighbouring states and overseas (Crentsil *et al.* 1997 and Kleih *et al.* 1994). Depending on distance and complexity of any particular marketing chain, each individual tuber would be removed from the field or store, and passed through cycles of stacking, loading, transportation, unloading and grading etc. by a series of different transporters and traders until their final sale. At each point in the chain, therefore, the produce is repeatedly exposed to a range of physical and environmental factors that singly or in combination tend to compromise the quality of the yams. Loss assessment studies (Bancroft *et al.* 1997, Crentsil and Danso 1996 and Crentsil *et al.* 1997) indicate that the most significant consequence of the shortcomings in the contemporary marketing systems is the premature degradation of tubers by rots resulting in either partial or absolute biological loss (refer to Figure 6 below) and price discounting often of the order of 35-80% (Gray *et al.*, 1997b). Also of particular significance is the observation that of all apparently 'healthy' yams sampled from the markets some 20-38% harbour chronic internal rots.

42. As the general level of development in the yam producing areas precludes the use of fungicides or refrigerated cool stores, the pre-storage 'curing' of yams has been advocated by a number of researchers as a means of diminishing the incidence and forestalling decay and moisture loss in tubers by encouraging the wound-healing of tissues immediately after harvest. There is scant evidence to suggest that this process has ever been deployed effectively on a large scale in West Africa. Observations made during project suggest that traditional curing techniques (if they occur) are generally too haphazard to make any significant impact on the shelf-life potential of yams and often hasten the onset of sprouting whereas, by contrast, the rigid adherence to specific curing and post-harvest protocols may significantly reduce the weight of rots recovered from tuber samples after three and four months storage. Laboratory research has sought to correlate the perishability of different varieties of tubers with a series of physiological indices. Associations are found to exist. It remains to be determined how this information

may be practically exploited to select yam cultivars of different perishabilities for different retail markets.

43. The main conclusion of studies undertaken in Ghana is that, to effect any significant diminution and control of the losses identified in the marketing chain in the foreseeable future, specific traditional post-harvest handling and marketing practices will need to be radically altered with the focus of change directed at the producers and the exporters in particular. The activities that need to be addressed are defined in the section 'Contribution of Outputs' (see Section 5, Page 44).

44. As a consequence of these observations the nature and value of the losses to the system are more fully understood, and critical points in the production/marketing chain where technical interventions may be successfully deployed have been identified. To fulfil the stated objectives of the NARS, and deliver tangible benefits to stakeholders operating in the yam marketing system, additional work is required to test, deploy and foster improved handling protocols that will provide viable alternatives to existing practices.

4.3 Specific Outputs of the Research[1]

4.3.1 Market System Characterisation & Identification of Principal Agents active within the Yam Marketing Systems

45. Output 1, Activity 1.1. Three major marketing systems in Ghana were characterised and the workings of the major yam market at Techiman was chosen for more intense study over successive yam trading seasons. Additional surveys were also conducted in the demand-orientated markets in Greater Accra.

46. Output 1, Activity 1.2. The socio-economic structure of the marketing systems observed were analysed. Yam trading has been found to be remarkably complex, economically sophisticated and labour intensive, providing employment to a diverse number of different agents. Most of those involved in production and trading may be considered resource poor. Traders cite transport costs, seasonality of production, poor market infrastructure, lack of credit, and mechanical damage to and rotting of tubers as their main constraints.

4.3.1.1 Marketing System of Yams in Ghana

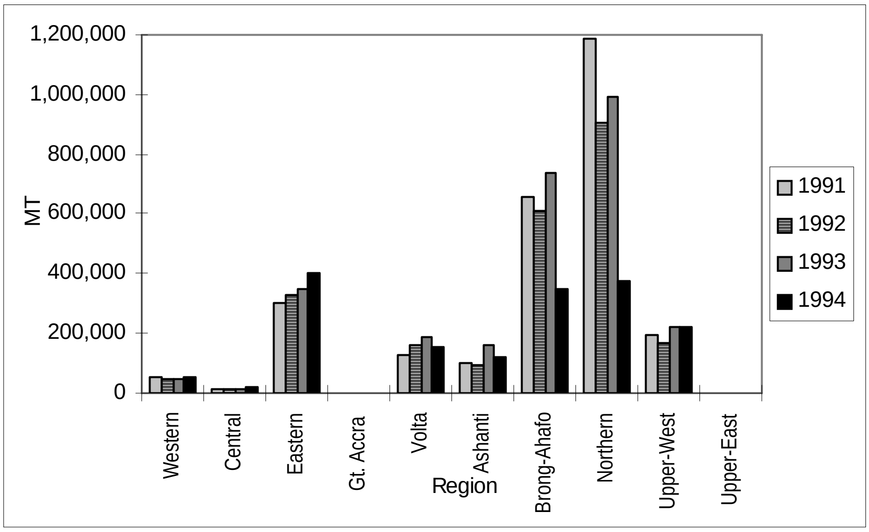
47. Between 1991 and 1993 the Northern Region of Ghana produced the largest quantity of yams of all the regions (1 million tonnes, 1993), followed by Bring Ahafo Region (700,000 tonnes, 1993). Eastern Region also generates significant quantities of yams (400,000 tonnes in 1994) [see Figure 3).

48. There are no processed forms of yam used in Ghana at present that might provide a stable product of longer shelf-life. In the markets, traders and chop bar (café-type food outlets) owners buy yams to roast, fry or prepare as fufu (a boiled and pounded preparation), but this does not increase the shelf life of the product. The trade in yams throughout the country is, therefore, in its original state as fresh tubers.

---

[1] Restrictions of space preclude the inclusion of all the findings of the socio-economic surveys. These details may be found in the technical reports generated as a result of this work. See Appendix C.

Figure 3. Production Estimates by Region for Yams in Ghana, 1991-1994
(metric tonnes)



Source: PPMED, Ministry of Agriculture

49. The marketing system for yams is handled mainly by the private sector with a small proportion of yams being distributed by the Ghana Food Distribution Corporation (GFDC). The GFDC's involvement in distributing yams has been almost completely eliminated as part of government policy of privatising state marketing boards in line with the Structural Adjustment Policy.

4.3.1.2 Market Structure

50. The major categories of markets, sales points and types of traders involved in yam marketing are shown in Tables 4 and 5. These form the principle components of the yam marketing chains observed during this study. The number of intermediaries in the marketing chain can be very variable, depending on whether supplies are moved through various hierarchies of markets or moved directly from the producing areas to the urban centres for resale to consumers. Although subject to many detailed deviations the predominant market chain encountered is represented in Figure 4.

51. In contrast to this system a second marketing chain was also identified, linking Konkomba farmers with other members of their community in Accra. In this instance most of the traders in Konkomba market have a direct link with family members in the Northern Region. The market channels used by this community appear to be of two types: either itinerant wholesalers hire a truck in Accra and go to the Northern Region to assemble the yams at the farmgate and transport them back to Accra to sell to retailers, or alternatively the farmers themselves transport the yam to Accra from the Northern Region and pay a fee to the wholesalers or retailers in the market to sell their produce. In these cases the farmer remains at the market until all the yams have been sold at which point the trader repays the farmer. This chain is very close knit and mutually supportive. For example, the traders accommodate the farmers at no expense, while they are waiting for their yams to be sold. Three principal types of traders are involved in getting yams to the consumers: the producer-sellers, the itinerant traders and the market-based traders.

Table 4. Categories of yam marketing outlets observed in Ghana.	
Market Type	Description
Farmgate	Trader comes to farm and buys direct from the farmer, e.g. in Bimbilla, Yendi and Salaga (Northern Region), Atebubu (Brong Ahafo).
Roadside markets	Small scale retail markets of traders who have assembled yam from the farmers for sale to passing traffic.
Village markets	Small markets offering few commodities to local consumers. These include weekly markets acting as a first-level assembly point for produce from the surrounding area. e.g. Kpalbe, Gindaturu (Northern Region). Most itinerant wholesalers interviewed stated that they always buy from the farm gate and never from the village market. The role of the village market as a first level assembly point may not, therefore be very strong in the case of yams.
Rural town market	Rural wholesale assembling markets where traders concentrate purchases made in the vicinity (e.g. Techiman in the Northern Region). These markets are under the jurisdiction of a particular District Assembly and have specific days on which marketing activities take place.
Large urban market	Markets where consignments are sold to consumers and retailers e.g. Kumasi Central Market in Ashanti region, Konkomba market in Accra. Also act as "transit markets" from which smaller lots of commodities are moved to other outlying markets.
Small urban market	Final markets where most produce is brought from the large urban market and sold to consumers e.g. Asafo and Bantama markets in Kumasi (Ashanti Region).

52. The predominant market chain starts with the independent producer. Following harvest the farmer groups his produce in sets of one hundred and ten for inspection of quality and size by an agent of a trader. A few days before market the trader will inspect the produce for himself travelling on a hired motorcycle or bicycle with the agent. Price negotiations then take place.

53. Depending on the nature of local resources, having agreed on a price, the trader normally hires a tractor to convey the produce from the farms to the nearest large town. For example, for the farms visited in Binjai, Kataba, Bawu and Sabongida, in the Northern Region, the nearest town is Salaga. The big trucks arrive on market day ready to load already bulked produce to their final destination in the south (*source:* Source: Commodity Transport Cost Study, Ministry of Transport and Communications, 1991, Ghana).

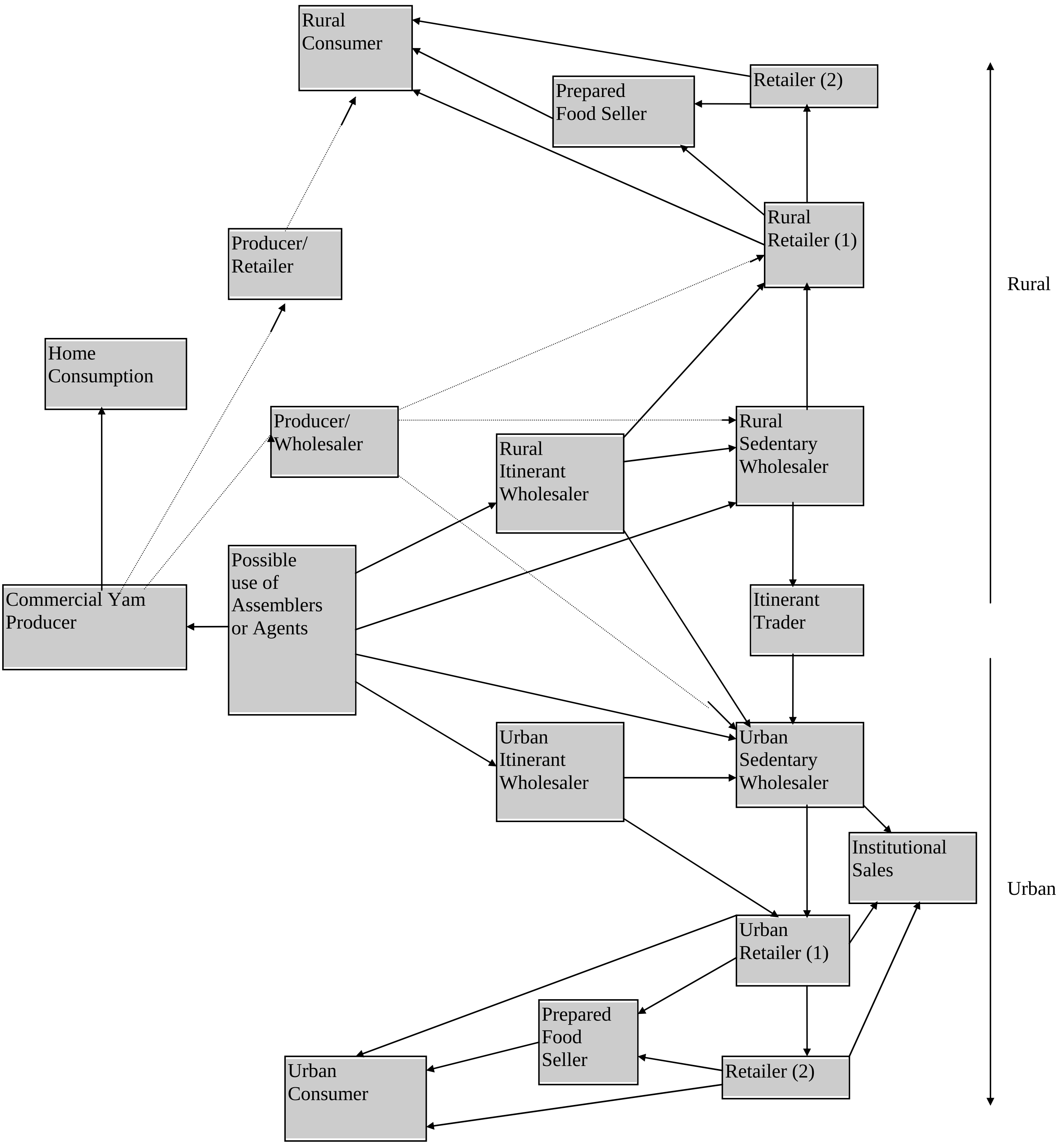
54. In instances where there are relatively good roads leading to surrounding villages, the urban-based assembly trader after agreeing with the farmer on price, quality and size of the yam uses truck to load yam and transport directly to destinations such as Accra.

Table 5. Main types of traders observed operating in the Ghanaian yam marketing system.	
Type of trader	Description
Producer-Sellers	Farmers may sell their own produce in the market (in the village, rural town or roadside) either by selling their produce to market based sedentary wholesalers on a commission or fixed price arrangement (producer/retailer) or fulfilling the wholesaler functions themselves (producer/wholesaler).
Rural Local Assemblers	Based in villages or rural towns. May buy direct from farmers, bulk up and sell on to itinerant traders.
Rural Based Itinerant Wholesalers	Based in the village markets. Buy from farmers in their region and transfer to rural town markets or urban markets. Sell to retailers or sedentary wholesalers
Urban Based Itinerant Wholesalers	Resident in the urban centre which is the destination of the yams and assembles produce from the various farmers in the production area. Often works together with an agent with whom the trader has a long-standing arrangement.
Trader's Agent	Based in the rural or producing area. Identifies location of yams to be purchased and inspects quality and size of yams on the farm.
Sedentary Wholesalers	Based in village, rural town or urban market. Buy from producer/sellers and both types of itinerant wholesalers and sell on to smaller wholesalers or retailers in the same market.
Sedentary Retailers	Based in village, rural town or urban market. Buy from producer/sellers and both types of itinerant wholesalers and sell on to retailers or consumers in the same market.
Itinerant Retailers	Buy from farmers, various types of wholesalers or retailers and take to nearby market or to the roadside to sell to consumers.

55. In the Northern Region on each purchasing trip an itinerant wholesaler visits on average seven farms to collect a truckload of yams. If the yams have been harvested but are still scattered around the farm, the trader has to wait about a day for the yams to be gathered. In general the traders from the south going to buy yams in the north spend two to three weeks in the production areas whereas those from Tamale market in the Northern Region may spend about 5 days procuring yams in the peak season and possibly 10 days when supplies are reduced.

56. Traders who come from the south sometimes hire bicycles in the villages and use them for transport around the farms. They either arrange transport in the production area once they have bought all their yams, or they arrange transport from the market before going to the production area, and the truck meets them there after a specified time.

Figure 4. The Main Distribution Channels for Marketing Yam



Key:

Marketing channels of producer/wholesaler or producer/retailer

Marketing channels of traders and agents

57. For most of the traders encountered, trading in yam was their only income earning activity. A few also owned farms on which they grew a few commercial crops to ensure income when the yam market was slack. Some also traded in other commodities, for example, cowpeas or soap, but these were in the minority. Generally it was considered that there were sufficient supplies of white and water yam to provide income throughout the year.

58 Though many farmers and traders have regular suppliers or buyers, many people interviewed said that they also buy (or sell) a large amount of their produce from casual suppliers.

59. The farmers from the north who traded their own produce in the south were generally wealthier with larger farms. One large farmer in Sal in the Northern Region, who owned 10 acres of land, estimated that he sold 70% of his yam harvest in the south and 30% locally. Large farmers in Kpalbe, however, estimated that 70% of their produce was sold locally and the residue transported to the south. The smaller farmers generally sold their produce from the farm or in the local market to traders who may then take it to the south.

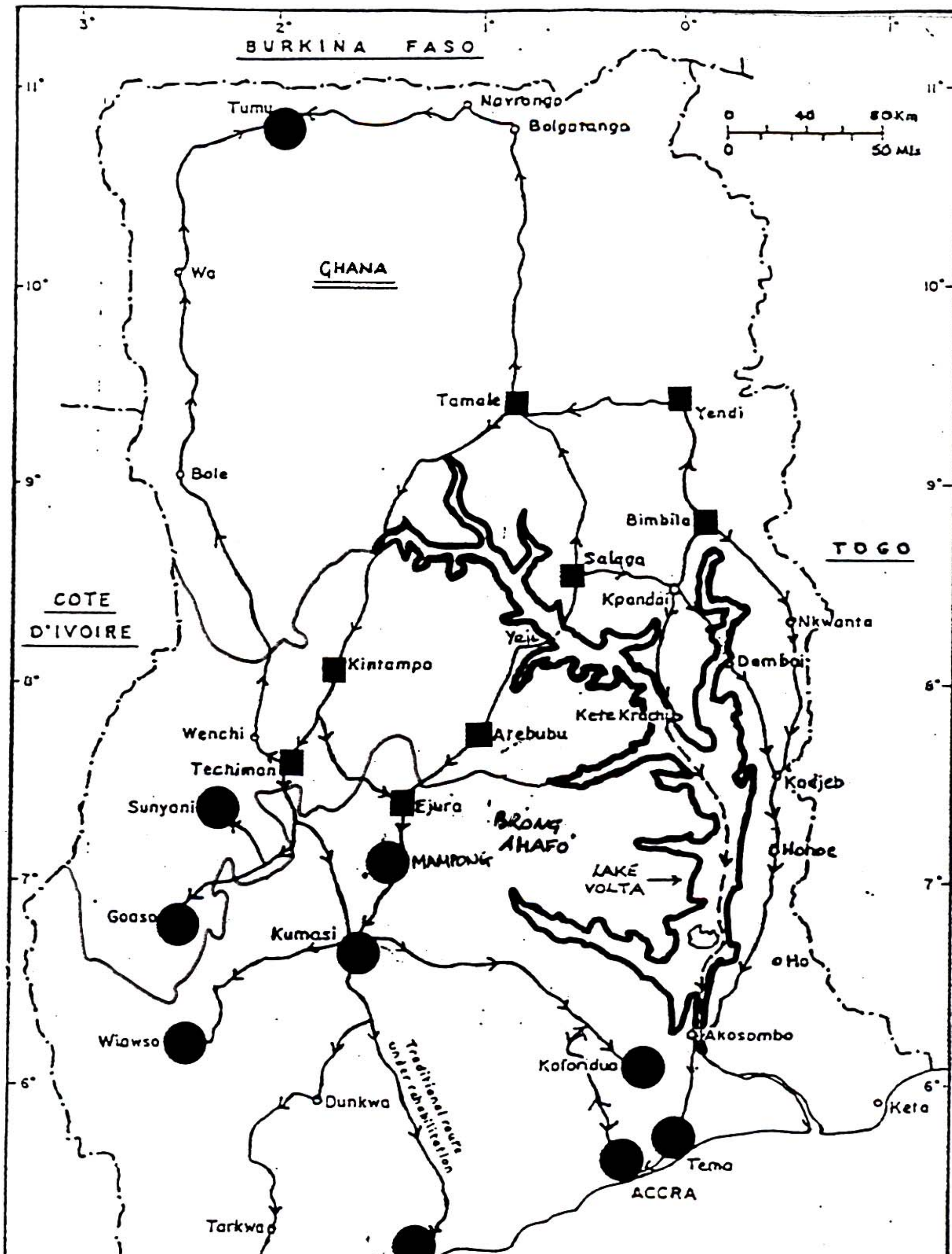
60. Within the confines of formal markets trading is strictly regulated by local 'Yam Queens' and their associated 'Trader's Associations'. In this environment the yam queen in each market wields extensive power over the trade in the market, but the extent to which she can limit supplies into the market and influence the price remains difficult to quantify, as is the effect of her interventions on the competition in the market.

4.3.1.3 Major Transport Routes for yams

61. The major transport routes for fresh yams in Ghana are summarised in Figure 5. As Gray (1996) shows, yam produced in the Northern Region (Yendi, Salaga, Bimbilla) going to Accra is transported to the south through the Volta Region. Some consignments go to Hohoe and then down to Akosombo and Accra by road, and some are transported by boat down the River Volta from Kete Krachi to Akosombo and then on to Accra and Tema by road. Koforidua may also be supplied by yams coming from the Northern Region via Accra.

62. Two other routes exist from the North to the south. From Salaga to Kumasi, for example, one route passes through Yeji, Atebubu, Ejura to Kumasi, a distance of 266km, and the other passes through Tamale and Techiman to Kumasi, which is a distance of 509km. The first route was preferred in the past, being little over half the distance of the second route. However, the ferry across the Volta Lake is not regular, and the road leading from Yeji through Atebubu, Ejura and Mampong to Kumasi is in a bad state of repair, lengthening the journey in terms of time, and increasing the risks of damage to vehicles (Ministry of Transport and Communications, 1991). The longer route was therefore preferred until the conflict in the Northern Region, which began in 1994. This prevented the Konkombe farmers from entering Tamale, and obliged them to find alternative marketing routes. The Ghana Private Road Transport Union (GPRTU) in Tamale estimated that in 1995-1996 about 15% of yams produced in the Northern Region pass through Tamale en route to Kumasi, Accra or Cape Coast.

Figure 5. A map of Ghana indicating the location of major transport routes used for the marketing of fresh yams (Source: Gray, 1996). The symbol ■ denote population centres in the major yam producing areas and ● denotes major urban centres for the consumption of yams.



63. Yam produced in the Brong Ahafo Region (Kintampo, Atebubu, Techiman) and Ashanti Region (Ejura) are transported to the major markets at Techiman, Kumasi or Accra, from where some are distributed further.

64. Traders from the south purchase yams from different areas depending on availability and the time of year. Those from Techiman buy yam from local areas such as Kintampo and Atebubu during the peak season when the supply of yams is plentiful. When the supply falls they go further afield to areas such as Bimbilla and Tamale in the Northern Region and Wa in the Upper West Region. There the yams are produced later in the season and compliment the fall in the supplies of yams from elsewhere.

65. Transport of the yams is a major problem, both in terms of cost and yam losses. Although the yams are carefully and tightly packed to reduce bruising, losses often occur as a result of delays, either because of a lack of availability of transport, or because of trucks breaking down en route to the market.

4.3.1.4 Profitability of trading in yams

66. To gain further insight into the workings of the yam marketing system, case study surveys were conducted in several markets (see Table 2). Data collected in the yam market in Techiman during October and November 1996 provided an indication of the profitability of trading in yams.

67. Itinerant trading requires the highest amount of initial capital and was exposed to the highest risks of all the trading activities in the market. The itinerant traders also secure the highest returns of all the traders, with returns on capital employed (ROCE)[2] ranging from 4%-16% over a period of about four weeks with an average ROCE of 11%.

68. Itinerant traders also bear the greatest marketing costs, as would be expected, since they must pay transport costs as well as taxes in both the production area and in the market. Their marketing costs were found to be around 60% of the marketing margin, although for one successful itinerant they were around 40%-50%. For others they could be as high as 92% or 184% for individual heaps[3], although this percentage would vary for different heaps in any one consignment.

69. The returns of the retailers appeared to be much lower, although there was some uncertainty about the accuracy of the data, since it was felt that there was a certain amount of distrust of the interviewer's questions. Some retailers were making much higher returns than others, ranging between 9,000 and 31,000 Cedis[4] per week, with an ROCE ranging from 3%-6% over a period of about one or two weeks. Other

---

[2] The ROCE is a financial indicator which shows the returns as a percentage of the total capital employed (i.e. buying price of the yams plus marketing costs). It must be noted that the time period in which the returns are gained is important, for example, retailers and sedentary wholesalers turnover one consignment over a period of a week or two. For the itinerant traders, however, the turnover is slower, with larger volumes, and one consignment may take a period of three weeks or more between purchase and resale.

[3] One heap of yams consists of 109 tubers. This quantity represent one wholesale unit.

[4] Exchange rate in Nov. 1996 UK£1 = 2,800 Cedis.

retailers were making very small returns or even losses. In one case a retailer made a loss of 23,000 Cedis in one week, and in another made only a small gain of 5,400 Cedis.

70. The returns of the sedentary wholesalers in the case studies were also lower than those of the itinerant traders, as would be expected in an efficiently functioning market, since they buy and sell within a relatively short period of time in the same market and therefore bear less risk than the itinerant traders. However, while returns ranged from around 24,000 – 25,000 Cedis, the average ROCE for the three sedentary wholesalers was 8%, ranging between 3% and 13%, not significantly lower than that of the itinerant traders. Furthermore the sedentary traders get these returns in a period of around one week or less, while the itinerant traders gain the returns over a three or four week period.

4.3.1.5 Credit and Banking (as reported in 1996)

71. There appears to be limited means of obtaining formal credit by the farmers or traders. They feel that the interest rate (at 38%) is too high despite the fact that the real cost of interest is negated by the rate of inflation at around 70%. They also find that the procedures are complicated and time consuming. Whether or not farmers or traders wish to obtain official credit, the banks are often unwilling to lend. Some male wholesalers in Aboabo Market in Tamale do keep their money in a bank, but they do not obtain loans from the banks. Most women retailers stated that they did not have enough money to be able to keep a bank account.

72. Individual cases were, however, encountered of traders obtaining formal credit supported by donor funding. One female wholesaler in Techiman Market in Brong Ahafo has obtained credit three times from the Agricultural Development Bank (ADB), at 45% interest, and does not borrow via the informal system. This credit was supported by an International Fund for Agricultural Development (IFAD) project and was distributed in such a way that to borrow, for example, 300,000 Cedis, then the trader must provide 50,000 Cedis as collateral. The repayment period was one year.

73. Generally the credit systems that exist are informal and tend to run from the wholesaler to the farmer or to the retailer. Sometimes also farmers borrow from other farmers in their village.

74. In the cases in which the wholesaler lends money to the farmer, they will lend at planting time and expect to be paid back (usually in yams) at the time of the harvest. This often traps the farmer into a situation of lack of capital, since he is obliged to sell the yams at a time when there is a glut of produce on the market and prices are lowest, rather than storing them for a period to speculate against market prices.

75. Many retailers obtain yams on credit from the wholesalers and repay once the yams are sold. In Techiman market, the yam traders' association gives short term credit of 2-3 days to be repaid when the market closes (it runs from Wednesday to Friday). This type of credit facility can be evident along the marketing chain. One retailer, interviewed in Yendi market in the Northern Region claimed that she had obtained the yams on credit from another retailer, who in turn had received them on credit from a wholesaler.

76. Although most of the yam traders were women, many of the female retailers in the markets have no means, formal or informal, of obtaining credit. Retailers in Bantama market in Kumasi, which is a small urban market, do not get yams on credit from the wholesalers in Kumasi Central Market, since they feel that the system is too complicated because they have to pay a third party 4,000 Cedis to witness the loan.

4.3.2 Interface between Yam Quality and Economic Value

77. Output 1, Activity 1.3. Various quality criteria for yam tubers were determined for different agents working in the yam marketing system. The relationship between the quality and economic value of yams observed in a study area were analysed on a number of occasions. Yam quality and economic value were found to be influenced by variety, source, handling practices and season and generally yam trading was found to be a relatively precarious existence often with poor returns on labour.

78. Preliminary analysis of the variables derived from the second economic survey conducted in Techiman market permitted the exclusion of "surface damage", "cooked spots" and "cut due to rot" because they showed zero or close to zero variation (refer to Table 6 for coefficients of variation).

Table 6. Coefficients of Variation for Price and Quality Variables

	Coefficients of Variation
Breakage	12.5%
Nematode damage	12.3%
Rotting	8.3%
Yam weight	4.1%
Termite damage	3.8%
Price per kg	2.1%
Sprouting	1.1%
Surface damage	0.1%
Cooked spots	0%
Tuber cut due to rot	0%

79. Regressions on price using the remaining quality variables, type of trader and week number as the independent variables yielded highly significant coefficients on the "type of trader" and "week number" variables, an unsurprising result in the light of Gray's findings (1997b), qualitative surveys of the Techiman market (Gray *et al.*,1997a). Unlike previous findings (Gray *et al.,* 1997b), yam variety did not have a significant impact on price, a discrepancy that was almost certainly caused by the different choice of varieties in each survey.

80. Of the quality variables, only "rotting" emerged as having a significant influence on price. Table 7 presents the regression results.

81. The t-values indicate whether the coefficients are significantly different from zero, or in other words, whether the variables can be proved to have an influence on price. T-values of above 1.96 suggest significant differences from zero albeit with a 5% chance of having made a mistake. Under this criteria, all the coefficients are significant, although the "rotting" coefficient only just scrapes home.

Table 7. Regression of Type of Trader, Week Number and Rotting on Price

Variable	Constant	Type of trader	Week number	Rotting
Coefficient	496.2	111.8	87.2	-329.3
Standard Error	52.9	29.5	11.0	167.0
t-value	9.38	3.79	7.90	-1.97

Adjusted R squared = 0.409

82. A normal probability plot of the residuals and a scatter graph of the residuals against the fitted values revealed that the ordinary least squares assumptions of normality and constant variance had not been violated. Visual inspection of scatter plots revealed that collinearity between week number and "rotting" almost certainly exists. Collinearity's effect is to increase coefficient variances and thereby reduce the likelihood of finding significant coefficients (note the high standard error of the "rotting" coefficient). Given that the "rotting" coefficient is on the borderline of significance, the existence of collinearity gives greater confidence that rotting does indeed have a significant influence on price. However, given the high variance, there can be little confidence in the estimated value of the "rotting" coefficient, and consequently the equation should not be used for predicting prices.

83. Despite this warning, there are two features of the results worth highlighting. Firstly, the rotting coefficient has a negative sign, reflecting the expected relationship between rotting and price. Secondly, the coefficient on type of trader indicates that the retail margin was 112 Cedis per kg[5]. With an average retail price of 960 Cedis per kg, the retail margin is approximately 12% of the selling price.

84. A more general examination of collinearity between the independent variables revealed a strong positive linear relationships between week number and nematode damage, and also between week number and "termite damage". Unfortunately, a lack of manpower during the November survey did not permit the survey team to heed Gray's advice on shortening the survey period. In the case of nematode and termite damage, the time relationship appears to have been caused by the delivery of consignments of damaged yams towards the end of the survey period. While both nematode and termite damage may indeed have a strong influence on price, the strong collinearity in the dataset dramatically reduces the chances of finding significant coefficients. This again highlights the importance of conducting the survey over as

[5] In the light of the results from regressions that returned non-significant price quality relationships, this finding is reasonably robust. Coefficient values on type of trader ranged between 105 and 112.

short a period as possible in order to reduce the impact of undesirable relationships between time and the other variables.

4.3.2.1 Comparisons with the previous study

85. Unfortunately, a scarcity of robust results, both in the current and the previous quantitative research, means that common findings are few. Both studies revealed that type of trader and time have a strong influence on price. But while the current study found a relationship between one of the quality variables and price, Gray *et al.*'s research revealed no such influence. This may have been caused by differences in analytical approach or simply by variations between the seasons in which the surveys were conducted.

4.3.2.2 Revisions to the survey methodology

86. Future surveys should attempt to minimise the impact of time on the price and quality variables. A concentration of resources in a much shorter survey period, possibly within the space of just one week, would require greater survey resources but the benefits in terms of reducing collinearity may warrant the expense. However, just as prices vary on a weekly basis, day to day fluctuations also occur. An understanding of how market price patterns develop throughout an average week would allow the research team to devise a data gathering methodology that would minimise the impact of time on price. The data could then concentrate on telling the story of how quality affects prices.

87. Gray *et al.*, 1997b recommended the collection of data on the best quality yam prices to establish a standard against which prices for inferior yams could be judged. Deviations from the average best quality price for a particular day could then be explained by variations in quality defects. This approach is appealing because it provides another method for eliminating the impact of time on price.

88. The lack of variation in the data is a cause for concern. A survey during the period January to May, when hot weather is reported to create quality problems (Gray *et al.*, 1997a), may reveal greater variation. However, just as quality has by and large been uniformly good during the first two surveys, a third survey may reveal uniformly bad quality and therefore add nothing to the understanding of the price quality relationship. Nevertheless, a survey during this period is necessary to complete the picture of the price quality relationship.

89. One way of injecting variability into the survey methodology may be to take a non- random sample. While ensuring that sufficient data is gathered throughout the whole ranges of the qualities variables, sampling could concentrate on poorer quality yams. This would be a useful approach if the aim of future studies is to establish the existence and nature of price quality relationships in the market. If, on the other hand, the aim is to establish the prevalence and therefore the economic importance of quality defects, then the biased sampling approach would give misleading results.

90. Another way of increasing variability may be to survey piles of yams rather than heaps. The first two surveys adopted yam heaps (wholesale units of 109 yams) as

the survey units, yet by sampling yams piles (retail units of between 1 and 4 yams), the problem of reduced variation caused by averaging quality variables over a whole heap could be eliminated. Clearly this technique is only relevant for surveys at the retail level.

91. It is tempting to eliminate some of the quality variables for which data is gathered in order to concentrate survey resources on those relationships that are perceived to be the most important. However, we have yet to determine whether any of the quality variables definitely does not have an impact on price. Instead, we have merely concluded that during the first two survey periods, there has been insufficient variation to establish links between price and most of the quality variables. In other words, financial losses due to quality have probably been slight.

92. Because statistical analysis necessarily works with conservative probabilities, it is pretty weak at proving the existence of quantitative relationships. Ultimately, better information may be obtainable from carefully conducted and widespread qualitative interviews with traders.

4.3.2.3 Recommendations

1. Conduct a thorough and widespread qualitative survey of traders to establish the financial importance of losses caused by quality defects.

2. If quality is an important financial issue, conduct a modified quantitative survey to establish the relationships between quality variables and market price. The timing of the new survey should be informed by the findings of the qualitative survey in order to maximise the likelihood of finding substantial variations in yam quality. The survey should be conducted over a short period, and an attempt should be made to gather information on best quality yam prices. Sampling should be deliberately biased to include higher numbers of poor quality yams. For retailers, yam piles rather than heaps should be surveyed.

4.3.3 Spatial Price Linkages in Ghanaian Yam Markets

93. Analysis of correlation coefficients and co-integration results suggest that approximately 60% of the yam markets for which data was available can be considered to be spatially integrated, that the markets are functioning competitively and that price transmission between the markets is relatively smooth.

94. Price linkages between markets that are geographically closer together appear strong. Conversely, price series tended to diverge as the distance between markets increased particularly between centres of supply and demand. Over the time period that data was available (1986-89; 1990-03 and 1993-99), the level of market integration did not appear to have changed significantly. Other computations suggest that the integration of the yam markets is demand-driven.

95. It should be pointed out, however, that these analyses are based on officially recorded data that do not necessarily reflect the complexity of the yam marketing

system. Two particular deviations that will influence the competence of the economic models are the following:

a) The traditional method of marketing yams is by grade and numbers of units of a particular grade. Although the biological assessment of yams suggests a high correlation between yam weight and grade (see Table 5plus below), the grading system used on the farms and in different markets is by no means uniform and will fluctuate according to the supply of yams, their variety, source and quality throughout the season and even on a daily basis. As a consequence the assessment of the price of a particular grade of yam in one market does not necessarily equate to the sale price of an equivalent yam in a different market.

b) An unknown but probably significant percentage of the yams marketed in Ghana do not pass through formal market centres and data on this produce is lacking from the analysis.

c) The official data collection system is based on monthly averages and therefore tends to suggest that the speed by which price intelligence is transmitted from one market to another is measured in units of months. Field observations suggest that market intelligence is more rapid with price transmission occurring within two weeks.

4.3.4 Biological Loss Assessment Studies

96. Output 2, Activity 2.1 Market based loss assessment studies were completed as a consequence of a series of surveys. A summary of the major findings are illustrated in Figure 6. Detailed analysis of the symptoms associated with the quality depreciation of fresh yams is provided in Table 8. Loss of yam quality is associated with certain pre-harvest infestations of nematodes (30% of all tubers infected) and termites (20%) as well as a systemic internal browning (13%); post-harvest tissue damage associated with the stacking of tubers (50-90%) and various rots (38%), and the prolonged exposure of tubers to intense sunlight in the market place (3%). Such deterioration may lead to price discounting of 25-63% with absolute biological losses on the market of 10% at the beginning of the season. Immediately post-harvest farm losses of sellable tubers may be of the order of 40-50%. The extent of post-harvest losses varies with the season. Generally losses are lowest at harvest time from August to November in the Northern Region, and July to September in the Brong Ahafo Region, when they are about 2-3% of the yams harvested. After January, as the yams become older and the temperatures are higher the loss in quality and rate of deterioration increases with the losses rising to 10-50%.

97. Within individual tubers the loss assessment studies revealed certain trends with respect to the weight and length of tubers and the location and severity of particular symptoms. Further detailed analysis of the data is required but some general inferences are summarised in Table 9. In very general terms, due to the traditional stacking patterns used during marketing, the tail section of yam tubers were prone to greater physical damage than either the head or the middle section of the tubers. As a consequence, most of the rots associated with the post-harvest marketing of tubers occurs in relation to the tail section. By contrast, on account of its

Figure 6. A Summary of Post-Harvest Loss of Yams

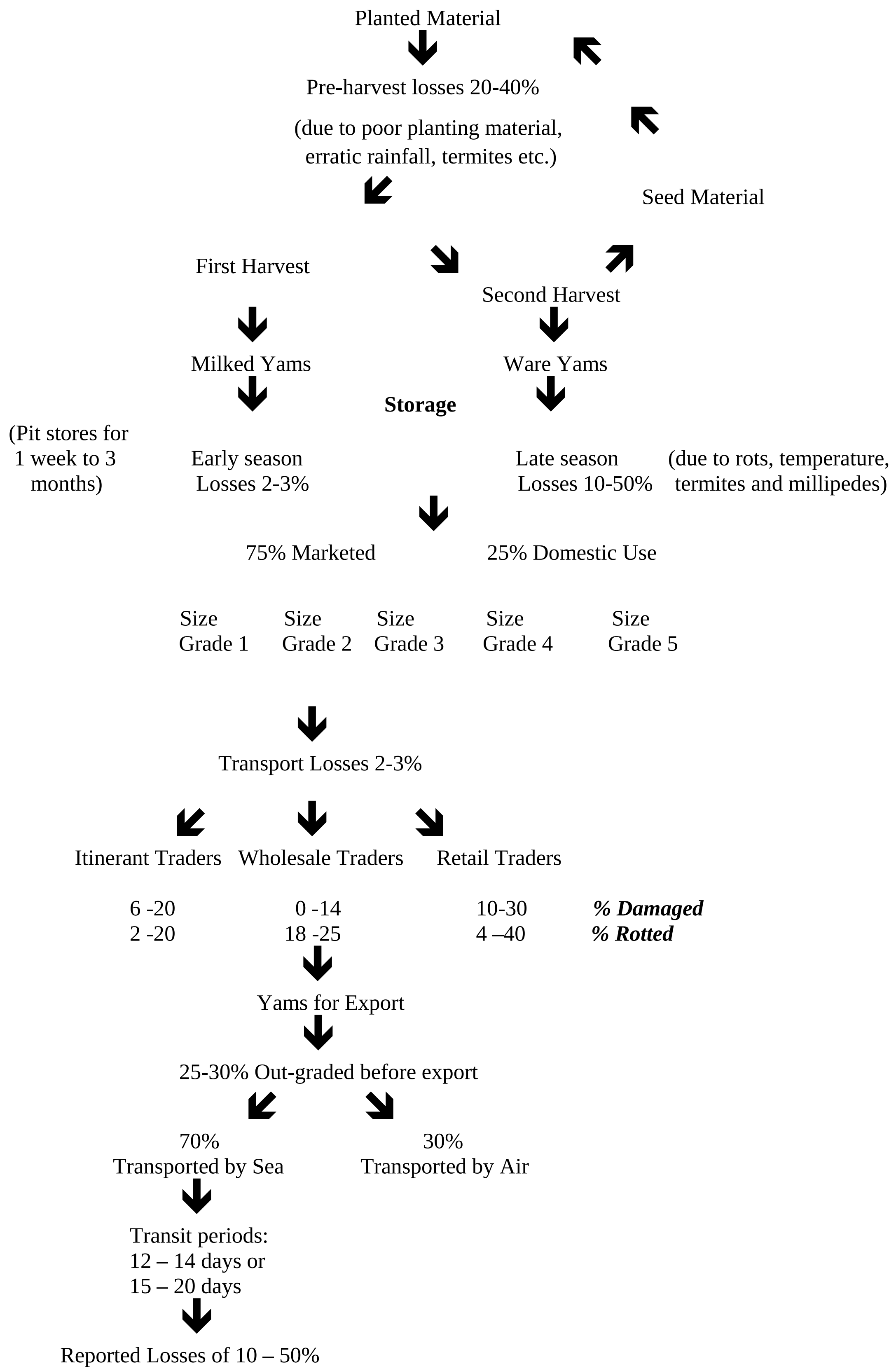


Table 8. An indication of the severity of symptoms associated with biological loss of harvested yams. Data gathered in Ghana in 1997 during the middle of the main marketing season.

External Symptoms	Percentage of Sample Population of Tubers	Internal Symptoms	Percentage of Sample Population of Tubers
Husbandry Factors			
Vine/head of tuber cut away	91%		
General cuts to tubers	50%		
Gashes to tuber surface	71%		
Grazes to tuber surface	90%		
Tuber breakages	<5%		
Agronomic Factors			
Growth deformities due to stones in seed bed etc.	12%		
Penetration of tubers by roots of weed species	44%		
Microbial Damage			
External signs of microbial rots	18%	Internal signs of microbial rots	38%
External signs of rot <10% of surface	10%	Internal signs of rots <10% of tuber volume	22%
External signs of rot > 50% of surface	2%	Internal signs of rots >50% of tuber volume	8%
		Hardened cortical tissues	13%
		Hardened cortical tissues <10% of tuber volume	4%
Animal Related Damage			
Termite burrows	22%	Termite damage <10% of internal tuber volume	3%
Nematode infestation <15% of surface area	11%		
Nematode infestation >25% of surface area	19%		
Rodent damage	1.5%		
Physiological			
Pre-harvest splits of tubers	32%	Tissues exhibiting heat stress	3%
		Heat stress in 10-70% of tuber volume	1%
Other Factors			
		Temperature of cortex during marketing	Range 26-44ºC, Mean Temp. 33ºC

Table 9. Summary of some of the factors influencing the quality of individual yam tubers.

Factors influencing tuber quality	Observation	Statistical Tests Applied	Source of Original Data
Weight, length and price of tubers	The price of tubers is closely related to its weight. Weight and to a lesser extent length of tuber dictate whether tubers are designated Grade 1 or Grade 2. Other criteria determine designation of Grades 3 and 4.	Analysis of Variance, orthogonal contrasts and correlations.	Techiman market, varieties considered Asana, Dente, Olondo and Pona.
External Grazes	T>H>M (across all marketing grades.	Contrast of counts and Chi Squared Test.	Techiman Market, Olondo variety considered.
External Gashes	T>H>M	Ditto	Techiman Market
Cuts	T>H=M	Ditto	Techiman Market
Physiological splits	T>H=M	Ditto	Techiman Market
Incidence of penetration of weed roots	H>M=T	Ditto	Techiman Market
Pest predation	Significant differences between varieties: Punjo (21%) >Olondo (12%) >Asana (4%).	Ditto	Volta Region
Termite predation	H>M>T	Ditto	Techiman Market
Internal volume of rots	Significant differences between varieties: Punjo>Asana> Olondo; T>H>M	Ditto	Volta Region

Legend: H=Head of yam tuber; M=Mid-section of yam tuber; T=Tail section of yam tuber. Example of scoring: T>H=M indicates that the frequency of symptoms on the tail section of the yam was greater than that on the head section, and that the frequency on the head section was approximately equivalent to that found on the mid-section.

physical position in the field, the head portion of the tuber is more prone to nematode attack and damage by invasive roots of local weed species both of which may influence the marketability of tubers if the symptoms of damage become obvious during trading.

4.3.5 Impact of Environmental Factors on Quality

98. Output 2, Activity 2.2. Loss assessment data was successfully recovered from a series of market transport studies to try and determine the impact of physical handling on the quality of yams (an example of the type of data recovered is available in Appendix F). Yams discarded prior to transportation where often characterised by higher numbers of grazes and gashes on the surface of the tubers. Other factors, which caused tubers to be out-graded, were higher surface areas infested with nematodes (rough skin) and higher incidence of rots. On those tubers successfully transported and sold at market, the present methodology could not detect any significant increases in the incidence or surface area of blemishes as the length of the marketing chain was extended.

99. Difficulties were encountered when trying to monitor temperature and humidity during these marketing operations. Unfortunately, datalogging equipment often failed to live up to expectations and the data that was recovered was eventually lost on a computer that suffered flood damage. The possible correlation between temperature stress, adverse impact of excessive levels of humidity and yam quality could not, therefore, be studied in detail.

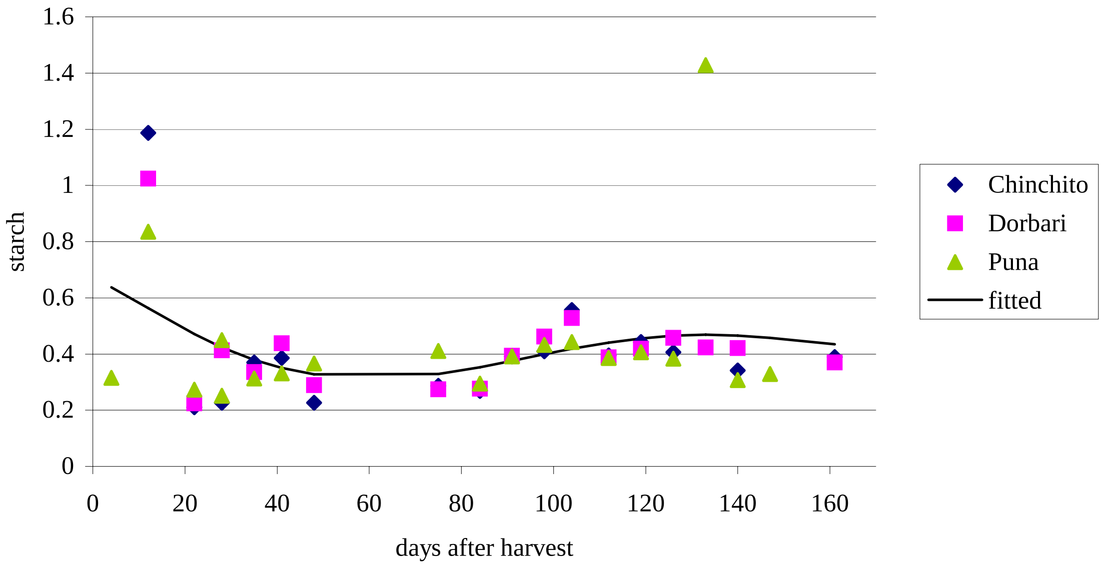
4.3.6 Correlation between Physio-chemical Attributes and Yam Perishability

100. Output 3, Activity 3.1, 3.2 and 3.3. Protocols to study various physio-chemical attributes of yam tubers were investigated by a Ghanaian member of the project team at the NRI. Subsequent work in Ghana has indicated that significant differences in physiological variables may exist both between varieties and different segments of the tubers (Figure Series 7 & 8). Analysis of this data has, however, not yet been able isolate any particular environmental factor or physiological characteristic that provides an unambiguous correlation with the potential storability of yams. A full account of the findings of work undertaken by the FRI on these topics is awaited as copies of a draft Ph.D. are due for release in October 2000. In the interim, a summary of the preliminary analysis is as follows:

- *Weight difference and Dry Matter Content show no significant differences between variety for any month*
- *Starch, lysozyme and protein show no significant differences between variety for any month*
- *Amylase shows a significant difference in month 3, but not in any other months*
- *Glucose shows significant differences between variety for months 1 and 2.*
- *Glucose, protein and amylase show a decline over time, with each variety having the same trend.*
- *The three varieties also have the same trend for starch, but this shows an initial decrease followed by an increase.*
- *Lysozyme and Texture show no trend*

Figure 8a Trend in starch content over time

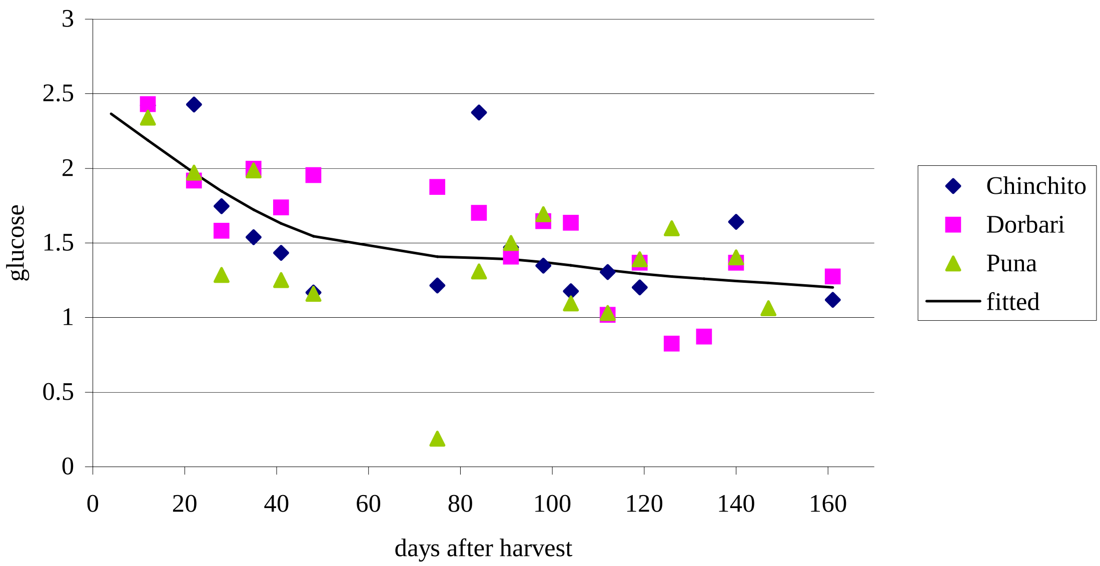
There was a significant trend (p-value = 0.03) with all varieties having the same trend.



Starch against days after harvest

Figure 8b Trend in glucose content over time

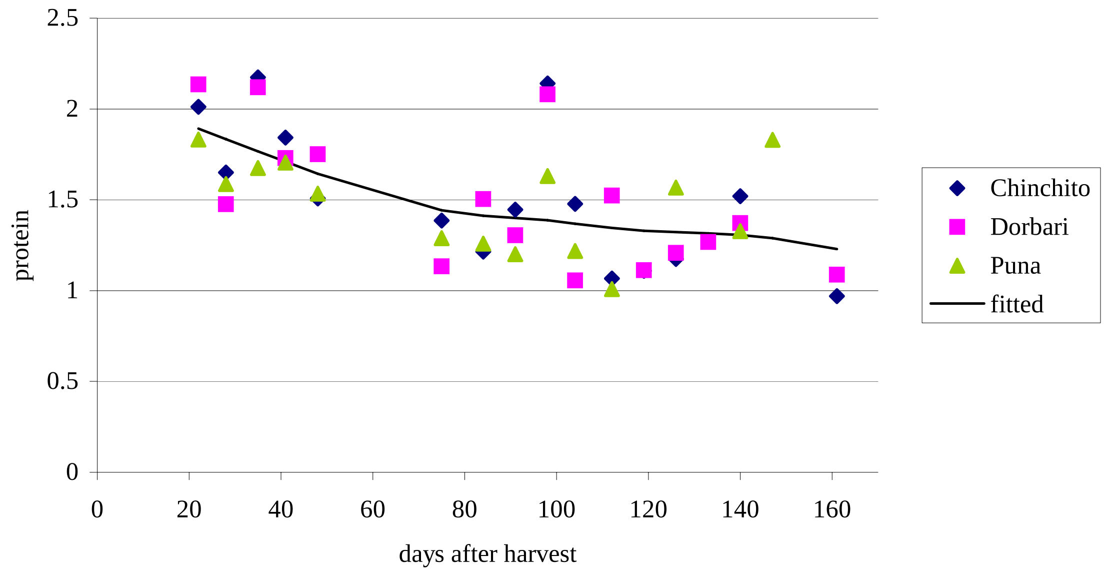
There was a significant trend (p-value = 0.001) with all varieties having the same trend.



Glucose against days after harvest

Figure 8c Trends in protein content over time

There was a significant trend (p-value = 0.001) with all varieties having the same trend.

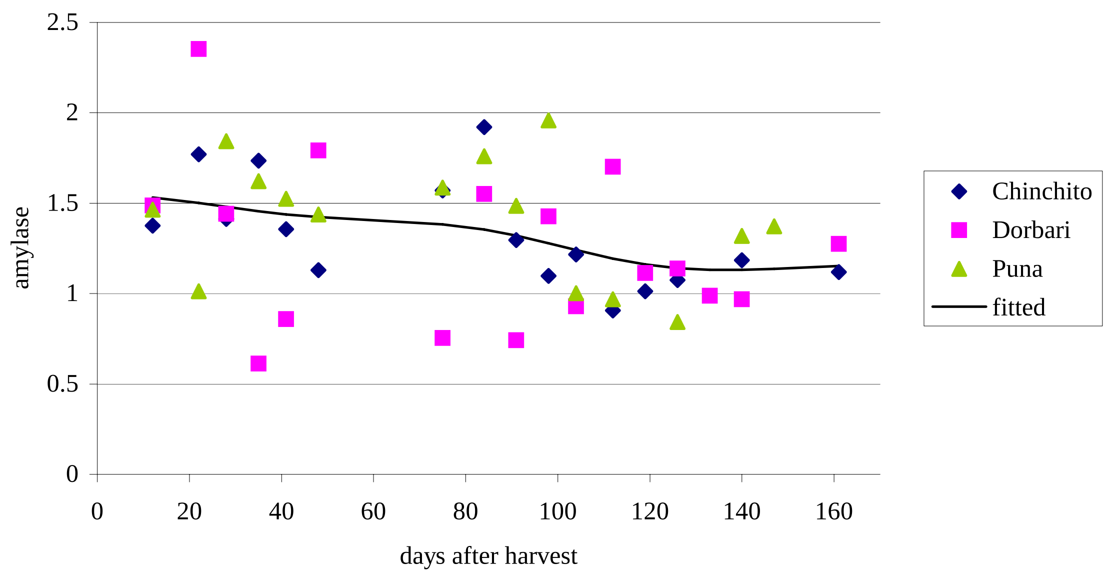


No data for 4 and 12 days after harvest.

Protein against days after harvest.

Figure 8d Trend in amylase content over time

There was a significant trend (p-value = 0.05) with all varieties having the same trend.



Amylase against days after harvest

4.3.7 Assessment of Modified Post-Harvest Protocols

101. Output 4, Activity 4.1 & 3. A complex factorial curing and storage trial was undertaken to assess the technical efficacy of particular post-harvest conditioning treatments on the biological status of stored and marketed yams. A summary of the findings as they relate to weights of rot recovered from inspected tubers are illustrated in Figure 9a and 9b.

102. Irrespective of the post-harvest handling protocol adopted, the application of the coating ‘Semperfresh’ accentuated the wastage of tubers due to increased microbial decay. Of the remaining treatments interactions were observed between all the factors (post-harvest handling and storage practices interacted with variety and time) If the influence of fungicide application is set to one side, the ‘most successful’ of the protocols appeared to be associated with the liming and curing of the tubers.

103. Table 10 provides an indication of the nature of the fungal pathogens recovered from tissue samples derived from the various treatments used during the storage trial.

4.3.8 Pilot Testing and Dissemination of Modified Post-Harvest Protocols

104. Output 4, Activity 4.2. The outcome of Activities 4.1 and 4.3 suggested that recommendations to adopt the post-harvest protocols investigated to date on a wider scale would be premature. Further trails are necessary to determine the veracity of the approach adopted so far, pilot scale semi-commercial trials would need to follow and these would have to be shown to be successful before precise recommendations could be formulated for dissemination.

105. A more detailed understanding of the nature of the losses experienced by the yam crop is emerging as a consequence of the project reported here, however, affordable and appropriate post-harvest protocols capable of making a significant impacting on the biological waste within the system will require further study and experimentation if a solution is to be devised.

Table 10. Fungal pathogenic cultures recovered from diseased tissues of yams derived from post-harvest handling and storage trial.

			Secondary Treatment			
Yam Variety	Primary Treatment	Month	Traditional Pit	Exposure in Improved Yam Barn	Semperfresh Coating and Exposure in Improved Yam Barn	Fungicide Application and Plastic Bag Enclosure
Pona	Liming and Curing (PTC1)	Sept.	Rhyzopus stolonifera		Rhyzopus stolonifera	Rhyzopus stolonifera
		Oct.	Fusarium oxysporum	Fusarium oxysporum	Erwinia caratovora	Fusarium oxysporum
		Nov.		Fusarium moniliforme	Erwinia caratovora	
		Dec.	Fusarium oxysporum	Rhyzopus stolonifera	Rhyzopus stolonifera	Rhyzopus stolonifera
	Pit Storage (PTC2)	Sept.	Rhyzopus stolonifera	Rhyzopus stolonifera	B. theobromae	
		Oct.		Fusarium oxysporum	Rhyzopus stolonifera	Fusarium oxysporum, B. theobromae
		Nov.	Aspergillus niger		Erwinia caratovora	Erwinia caratovora
		Dec.	Rhyzopus stolonifera	Fusarium oxysporum	Rhyzopus stolonifera	Rhyzopus stolonifera
	Drying, Liming and Curing (PDC1)	Sept.		Aspergillus oryzae	P. Brevi-compactum	Rhyzopus stolonifera
		Oct.			Erwinia caratovora	P. Brevi-compactum
		Nov.	Aspergillus niger	Fusarium oxysporum	Rhyzopus stolonifera	
		Dec.	Rhyzopus stolonifera	Fusarium oxysporum		Rhyzopus stolonifera
Lili	Liming and Curing (LTC1)	Sept.	Fusarium oxysporum		Fusarium oxysporum, Erwinia caratovora	Fusarium oxysporum
		Oct.				Rhyzopus stolonifera
		Nov.	Fusarium moniliforme	Fusarium oxysporum		Rhyzopus stolonifera
		Dec.		Rhyzopus stolonifera	Aspergillus niger	
	Pit Storage (LTC2)	Sept.	Rhyzopus stolonifera	Rhyzopus stolonifera		
		Oct.	Fusarium oxysporum	Fusarium oxysporum	Fusarium oxysporum, P. Brevi-compactum	
		Nov.	Fusarium oxysporum			
		Dec.	Rhyzopus stolonifera	Rhyzopus stolonifera	Rhyzopus stolonifera	Rhyzopus stolonifera
	Drying, Liming and Curing (LDC1)	Sept.	Fusarium oxysporum	Rhyzopus stolonifera		Rhyzopus stolonifera
		Oct.				Rhyzopus stolonifera
		Nov.	Fusarium oxysporum	Fusarium oxysporum		
		Dec.	Rhyzopus stolonifera		Rhyzopus stolonifera	Rhyzopus stolonifera

5. Contribution of Outputs

5.1 Contribution of Outputs to DFID's Development Goal:

105. The project has succeeded in characterising the principal modalities of the marketing systems serving the main yam producing areas of Ghana. For the first time data for the actual biological losses apparent in the main trading sites have been obtained and different categories of loss described. Certain data has also been recovered to provide an indication of how such biological losses equate to monitory value. The knowledge acquired to date suggests that any significant reduction in the post-harvest loss of yams will only be realised if measures are developed to either diminish or exclude chronically infected tubers from the main marketing channels. Trials indicate that improved grading protocols coupled with post-harvest conditioning of the tubers should prove beneficial if producers and traders could be encouraged to modify their traditional handling strategies. The present research has helped highlight critical weaknesses within the system that if addressed would lead to reduced losses and the improved profitability of the yam marketing system.

5.2 Promotion Pathways to Target Institutions and Beneficiaries

106. The rational for the promotion pathways to target institutions and other beneficiaries is the same as that outlined in more detail in Paragraph Nos. 110 (Page 48) through to 115. Due to the nature of the information developed by the project that has now terminated (Refer to Appendix C), these outputs are likely to be of more immediate utility to fellow researchers and of academic interest to those working in the extension agencies (particularly in Ghana). Copies of the documentation that have been finalised are being distributed to collaborating institutions and pertinent collaborators. The principal beneficiaries at this stage are likely to be those staff and members of the public that have been directly associated with the work to date namely: a) the natural resources scientists (post-harvest technologists and food scientists) collaborating with the programme and, b) the staff of associated government departments, institutes and resource persons who worked with the Project team.

107. Within Ghana, the more academic findings of the Project have already been disseminated to collaborators and target institutions by means progress reports, technical papers and by personal contact with university academic staff University of Ghana (UoG) - Legon; research workers of the Food Research Institute (FRI), and staff from MoFA.

5.3 Follow-up Action and Research Required

108. To fulfil the stated objectives of the 1994 National Agricultural Research Strategy (NARS) Plan for Ghana and deliver tangible benefits to stakeholders operating in the yam marketing system, further strategic and applied research together with developmental projects are required to determine whether:

a) The shelf-life potential of fresh yams may be more fully realised by the application of modified atmosphere storage and/or curing conditions;

b) Beneficial post-harvest protocols (such as those in ‘a’) may be integrated into the existing yam trading systems or whether a more radical integrated approach to the post-harvest management of yams is required to counter the existing levels of waste;

c) The array of volatiles known to be released from yams may be used practically not only to differentiate between yam varieties but also as a non-destructive method of determining whether yams are sound or chronically infected with rot;

d) Stringent post-harvest quality control of seed tubers (as facilitated by ‘c’) may be used successfully to reduce the levels of chronically diseased yams and so improve overall yield and post-harvest quality of ware yams;

e) Existing tissue culture technologies may be used to generate seed tubers free from internal disorders assumed to be caused by viral agents;

f) Production of smaller yams may not reduce post-harvest losses and increase trade with urban centres and overseas markets;

g) Improvements in the consistent post-harvest quality of yams (resulting from initiatives ‘a’ to ‘f’) may increase both their internal and export potential and thereby promote a larger market for yam producers

5.4 Follow-up Action and Research Planned

109. In February 2000 the Crop Post-Harvest Programme commissioned a second project entitled ‘Development of integrated protocols to safeguard the quality of fresh yams’. This project seeks to undertake additional work to test, deploy and foster improved handling protocols that will provide viable alternatives to existing practices and specifically address the following issues:

a) Determine the cause and source of the most significant post-harvest rots and devise strategies to reduce incidence of infection;

b) Develop and deploy more effective grading protocols to exclude diseased tubers from entering both the local and export marketing chains or from being used as seed material;

c) Deploy effective post-harvest handling/conditioning protocols and improved storage techniques at the farm level to safeguard yam ‘shelf-life’ potential, and

d) Foster direct links between producers and exporters to obviate deficiencies in the existing local transport and trading systems, and implement improve handling protocols for the exportation of yams.

5.4.1 Proposed Promotion Pathways

110. The knowledge and experience acquired by the investigators as a consequence of the proposed research activities will be disseminated via two main conduits: the generation of printed documentation; and the direct or recorded interaction of investigators with interested parties. Table 2 indicates the range of dissemination materials or activities that will be appropriate and also the different categories of audience. The design and content of each mode of information exchange should be determined by the nature of the target audience and, as necessary, developed in consultation with these end-users.

Table 11. Summary of Pertinent Dissemination Materials and Target Audiences

Range of Dissemination Materials & Activities	**Suggested Target Audiences**
Progress Reports – Monthly/Quarterly/Annually	Producers Farmers Groups
Technical Reports	
Published peer reviewed scientific papers	Traders
Manuals	Exporters
Pamphlets, posters etc.	Importers
Articles in Newsletters	Trade/Market Associations
Printed media – press releases etc.	Local Communities
Computer Mediated World-Wide Web	District Assemblies
Discussions & Briefing Meetings	MoFA and Extension Services
Seminars	Non-Government Organisations
Conferences	Research Institutes
Workshops	Technologists & Scientific Community
Demonstrations	Development Projects and Programmes
Training Courses	Policy Makers
Training Video	Donors & Sponsors
Radio & television interviews etc.	

111. Interactive forms of dissemination are an important means of transferring information and exposing project activities to direct external scrutiny. This is particularly important to client groups with limited literary ability such as producers and traders based in rural communities. The dissemination of knowledge over time and distance, however, requires documentation and possibly videotaped records.

112. Model protocols derived from the adaptive research components of the project will be developed in conjunction with selected producers and their local communities, traders, export/importers and their associations, while the strategic research elements will be more academically focused. During the initial research and adaptation phase of the project, information exchange will be encouraged by briefing meetings, sharing progress reports between the various working groups and hosting an annual workshop to keep all interested parties abreast of developments. The management of this process will rest with the NRI and MoFA with contributions from all principal investigators including the collaborators from the University of Legon. In the last

year of the project it is anticipated that a range of documents recording the findings of the project will be produced by the collaborators for dissemination to the target institutions and audiences already identified.

113. Within Ghana, the wider dissemination of the project findings will be managed and directed by MoFA and GTZ with possible complementary assistance of the Ghana Yam Producers and Export Association, USD and TechnoServe. Within the time period of the project, dissemination of documentation on a regional and international basis is likely to occur through the auspices of IITA and the CSRS, augmented by articles in specialist newsletters, conference presentations and the publication of technical papers.

114. By the end of the project, a range of dissemination materials will be generated that will explain the use and potential economic benefits of deploying various validated protocols developed to reduce the post-harvest biological and economic loss of yams and to promote more profitable marketing practices. The most important topics are likely to include those cited in Table 1. In addition, within the project cycle, one of the strategic research components of the project has the potential to evolve a prototype analyser for the non-destructive quality assessment of tubers. If successfully transferred to the commercial sector, such technology would have a profound effect on ensuring the quality of yams destined for the export market.

Table 12. Subject matter of proposed dissemination materials, their associated end-user groups and probable time scale to completion

Topics	Ultimate Target Group	Time-scale to completion
Strategies for producers to reduce the incidence of post-harvest diseases on-farm	Producers	3 years
Integrated post-harvest handling, curing and storage protocols to extend the shelf-life of yams	Producers	3 years
Improved grading strategies to ensure the quality of yams entering the marketing system	Producers, Traders, Exporters & Plant Breeders	3 years
An analysis of constraints to the profitable exportation and marketing of yams	Traders and Exporters	12-18 months
An integrated approach to reducing the loss of yams during export	Producers, Traders & Exporters	3 years
The potential for the non-destructive quality assessment of yam tubers	Exporters, Research Institutes & Technologists	3 years

De novo research, the pilot-scale validation of various handling protocols where appropriate, and the consequent development of serviceable dissemination materials is likely to take three years. Provided such materials are effectively transmitted to their appropriate target groups thereafter, practical benefits may begin to emerge in a further one or two yam marketing seasons. Should this be the case then it would be expected that significant changes in the traditional marketing chain would become established over a 5-10 year period. If improved protocols were found to be profitable in the export sector the rate of adoption of revised practices is likely to be much more rapid. Quantitative data indicative of the possible reductions in both the biological and economic loss of yams that may accrue from these proposed interventions is not yet available; however, any significant improvements to the present rates of loss would be considered advantageous by those working in this sector.

115. Should interventions prove effective, then the absolute biological losses due to initially asymptotic yams would be expected to fall from the present toll of 20-30% of marketed produce. In this manner the extent of loss suffered by traders would be diminished. From the producer's perspective, the generation of yams with improved post-harvest shelf-life potential, reduced disease load, and the development of direct linkages with exporters, should provide the elements necessary to promote a more sustainable and remunerative market for their produce. Projections in terms of the potential increased income that may accrue to producers are not available as base line data relating to these issues have never been collected previously.

5.4.2 Delivery of Commissioned Project

116. The second yam project is funded by the RNRRS, Crop Post Harvest Programme. The Institute selected to Lead this project is the Natural Resources Institute of the University of Greenwich. Work on the project commences on the 1st February 2000 and due to continue until the 31st March 2003. The principle collaborators are:

1. Ministry of Food and Agriculture, Accra and Brong Ahafo, Ghana;
2. Department of Crops Science, and
3. Department of Agricultural Economics, University of Ghana at Legon.

and the target institutions and stakeholders are as follows:

Governmental (GOs in Ghana):

a) District Assemblies for Sunyani, Techiman and Atebubu;
b) Ministry of Food and Agriculture (Brong Ahafo Region);
c) Dept. of Nutrition and Food Science, University of Ghana, Legon;
d) Crop Research Institute (CRI), Kumasi;
e) Food Research Institute (FRI), Accra, and
f) Dept. Agric., Extension and Economics at Uni. Dev. Studies (UDS), Tamale.

Non-Governmental Organisations (NGOs):

g) TechnoServe (Ghana); and
h) University of Reading (UK).

Commercial Sector:

i) Ghana Yam Producers and Export Association and membership (Ghana);
j) H. Singh International Ltd., Manchester (UK);
k) Oxford Fruit Co. Ltd., Birmingham (UK); and
l) Sparo Carmel – Exotic Produce Marketing, Middlesex (UK).

(Note: The numbers of commercial companies participating in the activities of the project are likely to change and expand over time.)
Stakeholders:

m) Farmer's Groups (Ghana); and
n) Traders' Associations (Ghana).

International Organisations:

o) International Institute for Tropical Agriculture (IITA);
p) Centre Suisse de Recherches Scientifiques en Côte d'Ivoire;
q) Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ);
r) Conference des Responsables de Recherche Agronomique Africains (CORAF), and
s) Institute National de la Recherche Agronomique (INRA).

117. In Ghana the major role of disseminating, promoting and supporting new or improved techniques and income-generating possibilities for the farming community rests with the Extension Services of MoFA at District Level. In this work MoFA is supported by Government and external donor funding. Other dissemination conduits include the Dept. Agric., Extension and Economics at Uni. Dev. Studies (UDS), Tamale; the GTZ, and community-based programmes such as those run by TechnoServe, an NGO supported by funds from the United States of America

118. The UDS together with NGOs and GOs have come together to form the 'Low External Input and Sustainable Agriculture technology Systems' (LEISA) network of Northern Ghana. This grouping has launched a new publication called the 'Savannah Farmer' funded by an organisation known as the 'Information on Low External Input Agriculture' (ILEIA) in the Netherlands. This publication will be distributed to producers, NGOs and others working in the field and potentially will provide one avenue by which the findings of the proposed project may be disseminated.

119. As a result of many years of operating in Ghana, the GTZ has developed and continues to pursue an active dissemination programme directed at farmers. For instance, in the past, this has played a key role in transferring information regarding improved designs for yam barns. It is proposed that the findings of the project will be actively taken up by agencies such as the GTZ who have the capability and interest to utilise this work in their current and future operations.

Table 2. Summary of location and time schedule of activities undertaken on behalf of Project 'Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana' (Part I)							
Location	**Survey Site**	**Socio-Economic Focus**			**Post-Harvest Biology Focus**		
Level		**Characterisation**					
		Market	**Agents**	**Biological Quality v. Economic Value**	**Biological Quality Assessment**	**Impact of External factors**	**Modified Handling Protocols**
Activities		1.1 & 1.2	1.1 & 1.2	1.3	2.1	2.2	4.3
Region	Ashanti						
Market(s)	Kumasi	Feb. 1996	Feb. 1996			Dec. 1998; Jan. 1998	
Region	Brong Ahafo						
Market(s)	Techiman & Nkoranza	Feb. 1996; Oct. 1996	Feb. 1996; Oct. 1996	Oct. 1996; July & Aug. 1997.	Oct. 1996; July & Aug. 1997.	Jan. 1999	
	Atabubu					Jan. 1999	
	Kintampo					Dec. 1998	
Community	Asantanso	Oct. 1996	Oct. 1996				
	Asuogya (Kintampo)	Dec. 1997	Dec. 1997				
	Batsaso (Atebubu)	Dec. 1997	Dec. 1997				
	Fiaso (Techiman)	Dec. 1998	Dec. 1998			Nov. 1998;	Sept. 1998 – Feb. 1999.
	Drepoho					Dec. 1998; Jan. 1999	
	Watro (Atebubu)	Dec. 1997	Dec. 1997				

Table 2. Summary of location and time schedule of activities undertaken on behalf of Project 'Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana' (Part II)							
Location	**Survey Site**	**Socio-Economic Focus**			**Post-Harvest Biology Focus**		
Level		**Characterisation**					
		Market	**Agents**	**Biological Quality v. Economic Value**	**Biological Quality Assessment**	**Impact of External factors**	**Modified Handling Protocols**
Activities		1.1 & 1.2	1.1 & 1.2	1.3	2.1	2.2	4.3
Region	Greater Accra						
Market(s)	Accra viz: Basere; Konkomba; Timber; and other smaller markets (Adabraka, Agblogboshie, Kaneshi, Madina, Makola, Malam Atta, Mamprobi, Nima and Salaha)	Feb. & July. 1996; Dec., 1996, Jan. – Feb. 1997	Feb. & July. 1996; Dec., 1996, Jan. – Feb. 1997	Dec., 1996, Jan. – Feb. 1997; Aug.- Sept. 1997; April – May 1998	Dec., 1996, Jan. – Feb. 1997	Nov. 1998; Jan. 1999	

Table 2. Summary of location and time schedule of activities undertaken on behalf of Project 'Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana' (Part III)

Location	**Survey Site**	**Socio-Economic Focus**			**Post-Harvest Biology Focus**		
Level		**Characterisation**					
		Market	**Agents**	**Biological Quality v. Economic Value**	**Biological Quality Assessment**	**Impact of External factors**	**Modified Handling Protocols**
Activities		1.1 & 1.2	1.1 & 1.2	1.3	2.1	2.2	4.3
	Tema & Ashaiman	Aug. 1996; Dec., 1996, Jan. – Feb. 1997	Aug. 1996; Dec., 1996, Jan. – Feb. 1997	Dec., 1996, Jan. – Feb. 1997	Dec., 1996, Jan. – Feb. 1997		
Region	Northern						
Market(s)	Tamale (Aboaba)	Feb. 1996	Feb. 1996				
Community	Farmers	Feb. 1996	Feb. 1996				
Region	Volta						
Market(s)	Dambai, Kpasse, Kabiti	Feb. & March 1997	Feb. & March 1997	Feb. & March 1997	Feb. & March 1997		
Community	Bonakye-Konkomba-Line	Feb. & March 1997	Feb. & March 1997				

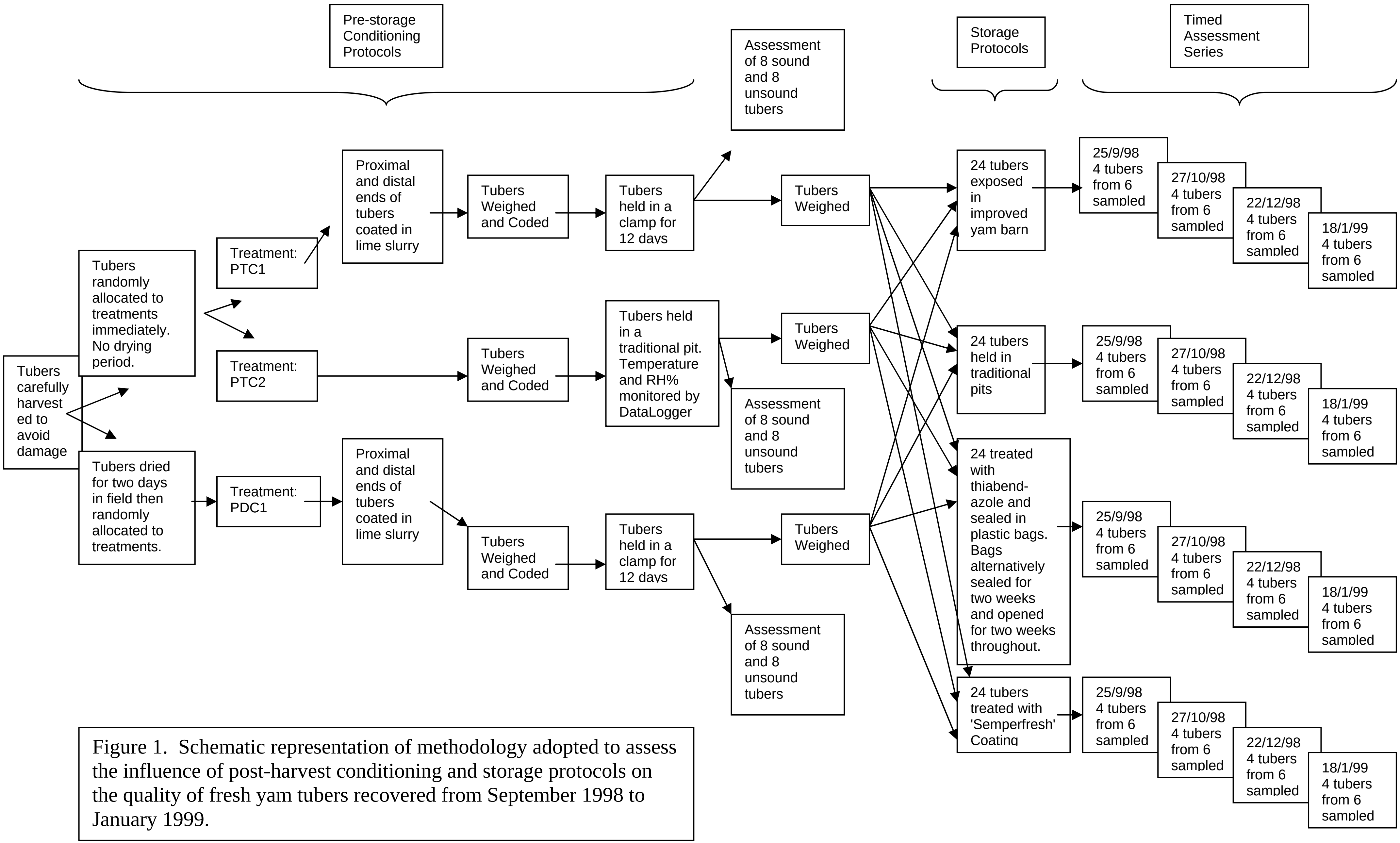


Figure 1. Schematic representation of methodology adopted to assess the influence of post-harvest conditioning and storage protocols on the quality of fresh yam tubers recovered from September 1998 to January 1999.

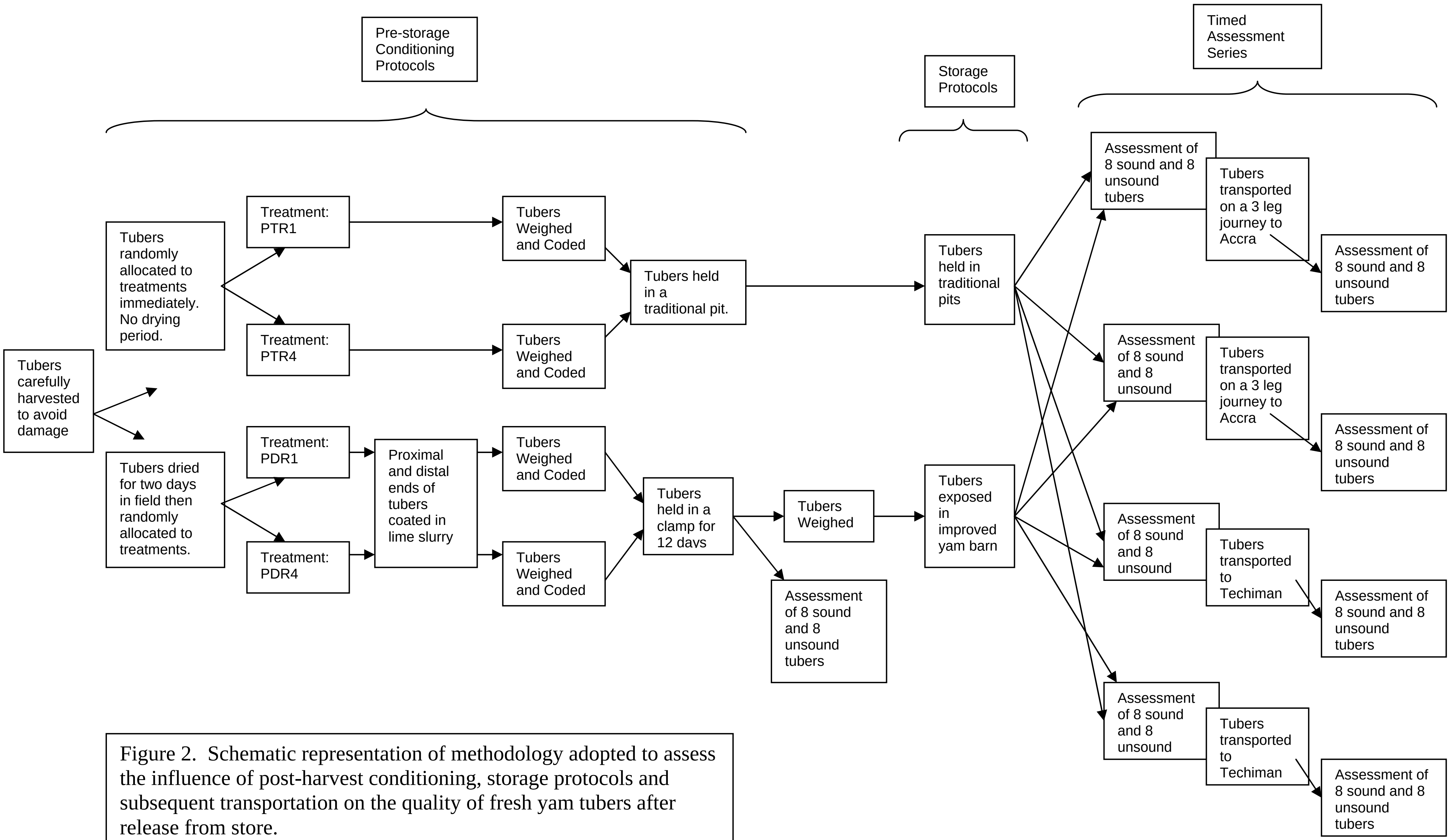


Figure 2. Schematic representation of methodology adopted to assess the influence of post-harvest conditioning, storage protocols and subsequent transportation on the quality of fresh yam tubers after release from store.

Figure 5. A map of Ghana indicating the location of major transport routes used for the marketing of fresh yams (Source: Gray, 1996). The symbol ■ denote population centres in the major yam producing areas and ● denotes major urban centres for the consumption of yams.

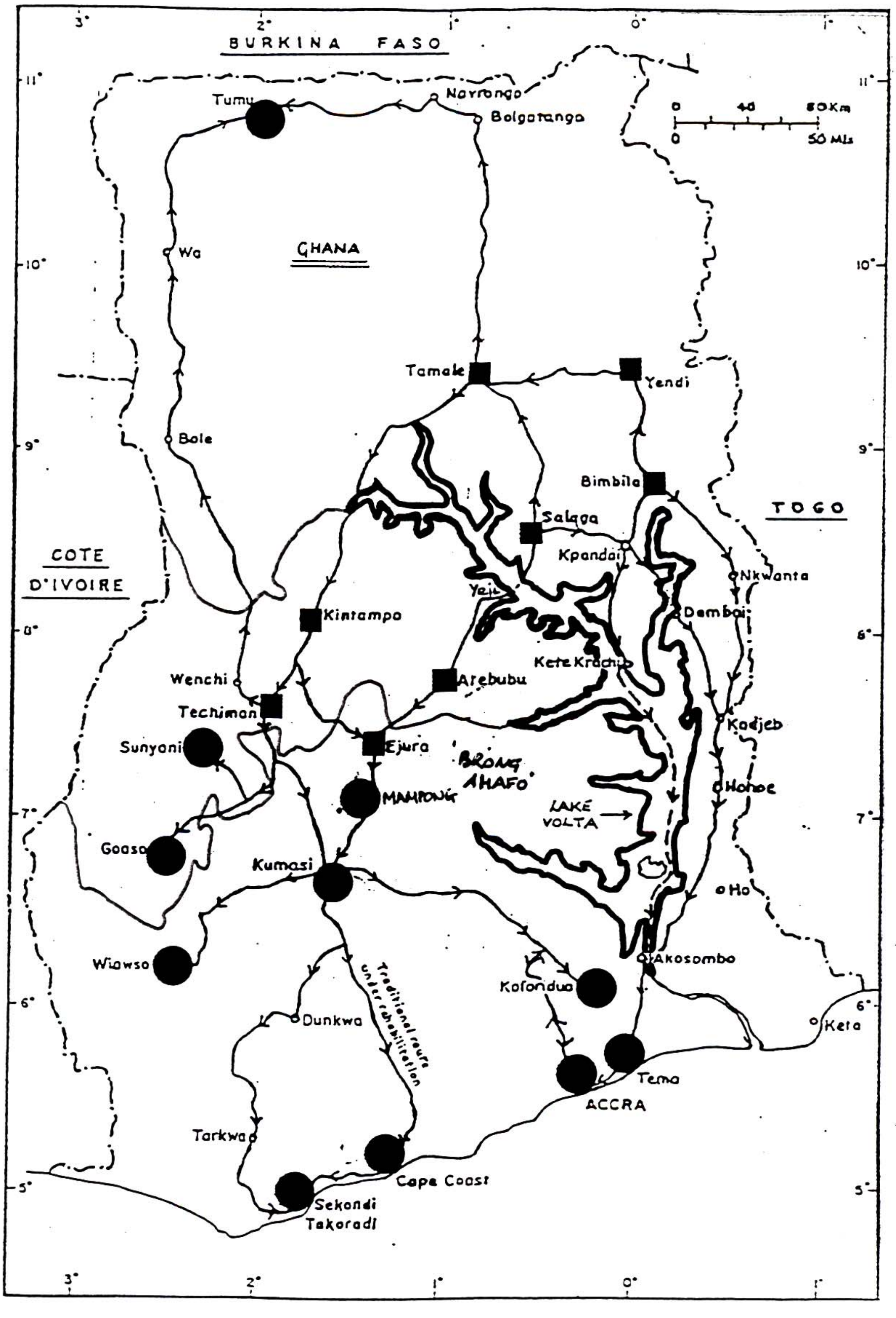


Figure Series 7. Preliminary findings of the differences observed in the proximal (head), middle and distal (tail) sections of fresh yam tubers with respect to 10 contrasting physio-chemical attributes.

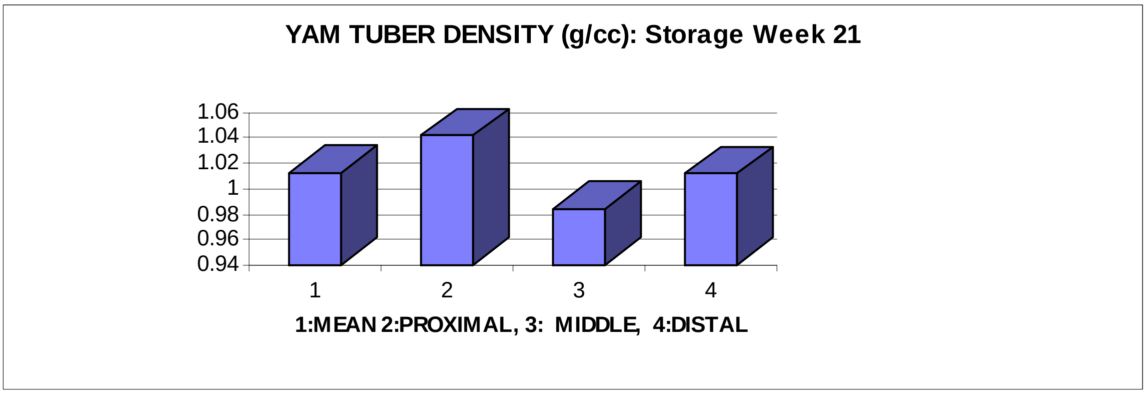


Figure 7a

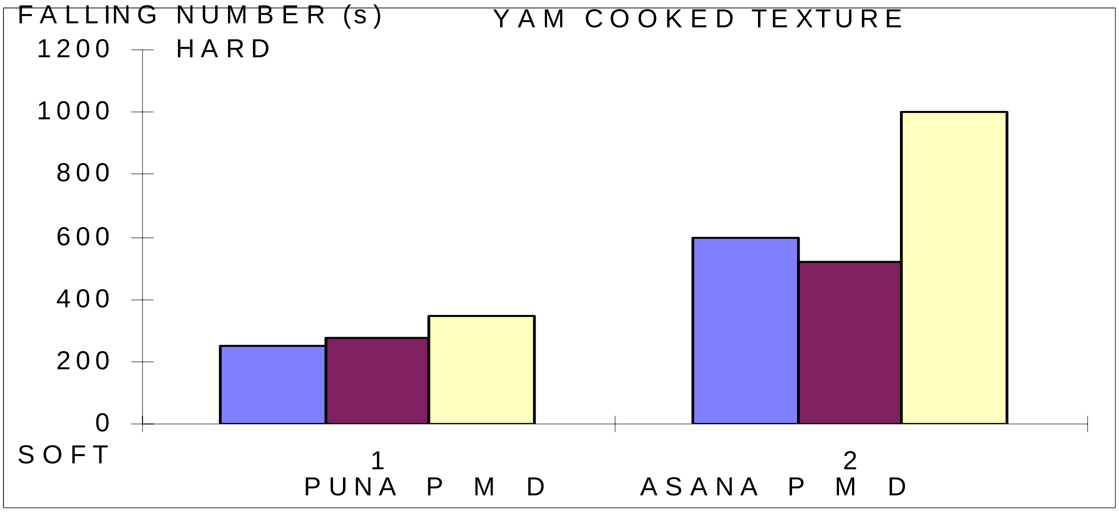


Figure 7b

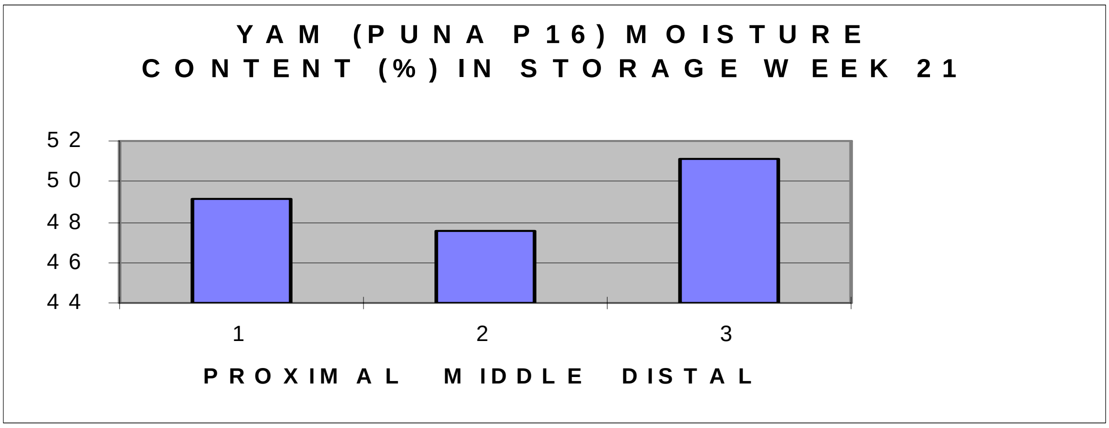


Figure 7c

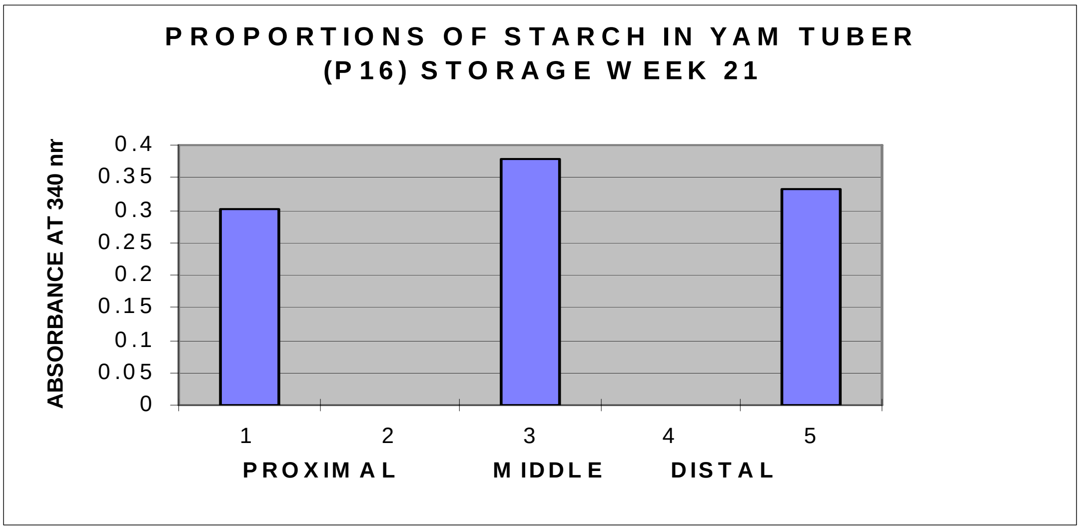


Figure 7d

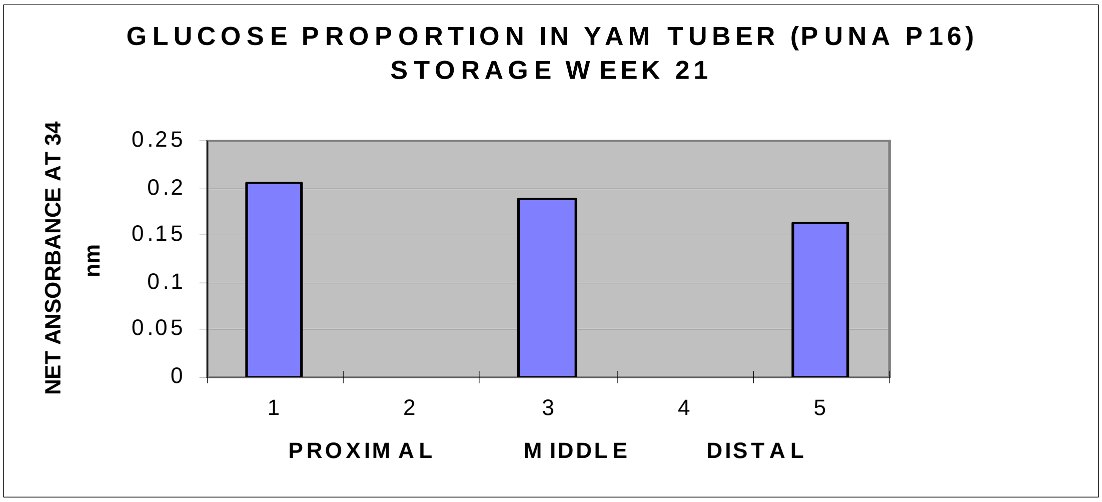


Figure 7e

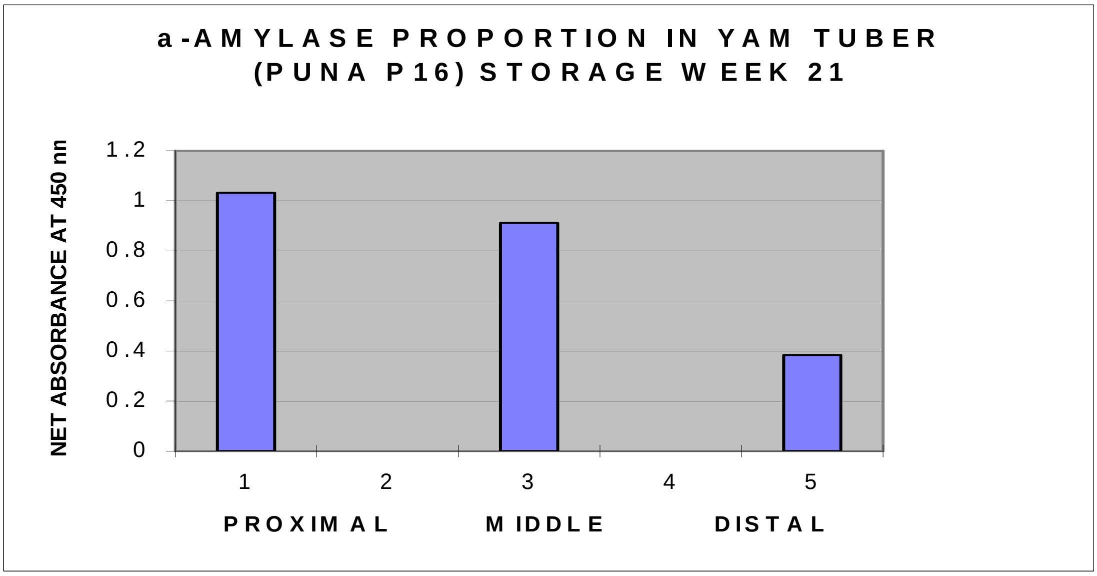


Figure 7f

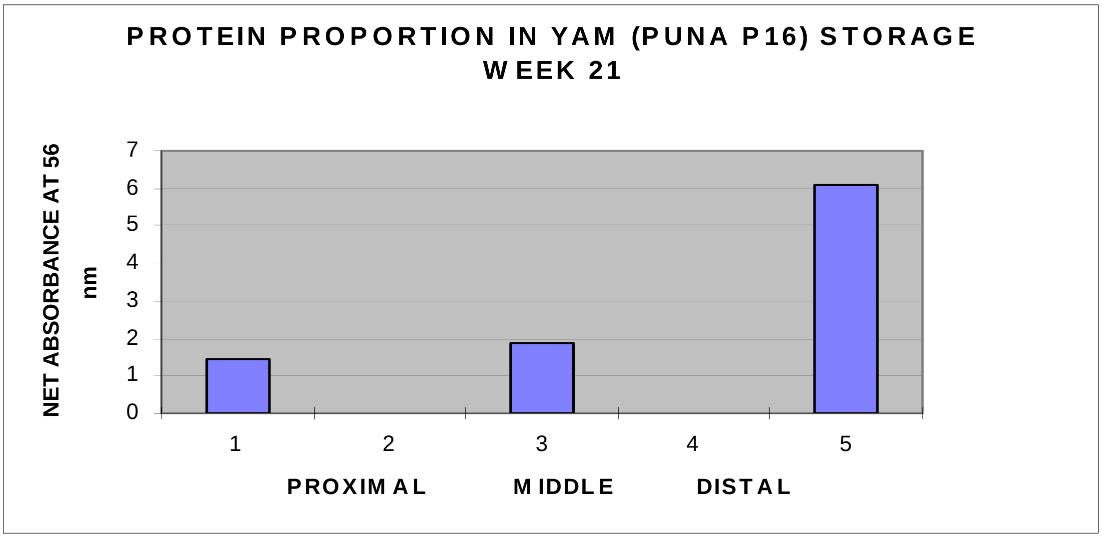


Figure 7g

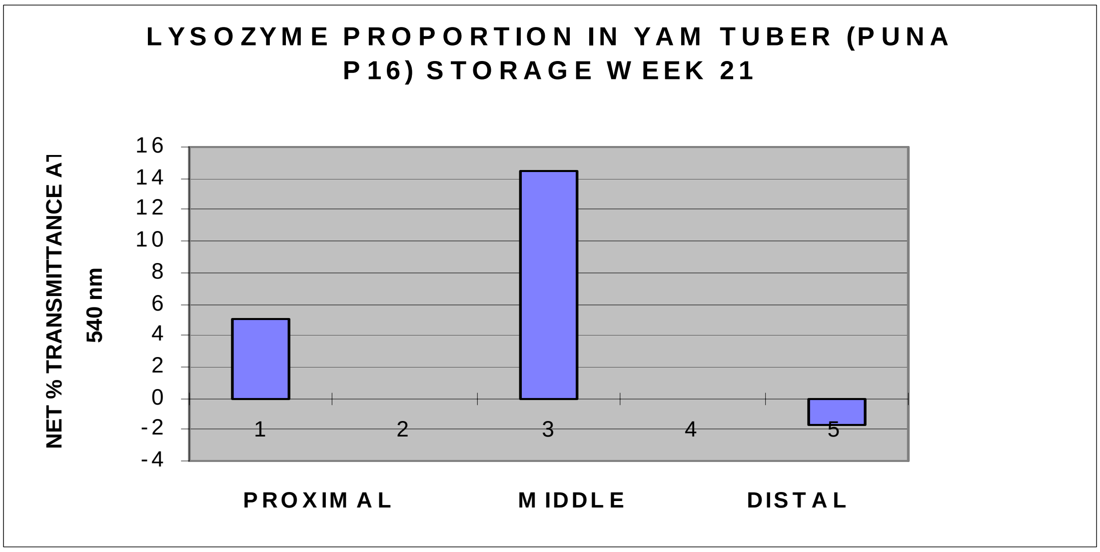


Figure 7h

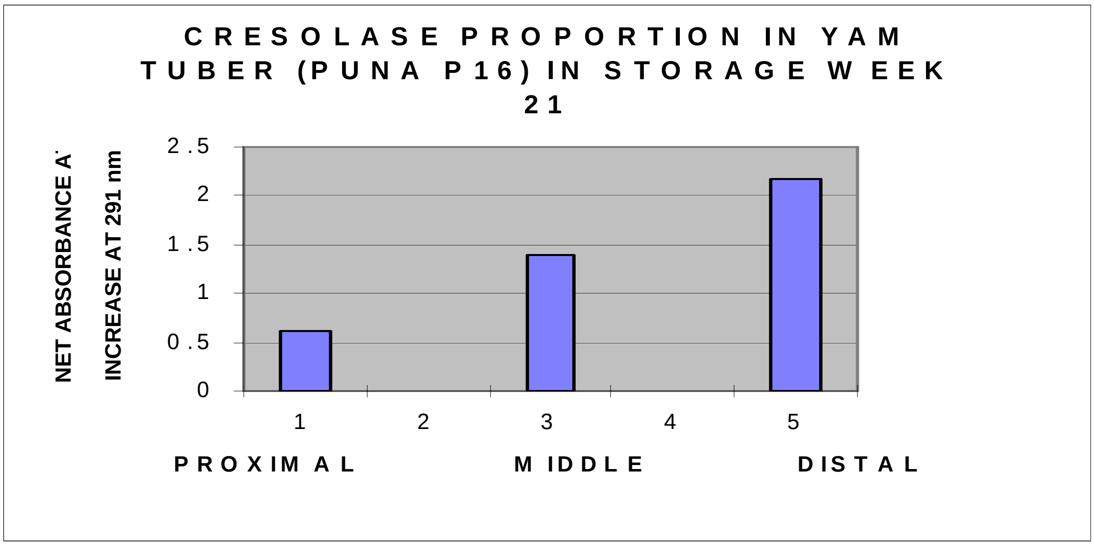


Figure 7i

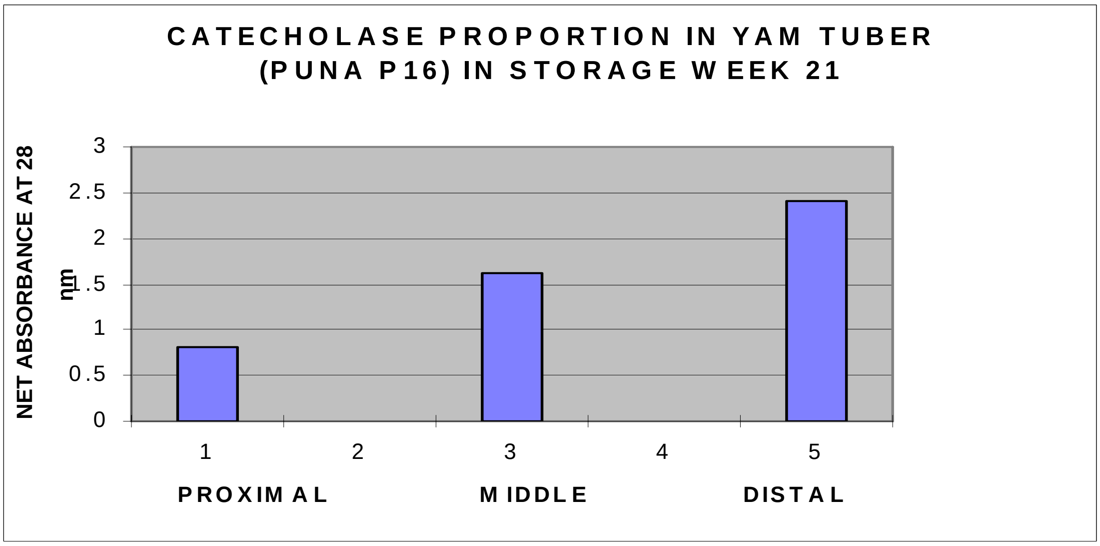


Figure 7j

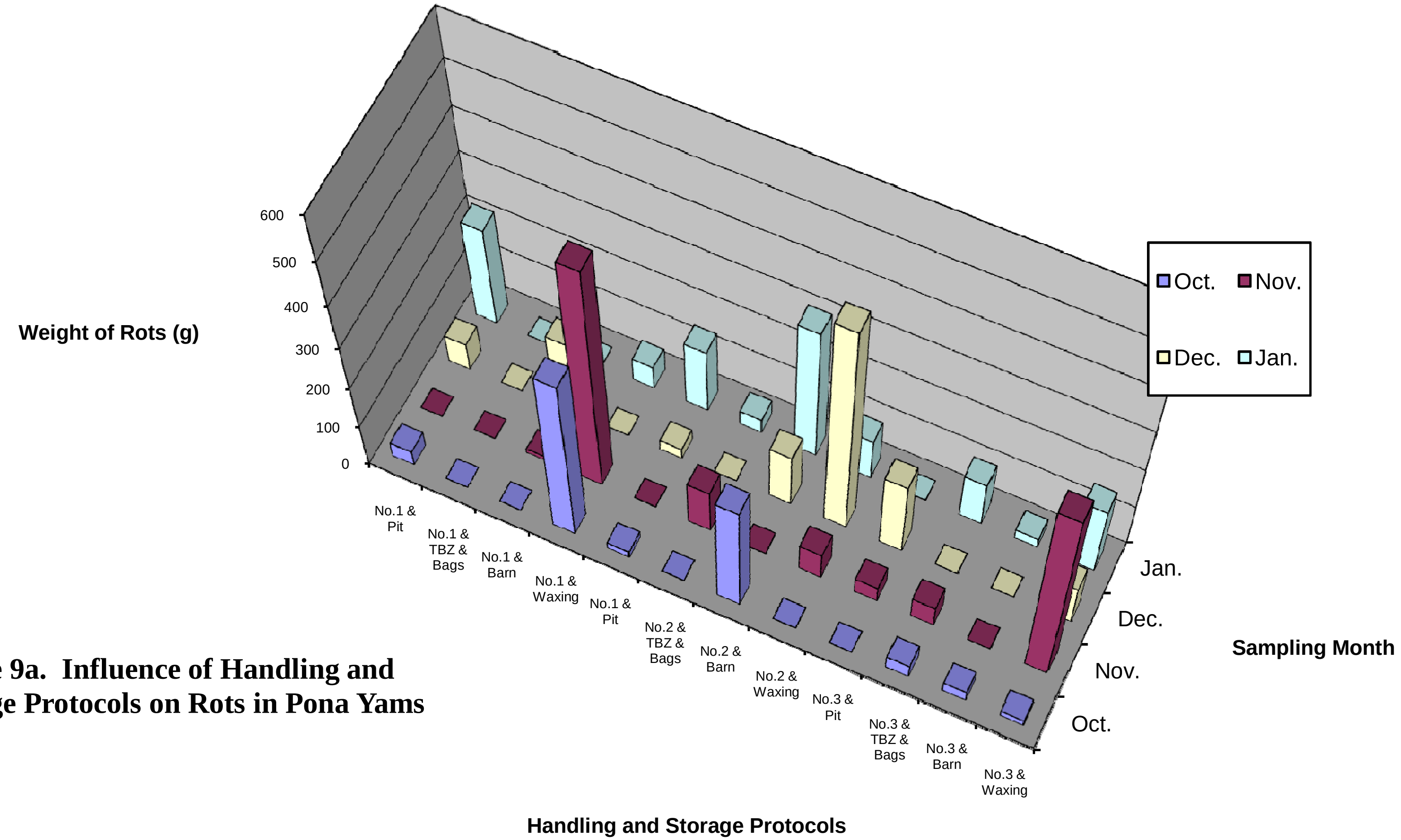


Figure 9a. Influence of Handling and Storage Protocols on Rots in Pona Yams

Appendix A

References

1. Adeniji, N.O. 1970. Fungi associated with the storage decay of yams in Nigeria. *Phytopathology* 60, 590-592.
2. Adesuyi, S.A. 1973. Advances in yam storage research in Nigeria. *Proceedings of the 3rd International Symposium on Tropical Root Crops*, IITA, Ibadan, Nigeria. 428-433.
3. Akoroda M.O. 1995. Yam research at IITA: 1971-1993. *Crop Improvement Division, Root and Tuber Improvement Program*. International Institute of Tropical Agriculture, Ibadan, Nigeria , PMB 5320, Ibadan, Nigeria.
4. Alhassan, A.Y. 1994. Postharvest aspects of yam and cassava in Ghana. *Unpublished Consultancy Report, Ghana Ministry of Agriculture/GTZ.* 18 pp.
5. Anon 1986. Pest control in tropical root crops. *Centre for Overseas pest Research, PANS Manual* **4**, 235 pp.
6. Been, B.O., Perkins, C. and Thompson, A.K. 1976. Yam curing for storage, *Acta Horticulturae* **62**, 311-316.
7. Been, B.O., Thompson, A.K. and Perkins, C. 1974. Effects of curing on stored yams. *Proceedings of the Caribbean Food Crops Society* **12**, 38-42.
8. Campbell, J.S., Chukwueke, V.O., Teriba, F.A. and Ho-a-shu, H.V.S. 1962. Some physiological experiments with the White Lisbon yam *Dioscorea alata* L. in Trinidad. III. The effect of chemicals on storage. *Empire Journal of Experimental Agriculture* **30**, 335-344.
9. Cooke, R.D., Rickard, J.E. and Thompson, A.K. 1988. The storage of tropical root and tuber crops - cassava, yam and edible aroids. *Experimental Agriculture* **24**, 457-470.
10. Coursey, D.G. 1967. *Yams.* London, Longmans. p 230.
11. Degras L. 1993. *The Yam*. London, Macmillian 408 pp.
12. Dumont, R. 1995. The nature and importance of tuber damage during yam storage in Côte d'Ivoire: improvements developed through research. *Workshop on pests and pathogens of yams in storage* International Institute of Tropical Agriculture, Ibadan, Nigeria, Summary Document, 25 May 1995.
13. Ezeh N.O.A. 1995. National Root Crops Research Institute, Umadike. *Workshop on pests and pathogens of yams in storage* International Institute of Tropical Agriculture, Ibadan, Nigeria, Summary Document 25 May 1995.
14. Ezeike, G.O.I. 1985. Experimental analysis of yam *Dioscorea* spp tuber stability in tropical storage. *Transactions of the American Society of Agricultural Engineers* **28**, 1641-1645.
15. Ezeike, G.O.I., Ghaly, A.E., Ngadi, M.O. and Okafor, O.C. 1989. Engineering features of a controlled underground yam storage structure. *Paper American Society of Agricultural Engineers* **89-5020**, 23 pp.
16. FAO 1975. *FAO Yearbook*.
17. FAO 1985. Prevention of postharvest food losses: fruits, vegetables and root crops. *FAO Training Series* **10**, 120 pp.
18. FAO 1994. *FAO Yearbook* **48.**
19. Girardin, O., Farah, Z., Escher, F. and Stamp, P. 1996. Effect of Modifying Two Traditional Storage Methods on Storability of Two Varieties in a Village in Côte d'Ivoire. Tropical Science. In press.
20. Gonzales M.A. and de Rivera A.C. 1972. Storage of fresh yams *Dioscorea alata* L under controlled conditions. *Journal of Agriculture of the University of Puerto Rico* **56**, 46-56.

21. Greeley, M. 1991. Postharvest Technologies. Implications for Food Policy Analysis,
p 7.
22. Green, KR. and Simons, S.A. 1994. 'Dead skin' on yams *Dioscorea alata* caused by *Colletotrichum gloeosporioides*. *Plant Pathology* **43**,1062-1065.
23. GTZ (1995) Market orientated storage of yams - a case study in Northern Ghana. GTZ Internal report.
24. Hayward, L.A.W. and Walker, H.M. 1961. The effects of preharvest foliar sprays of maleic hydrazide on the storage of yams. *Annual Report of the West African Stored Products Research unit, Technical Report* **19**, 107-115.
25. Henckes, C., Fuseini, H.A. and Nicol, K. 1995. Market-orientated yam storage: a key to increase the profit of yam production. *International Conference, Postharvest technology and Commodity Marketing* 27-29 November 1995, Accra Ghana.
26. Ihekoronye, A.I. and Ngoddy, P.O. 1985. Integrated Food Science and Technology for the Tropics. MacMillan, London, p. 266.
27. IITA 1995. Workshop on pests and pathogens of yams in storage International Institute of Tropical Agriculture, Ibadan, Nigeria, Summary Document 25 May 1995.
28. Kleih, U., Crentsil, D., Gallat, S., Gogoe, S.F., Nettey, D.A.S, and Yeboah, D. 1994. Assessment of post-harvest needs in non-grain starch staple food crops systems in Ghana. NRI report.
29. Lipton, M. 1972. Research into economics of food storage in less developed countries. Prospects for contribution from U.K. technical assistance. Communication Series
No. 61. England, pp. 1-15.
30. Martin, F. W. 1974. Effects of type of wound, species and humidity on curing of yam *Dioscorea alata* L. tubers before storage. *Journal of the Agricultural University of Puerto Rica* **58**, 211-221.
31. Mishra, D., Mishra, A.B. and Rath, G.C. 1989. Fungal rots of *Colocasia*, yam, beet and carrot in Orissa markets. *Orissa Journal of Agricultural Research* **2**, 156-159.
32. Mück, O. 1994. Improving small scale harvesting, handling, processing and storage of tropical root and tuber crops. Kumasi, Ghana, *Deutsche Stiftung für International Entwicklung, Deutsche Gesellschaft für Technische Zusammenarbeit.* International Seminar 4 to 17 December 1994.
33. Morse, S., Acholo, M., McNamara, N and Oliver , R. 1999. Control of storage insects as a means of limiting yam tuber fungal rots. Journal of Stored Products Research **36**, (2000), 37-45.
34. Noon, R. A. 1978. Storage and market diseases of yams. *Tropical Science* **20**, 177-188.
35. Nnodu, E.C. and Alozie, S.O. 1992. Using giberellic acid to control sprouting of yam tubers. *Tropical Agriculture* **69**, 329-332.
36. Nwankiti, A.O., Atu, U.G., Alozie, S.O., Igbokwe, M. Okpokiri, A. and Nnodu, E. 1988. Effect of modifying two traditional yam barn structures on storability of four cultivars of yam *Dioscorea* spp. *Tropical Agriculture* **65**, 125-128.
37. Okoh, R.N. 1996. Economic validation of Losses in Yams (Dioscorea spp.) stored in Traditional Yam Barns. Tropical Science in press.

38. Onwueme, I.C. and Charles W.B. 1994. Tropical Root and Tuber Crops. Production Perspectives and Future Prospects. FAO Plant Production and Protection Paper No. 126, Rome.
39. Passam, H. C., Read, S. J. and Rickard, J. E. 1976. Wound repair in yam tubers: the dependence of storage procedures on the nature of the wound and its repair. *Tropical Science* **18**, 1-11.
40. Tetteh, J.P. and Saakwa, C. 1991. Prospects and constraints to yam production in Ghana. Proceedings of the Ninth Symposium of the International Society for Tropical Root Crops. 20-26 October 1991, Accra, Ghana.
41. Thompson, A.K. 1972. Storage and transport of fruit and vegetables in the West Indies. In *Proceedings of the Seminar/Workshop on Horticultural Development in the Caribbean, Maturin, Venezuela* 170-176.
42. Thompson, A.K and Bancroft, R.D. (1996 in press)Review of Literature on Postharvest of Yams.
43. Thompson, A.K., Been, B.O. and Perkins, C. 1977. Fungicidal treatments of stored yams. *Tropical Agriculture* **54**, 179-183.
44. Thompson, A.K., Been, B.O. and Perkins, C. 1973. Reduction of wastage in stored yams. *Proceedings of the Third Symposium of the International Society for Tropical Root Crops, International Institute for Tropical Agriculture, Nigeria* 443-449.
45. Thompson, A.K., King, P.I. and New, J.N. 1979. Report on fresh produce export marketing from Jamaica. *Tropical Products Institute Report* R868 79 pp.
46. Waitt, A.W. 1961. Review of yam research in Nigeria (1921-1961). Fed. Agri. Res. Memo. No. 31.

Appendix B

Post-harvest constraints and opportunities for improving the Marketing of fresh yam in Ghana – Outputs and Research Activities (Part I).

Narrative Summary (NS)	Measurable Indicators (OVI)	Means of Verification (MOV)	
Outputs	**Activities**	**Proposed Nature of Textural Outputs**	**Ref. No. and date of Textural Outputs Generated (See Appendix C for more details)**
1. Major in-country marketing systems characterised and relationship between produce quality and economic value determined.	1.1 Identify major domestic and in-country export orientated yam marketing channels, and select representative systems for detailed study (by end Sept. 1996).	1. Project reports, publications in the scientific literature.	18 (1996);
	1.2 Determine socio-economic structure and mode of operation of contrasting selected marketing systems (by Sept. 1996).		11 (1997); 12 (1997); 14 (1996); 15 (1997); 16 (1998); 17 (1999); 19 (1997);
	1.3 Determine defined preferences and quality requirements with specific reference to species/varietal choice of traders, exporters/importer, wholesalers, retailers and domestic consumers; determine relationship between quality and economic value (by March 1997).		7 (1999); 10 (1999); 20 (1997); 21 (1997); 22 (1996);
2. Situations where significant post-harvest losses (physical and economic) occur, identified, quantified and characterised.	2.1 Assess biological condition and economic value of produce throughout the marketing chains in order to identify and quantify (level of damage, disease, sprouting, weight loss and consumer acceptability etc.) the situations where significant economic and physical losses occur (by June 1997).	2. Project reports, literature review and publications in the scientific literature.	3 (1996); 5 (1997); 6 (1997); 21 (1997); 22 (1996);
	2.2 Analyse physical and environmental conditions (temperature and relative humidity etc.) to which yams are exposed and their duration to characterise environments and handling practices associated with the biological and economic deterioration of yam quality (by June 1997).		13 (1999);

Post-harvest constraints and opportunities for improving the Marketing of fresh yam in Ghana – Outputs and Research Activities (Part II).

Narrative Summary (NS)	**Measurable Indicators (OVI)**	**Means of Verification (MOV)**	
Outputs	**Activities**	**Proposed Nature of Textural Outputs**	**Ref. No. and date of Textural Outputs Generated (See Appendix C for more details)**
3. Genetic, physiological and environmental factors associated with yam perishability established.	3.1 Monitor physiological changes under typical marketing environments over time (i.e. changes in biochemical composition, respiration, sprouting, wound-healing and water loss etc.) for a range of species/varieties relating physiological status of tubers with desirable attributes and consumer preferences (by Sept. 1998).	3. Project reports, publications in the scientific literature, PhD thesis.	23 (1998-99);
	3.2 Relate physiological characteristics of different species/varieties to storability (resistance to rots, disorders physical damage etc.) [by end 2000].		
	3.3 Establish relationship between physical environment and physiological changes for key species/varieties (by end 2000).		
4. Improved handling strategies developed and tested.	4.1 Formulate recommendations for technical interventions and improvements in marketing efficiency for both the internal Ghanaian market and for the handling of yams prior to export (by Dec. 1997).		
	4.2 Undertake cost benefit analyses of any such recommendations and investigate socio-economic repercussions of implementation. (by Dec. 1998).		
	4.3 Test efficiency and sustainability of interventions on a pilot scale (by end 1999).		4 (1998); 9 (1999);
General Management			1 (1996-99); 8 (1996-99);

Appendix C

Textural Outputs from Project

1. BANCROFT, R.D., (1996-1999) RNRRS Quarterly and Annual Reports. Natural Resources Institute, University of Greenwich, Chatham, Kent, UK. (Internal Report).

2. BANCROFT, R. D. (1996) Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana. In: *Proceedings of a Workshop entitled "Cassava utilisation in livestock feeds and market development of root and tuber crops"* . Westby, A., Gallat, S., Crentsil, D., Bancroft, R. D. and Graffham, A. (Eds.) Ministry of Food and Agriculture Kumasi, Ghana. 3-5 July. 1996. (Institutional/Organisational Report).

3. BANCROFT. R. D. (1996) Relieving post-harvest constraints and identifying opportunities for improving the marketing of fresh yam in Ghana, Ghana, 6 October - 15th November 1996. Report. Natural Resources Institute, University of Greenwich, Chatham, Kent, UK. (Internal/Technical Report).

4. BANCROFT, R.D. (1998). Yam Curing Experiment and Related Activities - An Experimental Methodology. Natural Resources Institute, University of Greenwich, Chatham, Kent, UK. [Science] (Manual).

5. BANCROFT, R.D., CRENTSIL, D., GRAY, A., GALLAT, S. and GOGOE, S. (1997). The marketing system for fresh yams in Techiman, Ghana and associated post-harvest losses. In: *Proceedings of the 30th anniversary meeting of the International Society for Tropical Root Crops, Trinidad.* 19-24 October. 1997. [Also: *Journal of Tropical Agriculture (Trinidad).* 1998.](Paper).

6. BANCROFT, R.D., CRENTSIL. D. and WESTBY, A. (1997) The Marketing of Yam in Ghana and the Associated Post-Harvest Losses. A poster presented at *The CORAF International Workshop on Yam: a secular plant and a crop for the future*. Montpellier, France. 3-6 June 1997 [Science] (Poster).

7. COLLINSON, C., CRENTSIL, D. and ACHEAMPONG, S. (1999). Analysis of the relationship between quality and price of yam in Ghana, Part II. Report. Natural Resources Institute, University of Greenwich, Chatham, Kent, UK. (Internal/Technical Report).

8. CRENTSIL, D. (1996-1999) Project Management Monthly Reports, 1 Aug. 1996 to 31 March 1999. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana. (Progress Reports).

9. CRENTSIL, D. and ACHEAMPONG, S. (1999) Yam curing experiment – initial observations. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana. (Progress Reports).

10. CRENTSIL, D. and ACHEAMPONG, S. (1999) Summaries of the participatory rural appraisal surveys undertaken with the farming communities at Asuuoga (Kintampo District), Batasaso and Watro (Atebubu District) and Fiaso (Techiman District) in the Brong Ahafo Region, December 1998, Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana. (Progress Reports).

11. CRENTSIL, D., ACHEAMPONG, S., MOTTE, F., and ASEMPAH. D. (1997) Survey of yam trading practices and loss assessment in the Volta Region of Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana. (Internal/Technical Report).

12. CRENTSIL, D., ACHEAMPONG, S., ZEWDIE-BOSUNER, A, and OPARE DANSO, W. (1997) Survey of yam trading practices and financial loss assessment in Accra/Tema markets, Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana (Internal/Technical Report).

13. CRENTSIL, D., BANCROFT. R. D. and ACHEAMPONG, S. (1999) Reports on marketing route trials undertaken in Brong Ahafo Region, Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana. (Progress Reports).

14. CRENTSIL, D. and DANSO, W. O. (1996) Report on Market Survey Carried Out in Yam Markets in Accra, Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana. (Internal/Technical Report).

15. CRENTSIL, D. and GRAY A. (1997) Report on Market Survey Carried Out in Yam Markets in Accra, Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana. (Internal/Technical Report).

16. CRENTSIL, D., GRAY, A. and GALLAT, S. (1998). The Marketing of Yams, Chapter Four In: *Analysis of Post-Harvest - and Marketing Systems of Yams and Tomatoes in Ghana.* Henckes, C. and Afful, F. (Eds.) MoFA/GTZ Publication, Ghana. March 1998. [Science] (Book Chapter).

17. DANSO, W.O. (1999) Market Integration Tests and Spatial Price Linkages in the Ghanaian Yam Markets. MPhil thesis. University of Ghana, Legon. (MPhil.)

18. GRAY, A. (1996), Report on Yam Marketing in Ghana, 13th February - 6th March 1996. Report. Natural Resources Institute, University of Greenwich, Chatham, Kent, UK. (Internal/Technical Report)

19. GRAY. A, and CRENTSIL, D. (1997) Preliminary Technical Report on Yam Market Practices and Yam Tuber Quality Depreciation, Volta Region, Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana and Natural Resources Institute, Chatham, (Technical Report).

20. GRAY A., CRENTSIL, D., and ACHEAMPONG, S. (1997a) Survey of yam trading practices and financial loss assessment in Brong Ahafo, Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana and Natural Resources Institute, Chatham, (Technical Report).

21. GRAY, A. CRENTSIL, D. ACHEAMPONG, S. and FLOYD, S. (1997b) Analysis of the relationship between quality and price of yam in Ghana. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana and Natural Resources Institute, Chatham, (Technical Report).

22. GRAY. A, BANCROFT, R.D., GALLAT, S., GOGOE, S. and CRENTSIL, D. (1996) Technical Report on Yam Market Practices and Yam Tuber Quality Depreciation, Techiman Market, Ghana. 20 October - 14 November 1996. Report (A0497). Ministry of Food and Agriculture, Accra, Ghana and Natural Resources Institute, Chatham, Kent, UK. (Internal/Technical Report).

23. NOAMESI, S. (1998/99) Yam Physiology Study Quarterly Progress Reports. 1 April 1998 to 31 December 1999. Reports (A0497). University of Ghana, Legon and Natural Resources Institute, Chatham, (Progress Reports).

Appendix D

Methodology Adopted to Correlate Yam Quality with Market Price

1. The following is an extract from Gray *et al.*, 1997b and describes the data gathering methodology used during the first survey conducted in Techiman in June 1997. The second survey followed an almost identical methodology, and so Gray's description remains relevant. The text has been amended to account for slight variations in approach adopted during the second survey.

Sample Size & Random Sampling

2. A random sample from a cross section of traders, including retailers, itinerant wholesalers and sedentary wholesalers was collected. Owing to time constraints itinerant and sedentary wholesalers were treated as one group. While differences in pricing practices for the two types of trader are in fact likely to exist, they are probably small.

3. Thirty heaps of each variety were sampled for each group of traders (retailers and wholesalers). Therefore, in total 120 heaps of yams were sampled.

4. Two yam varieties were sampled, Olondo and Dente. These two varieties were chosen because they were most common in the market at the time of the study.

5. The traders were randomly selected by a process which involved counting the number of traders in the market e.g. around 100 retailers. Each day the number of traders to be sampled was determined (this was usually around six retailers or three to four wholesalers per day, depending on the number of heaps each trader had for sampling). When selecting which retailers to sample, for example having decided to sample 6 in one day, every 17th trader was interviewed (100/6 = 17). The starting point was taken to be the area of the market where the Yam Association office was located, and a number between 1 and 17 was randomly selected to find the first trader to interview.

6. By the same method 18 yams in each heap were randomly selected for sampling. If, for example, one retailer had divided the heap into 36 piles of 3 tubers each, then 6 piles would be taken out of the heap for sampling. In this case every 6th pile was sampled (36/6 = 6). A number was randomly selected between 1 and 6 for the starting point.

7. In some cases the retailers had already sold some tubers by the time the team arrived to sample the heap. In these cases the price of those tubers which had already been sold was not included in the calculations, since they did not form part of the sample. The heap was still sampled if 50 or more tubers remained in the heap.

Quality Defects

8. Yams in the sample were assessed for the following quality defects:

- Rotting
- Rot due to cuts
- Breakage
- Surface damage (grazes, gashes, bruising, cuts)
- Termite damage
- Nematode damage
- Cooked spots
- Sprouting
- Ageing

9. The nine quality defects had been determined in previous interviews with farmers, traders and consumers to be those which were likely to have an impact on price.

10. The enumerator examined each tuber and gave a score between 1 and 3 for each quality characteristic apart from breakage, sprouting and ageing. The scores were given according to the following guidelines:

0 = no damage
1 = up to 1/3 of the tuber affected
2 = between 1/3 and 2/3 of the tuber affected
3 = over 2/3 of the tuber affected

11. For breakage and sprouting the responses were 'yes' or 'no'. When the data were analysed the percentage of tubers in each sample suffering from breakage or sprouting (i.e. with the response 'yes') was calculated.

12. For ageing, the number of days since harvest was noted. However, since most traders did not know when the consignment had been harvested, the time taken to sell the tubers after arrival in the market was found to be a more accurate estimation of the effect of ageing on price.

13. The analysis took into account the number of days that the tubers were in the market before sale[1] by calculating a weighted average to determine the average number of days in which the heap was sold. For example, if 18 piles were sold on day three of the market, 13 piles on day four and 5 piles left until the next week, the calculation of the weighted average was as follows:

$$\frac{((18 \times 1^{2}) + (13 \times 2) + (5 \times 7))}{36} = 2 \text{ days}$$

Therefore the average number of days for the heap to be sold was 2 days.

Weight

14. The tubers were weighed so that an average weight per yam could be established, and a price per kilogram was calculated.

Price Data

15. The selling price noted was the actual price received by the trader for each of the piles in the heap (i.e. all of the tubers which had not been sold by the time the heap was sampled).

16. The actual price of the heap was the sum of the actual price of piles times the number of piles. In some cases tubers from the consignment were taken home by the retailers for home consumption. In the cases where the yams taken home for consumption were healthy, the retailer was questioned about the price she felt she could have received for the yams and that price was used in the analysis. The price per yam sold was calculated in order to account for the fact that the heap may not have been complete when it was sampled.

17. In some cases the retailer had given extra tubers to the customer. While no price was paid for these tubers, they were counted as tubers sold, since it formed a part of the traders pricing strategy. In such a way they can reduce the price paid by the customer or give the customer extra for taking inferior quality.

Questionnaire

18. A separate questionnaire was filled in for each heap of tubers. The quality rating (0-3) was entered for each tuber.

[1] This applied to the retailers only, since it was assumed that age deterioration would only occur after 5-7 days in the market and most of the wholesalers managed to sell the yams within the week.

[2] Note that the fact that the first batch of tubers was sold on day three of the market does not mean that the retailers had held onto them for three days. It is more likely that they received the consignment on day three and begun to sell immediately. Therefore, in this instance the first batch was sold after one day with the retailer, the second batch after two days (on day four) and the third batch on the following week, taken to be day 7 for the purpose of calculation.

AN ANALYSIS OF THE QUALITY OF FRESH YAM TUBERS RECOVERED FROM THE CONSIGNMENTS OF FARMERS/TRAI

Location				Date											
Consignment No.	Variety	Tuber No.	Original Farmer's Grade	Original Trader's Grade	Trader's Grade Now	Premium Price per Heap of 109 or 3 Sound Tubers	Discount Price of Heap of 109 or 3 Degraded Tubers	Length of Tuber (cm)	Weight of Tubers kg.gms	Time when Sampling Temp.	Temp. of Tuber's Tissues External	Temp. of Tuber's Tissues Internal	No. of Grazes		
													H	M	T
1	Olondo	1	1		Sound	10,000		32	3.10	10.00	29.2	28	3	3	4
		2	1					31	2.90	10.05	30	29	1	4	6
		3	1					40	3.05	10.10	30.4	30	1	0	4
		4	1					44	2.70	10.14	29.6	28	2	1	5
		5	1					41	2.50	10.19	29.7	29	2	3	3
		6	1					40	3.10	10.26	29.6	28	5	2	3
		7	1					41	4.10	10.30	30.1	29	1	2	5
		8	1					36	3.15	10.36	30.3	29	3	1	4
1		1	2		Unsound		7,000	21	1.70	10.51	30.3	31	1	2	4
		2	2					39	2.75	10.54	30.4	31	2	2	2
		3	2					35	2.30	10.58	30.5	32	1	2	4
		4	2					37	2.55	11.01	30.3	31	2	1	4
		5	2					36	2.20	11.04	31.4	31	2	2	5
		6	2					34	2.20	11.11	30.1	31	2	1	3
		7	2					33	2.10	11.15	30.1	31	2	2	4
		8	2					31	2.30	11.20	30.5	31	2	0	2

AN ANALYSIS OF THE QUALITY OF FRESH YAM TUBERS RECOVERED FROM THE CONSIGNMENTS OF FARMERS/TRADERS																											
Location				Date																							
Consignment No.	Tuber No.	Total SA of Grazes			No. of Bruises			No. of Gashes			Total SA of Eaten Areas			No. of 'Cooked' Spots			Total SA of 'Cooked Spots'			Shrinkage - yes/no			Sprouting - yes/no	Harvest cut at apex - yes/no	No. of Other Cuts		
		1=0%;2<10 %;3=11-25%;4=26-50%;5=51-75%;6=76-100%									1=0%;2<10 %;3=11-25%;4=26-50%;5=51-75%;6=76-100%			1=0%;2<10 %;3=11-25%;4=26-50%;5=51-75%;6=76-100%			1=0%;2<10%; 3=11-25%;4=26-50%;5=51-75%;6=76-100%										
		H	M	T	H	M	T	H	M	T	H	M	T	H	M	T	H	M	T	H	M	T	H	H	H	M	T
1	1	2	2	2	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1	Y	N	Y	Y	N	0	0	0
	2	2	2	2	0	0	0	0	2	2	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	2
	3	2	1	2	0	0	0	0	0	2	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	1
	4	2	2	2	0	0	0	0	0	2	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	1
	5	2	2	2	0	0	0	0	2	1	1	1	1	0	0	0	1	1	1	N	Y	Y	Y	N	0	0	0
	6	2	2	2	0	0	0	1	0	1	1	1	1	0	0	0	1	1	1	N	Y	Y	Y	N	0	0	1
	7	2	2	2	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	0
	8	2	2	2	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	N	Y	Y	Y	N	0	0	0
1	1	2	2	2	0	0	0	0	3	3	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	0
	2	2	2	2	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	N	N	Y	Y	N	0	0	0
	3	2	2	2	0	0	0	0	0	2	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	0
	4	2	2	2	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	0
	5	2	2	2	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	0
	6	2	2	2	0	0	0	2	0	0	1	1	1	1	1	0	2	2	1	N	N	N	Y	N	0	0	0
	7	2	2	2	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	0
	8	2	1	2	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	N	N	N	Y	N	0	0	0

AN ANALYSIS OF THE QUALITY OF FRESH YAM TUBERS RECOVERED FROM THE CONSIGNMENTS OF FARMERS/TRADERS

Location				Date																						
Consignment No.	Tuber No.	No. of Splits and/or Cracks			No. of Breakages			No. of Termite Holes			No. of Spear Grass Holes			No. of Beetle Holes			No. of Millipede. Holes			No. of Other Holes			Associated with what causes?	SA of Visible Rough Skin		
																								1=0%;2<10%;3=11-25%;4=26-50%;5=51-75%;6=76-100%		
		H	M	T	H	M	T	H	M	T	H	M	T	H	M	T	H	M	T	H	M	T		H	M	T
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	2	0	0	0	0	0	0	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0		1	1	1
	3	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	5	0	0	1	0	0	0	3	3	0	1	1	0	0	0	0	1	0	1	0	0	0		1	1	1
	6	0	2	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		5	4	1
	7	0	0	0	0	0	0	3	5	0	1	0	1	0	0	0	0	0	0	0	0	0		1	1	1
	8	0	0	2	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1

AN ANALYSIS OF THE QUALITY OF FRESH YAM TUBERS RECOVERED FROM THE CONSIGNMENTS OF FARMERS/TRADERS																				
Location				Date																
Consignment No.	Tuber No.	SA of Visible Rots			SA of Surface Fungal Mats			Penetrometer of Sound Tissues - Side No.1	Penetrometer of Sound Tissues - Side No.2	Penetrometer of Soft Tissues	Assoc. with what?	Vol. of Internal Tissue Eaten			Vol. of Internal Rot Damage	Rots linked with what cause?		Rots linked with what cause?		Rots linked with what cause?
		1=0%;2<10%;3=11-25%;4=26-50%;5=51-75%;6=76-100%			1=0%;2<10%;3=11-25%;4=26-50%;5=51-75%;6=76-100%			Kg Pressure	Kg Pressure			1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%			1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%					
		H	M	T	H	M	T					H	M	T	H		M		T	
1	1	1	1	1	1	1	1	>13	>13			1	1	1	1		1		1	
	2	1	1	1	1	1	1	>13	12			1	1	1	1		1		1	
	3	1	1	1	1	1	1	>13	>13			1	1	1	1		1		1	
	4	1	1	1	1	1	3	>13	11.6			1	1	1	1		1		2	Gash
	5	1	1	1	1	1	1	>13	11.9			1	1	1	1		1		3	Gash
	6	1	1	1	1	1	1	>13	11.4			1	1	1	1		1		1	
	7	1	1	1	1	1	1	>13	12			1	1	1	1		1		1	
	8	1	1	1	1	1	1	12	12			1	1	1	1		1		3	Break
1	1	1	1	1	1	1	1	>13	>13			1	1	1	1		1		1	
	2	1	1	1	1	1	1	>13	>13			1	1	1	1		1		1	
	3	1	1	1	1	1	1	>13	>13			1	1	1	1		1		1	
	4	1	1	1	1	1	1	>13	>13			1	1	1	3	?	1		1	
	5	1	1	3	1	1	1	12.9	>13	3.5	Vis rot	1	1	1	1		1		6	Vis Rot
	6	1	1	1	2	1	1	>13	>13			1	1	1	1		1		1	
	7	1	1	1	1	1	2	>13	>13			1	1	1	1		1		4	Break
	8	1	1	1	1	1	1	>13	>13			1	1	1	1		1		1	

AN ANALYSIS OF THE QUALITY OF FRESH YAM TUBERS RECOVERED FROM THE CONSIGNMENTS OF FARMERS/TRADERS																					
Location				Date																	
Consignment No.	Tuber No.	Vol. of Internal Brown Spot Damage			Vol. of Internal 'Cooked' Areas			Vol. of Internal Termite Damage			Vol. of Internal Spear Grass Damage			Vol. of Internal Beetle Damage			Vol. of Internal Milli. Damage				
		1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%			1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%			1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%			1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%			1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%			1=0%;2=Trace;3=<10%;4=11-25%;5=26-50%;6=51-75%;7=76-100%				
		H	M	T	H	M	T	H	M	T	H	M	T	H	M	T	H	M	T		
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	2	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1		
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	4	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	5	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1		
	6	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		