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Final report

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2 Executive summary

The rationale for the project

The PNG coffee industry supports 350-400,000 families in Highlands PNG, and is the sole region cash crop, generating earnings of PGK300 million pa. The consistency and reliability of coffee quality has declined with the move from a plantation culture to the inherently variable smallholder industry (now over 85% of production), leading to severe downgrading of PNG coffee on the international commodity market.

The long term viability of the coffee industry is essential to the current model of smallholder production. Despite prior expectations at the commencement of the project, that the smallholder is receiving the majority of the export value, so there are gains in adding processing steps to the smallholder groups, the opposite is in fact true: processing (in a misguided attempt to value-add) at smallholder scale increases product variability, thus contributing to industry decline.

PNG highlands coffee is of the Arabica species, and the genotype and environment (soil, climate) are ideal for good quality coffee. So despite this general decline, premium PNG coffee retains a good reputation internationally, resulting in a scope to build demand for PNG coffee by improving consistency. Thus the best returns will be achieved by standardising post-harvest practises, so *reducing commodity variability*. Quality improvement, although always important, is a lesser factor to enhanced product standardisation. For this reason, the project was timely in reviewing current practise, providing research capacity, modernisation of post-harvest production, and documentation and extension of a standard practise.

Project achievements

The main achievement of the project was the development of standardised handling systems for post-harvest coffee production. Two separate solutions were provided: a set of recommendations for orchards with road access (where minimal processing is essential); and recommendations for more distant farm groups where tribal law ensures greater security and therefore consistency, yet the distance from roads means a higher degree of processing is required to ensure quality preservation.

The critical steps analysed were picking, cleaning, pulping, fermenting, washing, drying, grading, storage and transport. All steps affect coffee quality and grade/sales potential, yet there is a dichotomy between physical quality perception at the point of sale to the processor, and chemical or sensory quality perception (after roasting) for export trade. That is, quality indicators for the processor when purchasing are *not related* to the indicators used when the processor is selling. Traceability is the only solution to this dichotomy, and is currently being introduced into PNG. Consistent post-harvest practise is thus essential; the farmer assessment of quality must also be consistent across the Highlands for best return from the commodity markets. Niche markets do not necessarily accede to this requirement – plantation, specialist, organic and fair trade coffee (to give examples), and these smaller markets are surviving well and so were not considered in the project.

All major post-harvest steps were studied, and the recommendations made have been incorporated into the secondary school teaching curriculum for future generations. Pilot plant displays and village trials have been made available for this purpose.

Status of postharvest practices at smallholder level:

Three surveys were conducted over the course of the project. Questionnaires were designed by the UNSW and Coffee Industry Corporation (CIC) teams, and delivered in *tok Pisin* by the Coffee Research Institute (CRI) and extension staff. The first, a joint survey with other ACIAR projects (the Green Scale and Collaborative Marketing projects) evaluated current practise, labour, waste, marketing, technology adoption and many other issues, benchmarking current conditions. Significant results included the gendered division of labour, and the high degree of strip-picking occurring in response to coffee theft. Later surveys provided a rich source of information on changes from this initial state.

Provision of research capacity:

A thermophysical lab was funded and constructed at CRI, Aiyura. After construction, the lab was equipped with thermophysical measurement equipment, including balances, an incubator, sample refrigerator, thin layer drying equipment, physical analysis, offices, and chemical lab equipment for analysis.

The upstairs quality lab (roasting, cupping) was also refurbished from project funds, between them providing all of the facilities necessary for running and evaluating post-harvest trials. UNSW provided training on equipment operation, data analysis, simulation and model fitting. Protocols for experimental trials were jointly developed.

Interventions in Post-harvest Unit Operation:

Complete thermophysical property measurement and modelling were conducted throughout the course of the project. This included physical properties, isotherms, and thin layer drying rates. Improved estimates of the thin layer drying rate continued after project end.

Based on Tony Marsh's coffee consultant experience, an eco-processor was procured, installed and CIC staff trained in its use. A second, mobile unit was also procured and used for training of growers in various areas of the Eastern Highlands Province.

Sun drying experiments were conducted, which compared various drying surfaces, stirring methods, shading and depths. This resulted in best practice recommendations for drying of parchment coffee.

Alternative forms of drying were studied, mainly through the use of computer models. This led to the elimination of solar and mechanical drying as possible technologies for smallholder groups, and the development of a solution specifically designed for the Highlands climate and still under development, the Greenhouse dryer (which increases the temperature within for drying purposes). Initial tests show the technology works, and simulation / field studies will allow continuation of the co-operation between UNSW and CIC/CRI beyond the project.

Storage studies have been conducted. Social factors outside of the scope of the project (which include coffee theft) render this work less relevant at present.

Quality assessment studies based on modern analytical chemistry techniques were conducted, helping to identify the vast difference between the physical mechanisms for quality assessment used for green bean procurement, and the subjective means used for roasted coffee assessment by the international market.

Possible impacts of the project in the future

The CIC/CRI team now have the thermophysical laboratory, drying facilities and the eco-processor to devise more efficient postharvest systems for coffee processing. There is likely to be a significant contribution towards the reduction of water usage and release of effluents due to improved coffee processing. With other technologies developed by CRI, outside of the project, they now have a comprehensive set of demonstrable technologies for the coffee industry. There is a well-established methodology for extension through teaching programs.

Need for future action

The research work on improvement of solar drying is to be continued, especially with regard to further testing of the 'greenhouse dryer'. The problem of treatment of processing water, although reduced by the introduction of the eco-processor, needs to be addressed. Further efforts are needed in the training of farmers in the use of post harvest techniques improved/introduced under the project.

3 Background

Key issues that the project intended to address

The dependence of the Highlanders on coffee as the sole cash crop has been well documented. As international prices plummeted in recent years, the survival of the industry was threatened, and apart from a brief upturn in 2009, the international price has continued to be low. Many countries now produce coffee, and the drop in price simply reflects increased market competitiveness. The PNG coffee industry was poorly placed to meet this challenge, with severe restrictions on international contact and research infrastructure.

During project development, the key issue was thought to be the poor returns to the smallholders. This perception proved to be incorrect, and severely inhibited the initial development of the project goals, and damaged relationships with in-country processors. Once hard data on marketing was available (through the Collaborative Marketing project of Peter Batt), the high fractional returns to the farmers forced a re-think of the project objectives. Through consultation with CIC, local industry, the project co-ordinator, the project leaders, local police and extension/training groups, the problem was identified as a loss in value on the New York commodity market caused primarily by the inherent variability of the PNG product, and secondly the indifferent quality. From that point, a better return to the industry was pursued through increased uniformity, by development of best practise and its teaching/enforcement.

PNG coffee is predominantly Arabica, grown in good soils and from excellent genotypes, so is potentially of high quality. However, the consistency and reliability of coffee quality has declined with the move to the low-input management of the smallholder industry (>85%, the remaining plantation and 'block' production has received higher prices). Despite this general decline, premium PNG coffee retains a good reputation and there is good scope to build demand for PNG coffee by improving marketing and quality (Coffee grading is complex - Appendix 1 summarises key issues).

Critical post-harvest steps from picking through to delivery affect coffee quality. The key steps affecting quality were determined to be method of picking, drying and storage. A systems post-harvest analysis was proposed to study these factors in detail.

The project justification

The need for research on coffee quality was confirmed at a PNG coffee industry stakeholder consultation and at local stakeholder meetings in 2002. Farmers indicated to CIC/CRI personnel that improvement of drying capacity and reduction of taint risks (such as the 'Rio' taint encountered in 2000) through better drying and storage were the key actions needed to underpin system improvement, and in early consultations indicated a willingness to pay 4000 kina (Aus$2000) for a dryer of suitable capacity for a farmer group. Having identified a need, the feasibility of the project was considered.

There were several justifications for project implementation:

1. Current dependence of PNG people on coffee as sole cash crop.
2. Concern for maintaining Australian – PNG links by mutual help.
3. Crisis in international price, reducing incentive for coffee farming.
4. Concerns with law and order, and its impact on coffee farming as a disincentive to investment in labour.
5. Change from plantation coffee to smallholder coffee in recent years, leading to increased product variability.

6. This research aligns with the ACIAR 2004-2005 Operational Plan priorities for PNG, which included improvement of market competitiveness and product-ivity of tree crop systems.
7. Lack of existing research capacity within the coffee industry.
8. The relative capacity of Australia to provide suitable research capacity.

The project success depended on improved profitability. Variable product leads to a 10-25% reduction in smallholder income. Preservation factors affecting quality are reasonably well known, and can be addressed. These factors include over-processing, transport delays, inadequate drying, incorrect picking or cleaning. Standardising processing practises should lead to a significant improvement in product uniformity, which will be obvious in time as the new standards become entrenched in the smallholder culture.

During project development, marketing and pest control, sister projects enhanced the viability of a project utilising a systems analysis approach. Also the PNG coffee industry agreed (during consultations with ACIAR in 2004) that R & D to overcome postharvest deficiencies was a prerequisite to industry improvement. To fully capitalise on improved marketing options, additional support was requested to run surveys which would benchmark potential improvements, and to access international R & D in order to enhance available technologies. To achieve these goals, the employment of a project socio-economist was proposed, which allowed professionally devised survey methodologies to be used, both in formatting the questions and in survey delivery.

4 Objectives

The three project objectives were:

1. Assess postharvest system constraints to smallholder management of coffee quality and product consistency.
2. Develop and test solutions to system deficiencies, with particular attention to improvement of drying and storage.
3. Devise and implement strategies for the adoption of system improvements.

5 Methodology

Assess the socio-economic and technical constraints to smallholder coffee quality improvement, and develop strategies for addressing them.

The first objective was to identify constraints to change. The following steps were taken:

- **Stakeholder meetings**. The CRI ran several workshops directed at coffee industry participants prior to commencement of the project. These not only identified key interests from the farmers' point of view, but also started the process of identifying constraints. It was clear that there was considerable interest in solving issues such as effective drying, which led to links with farmer groups that greatly influenced project direction. In initial visits by the project leader to PNG, visits to processors helped to identify the industry problem of variable quality, and discussions with farmer groups were held on constraints to adoption. Farmers expressed a strong desire to solve the problems, even if at considerable cost. Sun-drying was no longer seen as the solution to coffee drying.
- **Collaborative groups project liaison.** Links were established with ASEM/2004/042, which led to a clear understanding of the financial and marketing structure of the industry.
- **Survey planning.** Survey questionnaires and transport logistics were developed, and the survey conducted over a three month period.
- **Identification of field trial groups.** Contact was made with potential field trial participation farmer groups, to review and confirm choice of smallholder communities, gain acceptance and seek advice from them regarding involvement.

Assess the technical parameters of PNG coffee quality and devise solutions to the effects of inadequate processing drying and storage.

The second objective was to assess quality and develop solutions to quality issues. The following steps were addressed:

- **Literature Review and Web search:** Current international literature on coffee postharvest practice was reviewed in order to research successful approaches and technologies as used in other countries. The projects coordinator Tony Marsh provided invaluable input for this component.
- **Standards of physical assessment** and grading were investigated, with most data being provided by the Coffee Research Institute.
- **The methodology of cupping**, which is a sensory and subjective assessment of quality, was studied through the resources of the export office in Lae, the quality laboratory at CRI, discussions and participation with processors, and review of the literature.
- **Chemical methods of quality analysis** were studied from the literature and from visits to the export office in Lae. This was pursued through establishment of GC-MS analysis of coffee volatiles and subsequent identification of critical volatile ratios which provided objective measurement of roasting. Time has not permitted a final step to be taken, which was correlation of the sensory method with the chemical analysis, and pragmatic assessment suggests this would not be possible in a development project.

Inadequate processing was investigated in the following areas:

- **Strip picking.** Coffee cherry is extensively stolen from trees throughout the region, by both adults and children, usually at night. The stolen cherry is normally strip-picked, which involves passing the hand down the cluster and so extracting all cherry regardless of stage of development and ripening. In response, farmers often also strip-pick, to prevent loss of product through theft. Survey results indicated that the majority of coffee picked near roads is strip-picked, so of poor quality and potentially damaging to processing equipment. Coffee brought in from further reaches is normally selectively-picked and of higher quality.
- **Inadequate drying.** The effect of inadequate drying is to allow mould taints which generate ‘off’ odours. The application of drying technologies was studied extensively throughout the project. The main concern is where drying cannot be completed due the limitations of sun-drying.
- **Storage and transport.** Delays in storage and transport may be deliberate (for example, playing the market for best price) or accidental (road impassable, bridge down, breakdowns etc), both of which are major factors in PNG. These issues are strongly connected with the Rio taint problem.

Develop and test strategies for improving coffee quality management during postharvest processing and storage and devise strategies for their adoption

On the basis of industry discussion as documented earlier, the task was expanded to include quality consistency (see executive summary for example). The basic steps taken in approaching this project goal were:

- To identify technologies which may assist in achieving greater uniformity and reduced quality loss in processing. Several were identified, some of which had already been researched by CRI prior to project commencement.
- To examine strategies for quality improvement and management in the field developed in other projects (for example, FAO, ICO coffee and ACIAR cocoa projects).
- To acquire the appropriate technology, and prototype test at CRI.
- On the basis of the field test, to initiate field trials at village level and evaluate, with the cooperation of local farmer groups, if warranted.
- To assess the impact of the technology, and to make a reasoned assessment of adoption potential.
- To recommend an adoption strategy, through contacting group leaders, promoting the technology through the established training programs and coffee manual.

There were two main examples of successful innovation which resulted from the project, and the methodologies used are explained in more detail in the following notes.

Innovation in wet processing:

Assessment of main variables in wet processing (as currently practiced) and their effect on quality, especially water quality, duration and temperature of fermentation, water pH and production of waste water. This resulted in identification of fermentation time and removal of mucilage as rate-determining steps. Shorter fermentation times are critical for maintaining quality. This suggested determination of the quality of pulped coffee with water at various temperatures should be studied, and technologies for mucilage removal be assessed. Since alternative technologies for pulp removal did exist, this was the methodology selected and implemented, leading to the eco-processor.

Innovation in drying:

Pilot trials on alternative sun drying strategies, for example product turnover, plastic substrate and absorptive properties, product covering and hot greenhouse effects, induced airflow (wind direction and channeling). Tests of sun-drying strategies were conducted at Aiyura initially, and then at the field trial sites.

Investigation of low cost solar dryers. There are many options/designs of solar dryers now available in the region, and it was intended to field test two or more specific designs and to modify those designs to suit the climatic conditions of the highlands. This methodology was overtaken by the results of computer simulations which indicated that solar technology was not appropriate for the region, on the basis of climatic conditions, equipment cost and difficulties in dryer maintenance.

Investigation of practicality of alternative low cost mechanical drying methods. Possible mechanical options included tray dryers and kiln dryers, both of which are low tech and versatile in fuel source. Theoretical trials were conducted at UNSW, again indicating the unsuitability of mechanical dryers for Highlands smallholder operations. Promotion of in-store holding/aeration facilities would have been of use at processor level, but opportunities for discussion on this topic were limited and mechanical dryers not studied further.

Innovation in storage:

- An assessment of the length and conditions of current storage practice and factors that affect quality deterioration was made.
- Tests were then conducted on the degree of aeration required in storage.
- Equipment for temperature monitoring studies was installed.
- The next stage was identification of optimum storage conditions (temperature and relative humidity), based on previous results and isothermal data.
- Assessment of rodent and insect controls was made, leading to recommendations for hygienic storage.
- Determinations were made of allowable storage times for different moistures, and a system of store management to facilitate this was developed (where possible).
- Development of strategies for forced aeration where delays in transport are insurmountable was considered, but project time proved inadequate to complete this aspect.

6 Achievements against activities and outputs/milestones

Objective 1: To assess postharvest system constraints to smallholder management of coffee quality and product consistency

no.	Activity	outputs/ milestones	completion date	Comments
1.1	Visit by socio-economist and project leader to establish broad guidelines for survey/observation methods. Modify/revise survey through CIC, ASEM/ 2004/042 and local experts. (PC&A?)	Meeting outcomes which endorse and improve project framing, reports and notes on liaison with industry representatives and researchers. Deliverable survey	End of 2006	
1.2	Survey/observations conducted in liaison with project ASEM/2004/042 and CIC/CRI. Survey one site> analyse> review/adjust> then survey additional two sites (PC&A)	Detailed analysis of current research and literature and PH alternatives. Survey results.	November 2006, and March/April 2007	
1.3	Evaluated survey results, workshop at Aiyura to assess quality constraints, meet with processors. (PC&A)	From surveys: data and analysis of current socio-economic dimensions and labour inputs. Identify quality constraints.	November 2007	
1.4	Upgraded research facilities at CIC/CRI Aiyura. (PC&A)	Plans for field trials to accommodate socio-economic constraints and allow comparison of options available. Ability to measure quality and physical properties.	Completed early June 2009.	Facilities built & upgraded (laboratory premises), equipment installed

Objective 2: To develop and test solutions to system deficiencies, with particular attention to improvement of drying and storage.

no.	Activity	outputs/ milestones	completion date	comments
2.1	Assessment of coffee quality from survey samples. (PC&A)	Experiments on properties. (PC&A) Listing of measurable quality attributes by PNG current practise. Detailed coffee property database x practice x Agri-environmental conditions.	End of June 2009 Will be continued by CRI beyond the completion date of the project	
2.2	Workshops in PNG. (PC&A).	Facilities at CIC upgraded to allow measurement of required quality and physical attributes. Plan experiments. Proposed solutions (as experimental plans) for identified problems.	March 2008	Informal workshop involving the Australian project leader and key CIC technical staff

Objective 3: To devise and implement strategies for the adoption of system improvements.

no.	Activity	outputs/ milestones	completion date	comments
3.1	Wet processing, drying, storage and distribution experiments. (PC&A).	Data, reports and recommendations from pilot trials of storage. Comparison of PH alternative methods, at three key sites (Aiyura then 2 others), with recommendations for best practise	June 2009 Ongoing	Continuing beyond the completion date of the project
3.2	Involve socio-economist in developing adoption strategy. (PC&A).	3.2.1-3.2.5 data, reports and recommendations from 3.2.1 pilot trials of storage. 3.2 Pilot studies of wet processing. 3.2.3 Pilot studies of drying alternatives. 3.2.4 Studies of parchment removal. 3.2.5 Trials to assess best practise. CIC formal approval and endorsement of recommendations. Materials for extension services.	End of June 2009	Some of these tasks were carried out, others are on-going and are expected to be completed in the extension phase of the project that will be proposed during the project evaluation planned for October 2009

7 Key results and discussion

7.1 Introduction

A large-scale survey instrument was administered to establish the social dimensions and postharvest practices currently underway along the coffee supply chain. A participatory supply-chain approach, working in tandem with the marketing surveys of ASEM/2004/042 enabled system assessments, and the mapping of social, economic, technological and temporal aspects of coffee processing. Quality loss, at various stages of the supply chain, was assessed, paying particular attention to the critical phases of wet processing (where moulds may lead to tainting, and water disposal is a problem), drying (weather can hamper sun-drying, drying on the ground can increase contamination, under-drying leads to mouldiness and off-flavour development), de-hulling, transport and storage (where build-up of moisture in storage can lead to mould and off flavour development and access to suitable storage bags or space may be a problem).

The assessments identified industry-wide and site-specific problems and opportunities. Survey sites included different (major) growing region/agro-ecological conditions. The surveys documented current practice, but also allowed identification of aspects of postharvest where research intervention was feasible and could prove beneficial. Some bench-marking surveys of the plantation and block sectors were also undertaken. Construction of the survey was planned as a two-way process, where CIC/CRI personnel prepared an initial draft in consultation UNSW partners and then integrated with ASEM/2004/042 surveys.

This survey, conducted by the CRI research teams and CIC extension personnel, was invaluable in the early stages of project implementation, and helped to identify potential points of intervention.

Critical to the adoption of technologies described in this document is the understanding of two completely disparate regions, those with road access (from here, dubbed ‘ROAD’ group) and those in the bush (from here, dubbed ‘BUSH’ group). Approximately 40% of farmers are thought to have reasonable road access. Counter-intuitively, road access is not a good attribute to coffee quality. There is strong agreement between extension personnel that ROAD coffee is of poorer quality than BUSH coffee, where tribal law provides sufficient social control to minimise cherry theft, and the difficulty of transporting product to roadside sellers is a further deterrent.

This result was significant, and posited the need for two completely different technological solutions to post-harvest issues.

Farmers can sell ripe coffee cherries or semi-processed (parchment stage) or dehulled (green bean) beans to processors or exporters, with higher price/return potential for growers who process to the parchment or green bean stages. Project personnel were initially told the opposite, that farmers got a higher price for green bean (dried and husked). Looking at the return on the basis of the weight of coffee bean, there is a substantially better return for selling cherry. One group of growers said that they sold green bean coffee on the basis of price. After discussion, they agreed they got a lesser return but would sell green bean if they are near roads, because of coffee theft. Cherry is stolen, but green beans are easier to store safely. The reality is that processors want coffee cherry, not green bean, and therefore pay more for cherry.

In very remote locations, farmers must process and store coffee for long period before it gets to market. While farmer processing has the potential to improve returns by slowing quality deterioration and cutting transport costs, inadequate processing, drying or storage and the lack of consistency of product often reduces the product reliability and lowers prices (compare with the greater control that commercial processers have over quality through directly buying cherries and managing processing operations themselves). Key elements of the quality deterioration that can result from grower processing are: mouldiness and the development of off-flavours due to inadequate drying and storage, and poor grading (product variability, mixed ripe and green cherries, inclusion of small or defective beans or foreign matter). Income to smallholders is 10-25 percent lower than it could be if product attributes and quality were consistently acceptable.

If the theft problem were controlled, then there are two solutions:

- ROAD: minimal processing for product uniformity and best price. Systems interventions should be directed at speeding the product to market with minimal processing, possibly just cleaning.
- BUSH: processing is advantageous due to quality deterioration mechanisms resulting from longer transport times. For larger groups, eco-processors, sun and greenhouse drying, aeration and possibly bag sprays will be of benefit. For smaller groups, CRI have designed a small-scale village pulp processing /fermentation process which is ideally suited to their needs. Dehulling would not be a sensible choice in this case, as the hull provides some transport protection.

These project outcomes are being implemented through the CRI School, Open Day, and reporting initiatives.

7.2 Constraints to adoption

Constraints to post-harvest improvement were successfully identified. The following sections discuss the stages achieved in the identification process.

Meetings with Farmer Groups. The main constraint identified was (a perceived lack of) access to technology. In hindsight this was a mistaken understanding, based on the assumption that additional processing would improve grower return, which is not the case. The identification of lack of access to technology, as a constraint, does reflect a distinction between those with processing knowledge and the farmers without. The effect of cost was not identified as a specific constraint, suggesting that group capital was not perceived as the primary difficulty. Later discussions with extension personnel corroborated this finding, showing that access to solutions and knowledge of post-harvest alternatives was the main barrier. This reflects a breakdown in contact, firstly between the international community and CIC/CRI researchers, and secondly between the CRI and farmers. Over the course of the project, efforts were made to redress this, with little effect. The future of the CRI depends on its ability to renew contact with its end-users. Extension officers within CRI and CIC reach a limited subset of the total Farmer Group community, but an extension program called PRAP offers some hope for an improvement in the future.

Meetings with Processors. The processors generally are not aware of the CRI work, nor do they demonstrate a research and development (R&D) culture. On hearing of a new technology, the approach by industry was to purchase a unit and trial it, in effect doing their own research by a trial and error method. Suggestions to have CRI staff placed in industry, for the long term good of both, were not taken up by CIC/CRI. Generally processors disagreed with the concept that farmer groups could improve their income by doing more of the processing themselves. Financial plots were shown, indicating that most processors were now operating at a loss, and this was substantiated by a large number of plantation companies going out of business. The logic underpinning this downturn is based on the devaluing, internationally, of PNG coffee due to product variability. A lower quality product of greater consistency would achieve a better price. Variability is inevitably increased by a trend from large to small scale processing. By handling processing at the processor level, a better return would be achieved. The fact that profits are currently passed on was established unequivocally by the ACIAR Collaborative Groups project (ASEM/2004/042).

Collaborative Groups project liaison. Links were established with ASEM/2004/042, which led to a clear understanding of the financial and marketing structure of the industry. The benefits of this could not be understated in a changed view of the industry based on their work. Some of the details of this project are sensitive, and so will not be outlined here. But an important consideration was trying to make CRI relevant by supporting its research and encouraging contact with the industry. Collaboration with ASEM/2004/017 provided additional socio-economic survey results during the course of the project.

Survey planning. Survey questionnaires and transport logistics were developed, and the main survey conducted over a three month period. The results are listed in detail in the attached report (Appendix 2) by Susan Inu. The main results were:

1. Survey covered PRAP groups (a form of Farmer group supported by the CIC/CRI, and now the dominant form of farmer group) in three provinces, Eastern Highlands, Simbu and Western Highlands. More than 500 farmer groups participated in the surveys.
2. Statistical analysis gave a clear picture of farmer practice and current technology.
3. Most farmers had a poor understanding of the relationship between post harvest techniques used and quality.
4. 56% of farmers strip pick coffee trees.
5. Almost half do not clean the product after harvest.
6. The blue canvas method of sun-drying is dominant (80%).
7. Half will store the product for over a month.
8. Almost all farmers do not use chemicals
9. Women do most of the post-harvest work.

This is a small sample of the results from a long and comprehensive survey. The results (from this and subsequent surveys) helped inform our research directions and potential constraints to adoption.

Identification of field trial groups. During the course of the project, several groups were contacted and expressed willingness to participate in the project. This led to discussions on adoption. As is typical for development projects, there was an interest in getting the new technology for no cost, and we were careful to avoid this pitfall, making sure that there was a clear understanding that testing the technology did not give a right to own the equipment for free. This led to rejection of some groups as possible collaborators in the project, but ensured that the real cost of adoption was appreciated and evaluated. This indicated that cost *would* indeed be a factor, as expected (but not corroborated in survey data). Market forces would ultimately determine the capacity for uptake, through affordability (notwithstanding other farm-based expenses, which include substantial bride and death costs).

Evaluation of Adoption

The indications at the end of the project were clear that the eco-processor technology would be adopted, and in fact was being taken up as quickly as possible, even before the release of research findings on the suitability for PNG coffee. The sun-drying recommendations were adopted and written into the school curriculum and Coffee Manual. The indications for the Greenhouse dryer were positive, in the sense that because of its relative low cost, groups were prepared and able to pay realistic amounts for a technology that would solve the sun-drying problems (such as seep moisture, dust and inclement weather), and that there was no possible alternative technology. Storage studies at the time of completing the project had not been developed to the point of incorporation into mainstream documentation, but should in time also lead to complete adoption of the recommendations. Unfortunately the circumstances that require its application are those where implementation is most difficult, so at this stage it is the technology of storage implementation which most requires more work.

In summary, adoption was seen as successful, suggesting that constraints were successfully overcome. This was despite the relatively low industrial profile of the research association CRI, and was due to two other factors, the network of communication through the PRAP training process and the school teaching programs (both primary and secondary) which will see future generations trained in correct techniques. This is not to say that adoption could not be improved – there are many farmers operating outside of the PRAP process, which is in its infancy, and unable to travel to certain areas -- who will not get an answer to their requests for technological information for some time, and who cannot access the reports, open days and informal networks which assist those closer to roads.

7.3 Assessment of Quality

The second objective was to assess quality and develop solutions to quality issues. The main achievements were:

Documentation of physical quality standards. Criteria were identified from discussions with CRI staff and some of the complexity of quality assessment is described in Appendix 1.

Application of cupping. This is a sensory analysis quality assessment technique which has all of the hallmarks of subjectivity, as no blinding is performed; there is no privacy in assessment (allowing a dominant personality to lead the group). Terms of assessment are vague, and training varies – there are few trained professional cuppers in PNG. Nevertheless the industry has survived as an industry standard internationally, due to the difficulties in relating the sensation of coffee drinking to a set of numbers. Attempts were made in introducing triangle testing, and some preliminary work was performed in connecting cupping with chemical methods (see next section). Cupping was used as the main quality test for all field trials at CRI, but as triangle testing was introduced, results from the cupping trials were not found to have substantial validity, i.e. disagreed with the objective statistically based test, particularly by indicating differences where there were none. Anecdotal accounts abound of submitting samples for cupping, the sample being rejected, and resubmitting a year later with opposite results.

Chemical methods of quality analysis. Combination Gas chromatography Mass spectrometry (GC-MS) was used extensively in early student projects in an attempt to objectify roasted coffee assessment (which apart from trigonelline, is not common practice). Identification of the importance of the ratio of dimethyl pyrazines showed excellent promise as an indicator of degree of roasting, and hundreds of trace volatiles were successfully identified. At the current stage this work has not been written up for publication. However there was one crucial outcome of this work, which was of immediate and vital importance to the project, and this was assessment of the effect of drying air temperature on coffee quality. Studies of the three most important aroma volatiles showed a definite downward trend once the air temperature exceeded 45^{o}C, and this one factor became the severest limitation on adoption of mechanical dryers for two reasons: at low temperatures the dryer is no more efficient than sun-drying, and secondly the temptation to use higher temperatures in order to speed up drying would compromise coffee quality. Future studies in the area of chemical analysis are recommended, in pursuit of a true objective assessment of quality, and potentially its correlation with observable physical characteristics prior to roasting.

Inadequate processing was addressed as follows:

Strip picking. Strip picking causes indifferent, variable quality and can destroy pulping and demucilaging equipment. The “Cherry Ban” was imposed during the project, as an initiative suggested by the Collaborative Groups project, and enforced by the CIC and local police. This prevents sale of cherry without a license, and has proved effective in controlling cherry theft. Otherwise however this is a problem beyond the capacity or scope of this project to address.

Inadequate drying. Detailed methodologies can be provided by the research leader and from project papers and reports still in preparation. Best practice sun-drying was developed through field trials and implemented through teaching programs at schools. Future Open Days and the research institute will also highlight correct methods. A rewrite of the coffee manual with best practice has been achieved by the CRI staff. Research has identified those drying technologies which should not be researched further (namely mechanical drying and solar drying), and CRI / UNSW is attempting to develop a new alternative called greenhouse drying. These will improve quality and enhance drying capacity under inclement drying conditions.

Storage and transport. This issue was addressed through storage studies and isotherm data, which lead to recommendations on best storage practice. No investigations of surface sprays were performed, and this would be of value in a sequel project, but data on deterioration as a function of climate and delay was collected. The survey provided some (anecdotal) information on the effects of storage delays.

7.4 Improved post-harvest systems

7.4.1 Demucilager

The eco-processor (or demucilager) was introduced by Tony March as project's coordinator, and proved effective from the outset in replacing three existing post-harvest steps with a single step which ran at one tenth of the water usage.

An attempt was made to complete scientific testing prior to release of the technology, but word of mouth resulted in premature purchase by several companies. This caused significant difficulties:

1. Incorrect units were purchased. There are two standard designs, one for Robusta and one for Arabica species (which have different sized fruits).
2. Inadequate training meant that essential adjustments to the clearance between mesh and screw are not made, leaving some of the pulp on the kernel husks.
3. Strip-picked cherry was passed through the machine, damaging some of its internal surfaces, and again leading to poorer quality.

As a result, the project leader was informed by CIC that the eco-processor had serious problems, and compromised the unique qualities of PNG coffee (as stated by an exporter who had cupped some of the product). This resulted in CRI conducting studies on an additional fermentation stage (of 8 hours or overnight) to remove the last of the pulp from the beans, when in reality, the problem appears to have been caused by damage to the equipment caused by feeding strip-picked coffee into the unit. Immature beans are relatively hard, and can bend the separation meshes. In the long term, with correct equipment operation, no soaking should be necessary.

All of the methodology stages listed in section 5.2 were followed carefully during assessment of the suitability of this technology. The eco-processor was found from these properly conducted trials at CRI to give bean indistinguishable from coffee prepared by the old wet processing method, and should eventually replace this method At this point there appears to be no further caution about implementation with larger groups throughout PNG.

7.4.2 Drying

Lowering and maintaining bean moisture during drying and storage is considered by the local smallholders to be the most urgent research need for postharvest quality control. Correct sun drying techniques developed for other crops have been effective in improving quality and reducing contamination (for example cereal grains such as rice and corn).

The optimum solution to drying of coffee parchment for smaller groups is based around current practice. In detailed comparative studies of a range of surfaces and methods, current practice was consistently in the top three, and the differences were not considered to be sufficient to warrant modification of accepted practice, especially as this would incur additional cost.

However, this does not solve the difficulties associated with sun drying generally, which include security, moisture seepage and ground moisture effects, poor weather, dust and other contamination, non-uniformity and surface cracking. As a result considerable research effort was devoted to developing a new solution. Several technologies were considered:

Low cost solar dryers. There are many options/designs of solar dryers now available in the region, and it was intended to field test two or more specific designs and to modify those designs to suit the climatic conditions of the highlands. This methodology was superseded with the results of computer simulations which indicated that solar technology was not appropriate for the region, on the basis of climatic conditions, equipment cost and difficulties in dryer maintenance.

Mechanical dryers: Possible mechanical options include tray dryers and kiln dryers, both of which are low tech and versatile in fuel source. Theoretical trials were conducted at UNSW, again indicating the unsuitability of mechanical dryers for Highlands smallholder operations. An important factor was the low maximum allowable drying temperature (see results on chemical quality analysis). However the main limitations, as always, were the high capital and fuel costs.

7.4.3 Storage

Farmers often store parchment stage or green-bean coffee for long periods before it can be transported to a sale point (particularly more remote farmers). In the humid/rainy conditions, moisture can build up in stored beans promoting mould and taint development. For coffee storage improvement, the research focus was on improvement of household storage and developing alternatives to the polythene bags that are widely used.

An assessment of the length and conditions of current storage practice and factors that affect quality deterioration was made. Tests were then conducted at Aiyura on the degree of aeration required in storage in order to maintain quality by controlling temperature. Equipment for temperature monitoring studies was installed.

Following the aeration studies, studies on optimum storage conditions were performed (temperature and relative humidity), based on previous results and isothermal data. Types of storage bag were tested.

Assessment of rodent and insect controls was made, leading to recommendations for more hygienic storage.

Determinations were made of allowable storage times for different moistures, and a system of store management to facilitate this was developed (where possible).

Development of strategies for forced aeration where delays in transport are insurmountable was considered, but project time proved inadequate to complete this aspect. However results of the storage studies were integrated into the Coffee Manual recommendations.

7.4.4 Logistics and Project Interaction

In focussing on initial pulp removal and drying, attention to the socio-economic context, wet processing and other smallholder practices and agro-ecological effects was critical. The project has capitalised on the activities and farmer/processor linkages developed under

(a) ASEM/2004/042, to describe those innovative collaborative collection, pricing and processing schemes that are thought to be providing superior quality coffee to customers and rewarding smallholder coffee producers and identify the factors (especially financial) that influence the adoption and on-going success of these innovative schemes, and ASEM/2004/017 for extended survey details.

(b) the support provided to CIC under the AusAID Agricultural Innovation Grant Facility (AIGF), which is to:

1. develop farmer-grouping arrangements under which coffee growers can grow, process and market coffee as ‘special quality’ and solicit better prices;
2. publish and disseminate extension materials that foster industry improvement;
3. improve maintenance of coffee pulping machinery; and
4. benchmark PNG coffee quality against international standards in addition to activities funded by Japan International Co-operation Agency (JICA).

Activities undertaken by CIC under the AIGF support in 2004-2005 have confirmed the appropriateness of working with farmer groups and links to NGOs, and highlighted the need to address drying and storage within a systems context.

While this new project did not build directly on previous ACIAR work, it was able to capitalise on drying technology and grower-uptake findings of ACIAR and AusAID supported activities with the PNG cocoa industry to improve fermentation and drying (PHT/1995/136) and to improve farmer access to labour for improving harvest quality/quantity (ASEM/2002/014).

Close collaboration with ASEM/2004/042 was a key strategy for the project. Without an understanding of the market driving forces and the social context, technological intervention is of little value and assumptions on critical control points may be misplaced. Joint meetings and project visits have been scheduled to facilitate communication and capitalise on synergies between the two projects, and cross-project collaboration in implementation of socio-economic surveys and technological improvements have been planned to place postharvest structural changes in a full socio-economic context.

There is also considerable international support for research to improve smallholder systems for coffee in other countries (e.g. FAO with Vietnam and International Coffee Organisation (ICO) project with Indonesia, India, South America), and with advice from project consultant Tony Marsh, the project has assessed spill-over options for some technologies trialled and lessons learned in these projects.

The possibility that improved wet processing, drying and storage technologies could be adopted and maintained by the progressive sector of the coffee smallholder industry in PNG is indicated by outcomes of the ACIAR cocoa project PHT/1995/136: In 2004, 20% of the dryers (6/30) installed in East New Britain a decade earlier, and 1/3 of the dryers (2/6) installed in East Sepik and Madang 5 years earlier were still in use. In addition, 3 privately funded units had been constructed in East New Britain, and a range of combination solar/kiln dryers have been developed and distributed in Bougainville under AusAID/UNDP initiatives.

The project used benchmarking to allow later determination of the effectiveness of the project. The initial survey conducted in tandem with the ASEM/2004/042 project established the current postharvest practises used. At the end of the project, changes were to be documented relative to this initial assessment. Although three surveys were conducted (two in tandem with ASEM/2004/017), a final survey on the scale of the initial one was not possible, but future benchmarking would be of great interest.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Benchmarking: the surveys conducted during the project represent a snapshot of the industry for the period around 2004-2008, and the openness of the responses is a reflection on the professional standards achieved by the questioners. In five years, a follow-up survey would reveal substantial change in coffee industry practise.

Product data: all significant thermophysical properties of the Arabica (variety: typica) were studied, and the results are in publication. In addition, transfer of methodologies was completed by laboratory construction, equipping and training of key personnel, empowering staff at CRI to continue measuring properties as varieties change over time. Without scientific knowledge of the product, such as drying rates at different conditions, equipment design is compromised. The CRI Quality lab was also refurbished to allow field trial assessment and farmer teaching.

Eco-processor: Tests conducted at Aiyura and in a local village the eco-processor have shown that the coffee beans are of similar quality to those produced using the conventional system. The Eco-processor provides a rapid way of processing coffee and offers the advantage of considerably reduced water usage. No more need or could be done to ensure adoption, and the emphasis now is on correct training in its use, and within the next decade it should substantially replace the traditional pulping method with larger groups.

Sun drying was thoroughly tested, using all possible variations of surface, elevation, shading and mixing. The present method (using blue 'canvas'/plastic sheeting) performed within 10% of the best options, and the recommendation is NOT to change the current methodology. This supports the thermophysical data which showed internal moisture movement is the main barrier to drying. However there are problems with sun-drying as a stand-alone technology. Most alternative forms of drying were eliminated, but a new form of dryer, called the Greenhouse dryer, offers potential at an affordable price to supplement the current methods. Adoption will be slow, but within 5 to 10 years there may be substantial numbers of Greenhouse dryers in support of sun-drying.

Solar dryers were analysed and eliminated as a possible drying alternative on the basis of computer simulations which showed high space usage, high performance loss over a year, and small gains over sundrying due to the relatively poor Highlands drying air quality.

Mechanical dryers were also evaluated and eliminated as an alternative form of drying for smallholder / farmer groups, due to a low maximum air temperature, high potential to damage the product, high capital costs and high fuel costs. However mechanical dryers are appropriate for large scale operations (plantations or processors), and the possibility of aeration bins should also be considered at this scale.

Greenhouse dryers were the major research initiative of the project. The dryer is essentially a sweat box, where heat is retained within a small space and only liquid water removed, resulting in a smaller footprint than a solar dryer. Two trials were completed and three dryers constructed, and initial results exceeded predictions. Presently, redesign to compete more equitably with sun drying is in progress.

Waste management remains in its infancy, with a growing perception of the enormous downstream (literally) environmental damage that is being caused by dumping the cherry pulp. A partial solution is provided by the eco-processor, which reduces the water usage by a factor of 10, allowing easier separation of the solid waste which can then be utilised more readily.

Storage studies were performed, and recommendations on handling transport delays have resulted and been incorporated into the formal industry Coffee Manual and teaching curricula.

Systems analysis: Two complete post-harvest operations streams have resulted from synthesis of this work, a ROAD stream and a BUSH stream, defined by access to coffee transportation. Profitability within the systems depends on reducing processing for the ROAD farmer groups, and improving processing up to (but not including) hulling with the BUSH stream. There is also a need to distinguish between smaller groups, who could use village-level processing, and larger groups who could afford the eco-processor. Standardisation of the systems is essential for PNG to remain competitive.

8.2 Capacity impacts – now and in 5 years

Thermophysical and Quality Labs: The thermophysical lab was constructed from the ground up, and equipped with offices, an incubator, isotherm, specific heat, thermal conductivity, bulk density and thin layer drying equipment. It now provides a base for physical quality assessment for field trials. Staff were trained in measurement of properties, analysis of data, simulation, model-fitting, triangle testing and writing experimental protocols. The quality lab was upgraded.

Open Days: CRI have been encouraged to re-establish open days. This would show the many various technologies now available at CRI, and encourage contact with the industry. In addition it could be a platform for teaching farmers the effects of incorrect use of technologies, through cupping trials.

Other training: Staff were trained is using specific equipment (especially the eco-processor), interpretation of weather data, conducting drying experiments and quality assessment of coffee (cupping and triangle testing).

Training modules: CRI staff have developed training modules that are used in training courses for farmers. One of the eco-processors is a mobile unit and is being transported to villages to train farmers in its use. Equipment for training delivery (a video camera and a data-video projector) has been provided to CRI in order to be used in training courses

8.3 Community impacts – now and in 5 years

There should be a positive effect on quality consistency within the Eastern Highlands over the next few years. This should have the following impacts:

8.3.1 Economic impacts

The introduction of the eco-processor will reduce the production cost of parchment coffee. Improved drying techniques will reduce product variability and thus provide upward pressure on the commodity trading price. To achieve this, the onus is on CIC to enforce the requirements of the Coffee Manual, to encourage the primary and secondary school curricula, and to support Open Day demonstrations of technology. Direct extension work to non-PRAP groups appears to be non-existent, but the training and extension to PRAP groups appears to be adequate.

8.3.2 Social impacts

To realise the benefits of the project, security and transport are essential. Security issues result in strip picking and variable quality. No amount of teaching can fix the problem, which is essentially a law enforcement issue. Transport delays also create variable quality product, and although main roads are well-supported at present, bridges and subsidiary roads are not. Government regional support for infrastructure maintenance is prerequisite to realising the potential gains from the project. If these things are achieved, PNG should become more competitive in the international market, reducing the current price downgrading caused by product variability.

The coffee ban has been effective for two years, but is a factor outside of the project so cannot be counted as a project impact. However, by encouraging farmers to return to coffee production by providing a safer environment, the ban provides an environment where the project benefits may be realised.

The equipment developed within the project is not gender specific, but the reality is that women are doing most of the orchard work, whereas men control the money. The project cannot have an impact in these areas, apart from raising awareness of this issue.

8.3.3 Environmental impacts

The introduction of eco-processor is likely to produce a major impact on the quality of water in the highlands. The quantity of the water used for coffee processing can be reduced fifty fold by using the eco-processor in comparison with the conventional processing system. Follow-up studies on treatment of water produced by the eco-processor are recommended. In addition, by not recommending a switch to a fuel-based drying method, environmental impacts of the industry are kept minimal.

8.4 Communication and dissemination activities

Papers: Eight papers (see publication list), of which 4 are complete, and 4 in process.

Presentations: Several formal and informal presentations have resulted from the project, as progress reports to CIC and to local workshops. Presentations have also been made at conferences in the UK, Taiwan and Cairns.

Coffee Manual: a formal document which disseminates best practise throughout PNG, and is a formal publication of the CIC/CRI.

Training activities: research results have been incorporated into PRAP training group materials by the CRI staff.

Other: Pamphlets, Open Days, Posters in *tok pisin* etc are being developed by the CRI staff, and incorporate project research results and technologies

9 Conclusions and recommendations

The initial project contained both research and development aspects. Progress was made in both areas, more so in application than in new ideas. Analysis of post-harvest practise, through surveys, discussions with farmer groups, direct observation have provided a platform for recommendations on best practise, which have become a part of the extension literature in the Highlands. Many preconceptions were found to be incorrect, and the project debt to the clear-sighted analysis of Dr Peter Batt's group, plus the deep understanding of people such as Potaisa Hombunaka and increasingly Nosare Maika, have corrected initial perceptions so that the solutions recommended here are based on a correct understanding of the industry.

9.1 Conclusions

Since farmers initiated the request for post-harvest assistance, it is not surprising that they have expressed a strong interest in new technologies which might offer solutions to their problems (see survey results, Appendix 1).

Post-harvest systems handling of coffee in PNG is chaotic, uncontrolled and fragmented. Environmental factors, lack of dissemination of information, deteriorating infrastructure and coffee theft create pressures which preclude best practise, resulting in a highly variable product of indifferent quality.

International competitiveness and oversupply have reduced the export price of coffee in recent years to levels where industry survival was threatened. Occasional price increases this year have provided some respite, but instead of creating a more competitive industry in PNG, the effect has been for many farmers to walk away from their orchards, with few in the next generation even interested in continuing this work.

Processors are clearly under enormous pressure as well, with most not surviving. Some have traded on negative returns for a few years. Despite this, the return to the grower is extremely high, with most of the coffee value being passed on.

This suggests that a solution in the interests of the coffee industry cannot ignore the processor perspective. They are purchasing a variable product and blending to try to meet standard requirements. Increased processing by the farmers increases the work the processors need to do in order to salvage a reasonable product. Furthermore, the inherent product variability destroys PNG's marketing credibility, leading to a poor international price.

These problems are not caused by the environment or tree variety, which are both capable of producing product of good quality. The main factor is the variability introduced by the factors described in the first paragraph and exacerbated by a false perception of increased returns through increased processing.

Two main coffee growing regions should be identified, the ROAD region, distinguished by good road access, and the BUSH region, at some distance from the roads. As a generalisation, good quality coffee comes from the BUSH. Poor quality comes from near ROADS. There are several reasons, but the main factor appears to be security: cherry is more difficult to steal if it must be transported on a person's back over long distances through hilly terrain. Tribal law reinforces the ability to control product quality in the bush.

To some extent this problem is being tackled by the "Cherry Ban", a police-enforced initiative which requires the presence of a licence attached to a vehicle before coffee can be traded. This has already restored some confidence within the industry, and a return to orchard husbandry has been noted. It should also reduce the incidence of strip-picking. This may in the future increase the need for processing facilities in bush regions, but should lead to the sale of cherry only in regions with road access. Current prices clearly show that processors prefer cherry, and offer a better price than for parchment or green bean.

Analysis of post-harvest systems in PNG has led to the following recommendations:

1. **Selective picking** must be enforced.
2. **Product cleaning** is essential to prevent equipment damage and variable product.
3. **If access permits,** coffee should be sold on to the processor as quickly as possible. If transport delays prevent sale before significant deterioration, the following steps should be followed.
4. **Small Scale Wet Processing Factory**: provides a pulping and fermentation solution for village-sized units. The so-called “fermentation” stage must be done carefully and completely.
5. **Eco-processor**: provides a complete bean extraction process with minimal water use for a centralised processing facility (large group).
6. **Drying** should be by sun on blue plastic, and an alternative drying technology is being developed as a continuation of the project collaborative between CRI and UNSW.
7. **Delays** in processing must be minimised at all stages, by planning and coordination of equipment use.
8. **Storage** should be cool and as dry as possible, with natural aeration around breathable sacks being facilitated.
9. **No dehulling should be done before sale to the processor.**

The technologies are set up as demonstrations at CRI, Aiyura.

Technical difficulties (as distinct from those listed above) were identified as:

1. Fermenting process is sometimes rushed or prolongs, and its effect on quality is not always well understood. Cupping tests which demonstrate the effect of rushed processing could be used to teach farmers about its importance.
2. Lack of water in some areas makes washing of parchment coffee difficult. Reasonable results can be achieved by dipping the product in a river.
3. Drying techniques vary, and problems with sun drying have been clearly identified, leading to product variability. No current alternative technology exists, and this project has invested time heavily in trying to find a reasonable alternative.

The CRI at Aiyura should do well from this point, notwithstanding funding. There exists a clear understanding of product properties, good laboratory equipment, high level training in many scientific aspects of coffee research, potentially good practical contacts with farmers and processors, and a strong extension effective extension methodology. The CRI has the capacity now to continue research.

The eco-processor was the star performer of the project, and offers enormous savings in cost, time and water consumption if adopted. Most importantly it is a key step in reducing quality variation throughout the industry.

9.2 Recommendations

1. Eco-processor be promoted and supported by the CIC.
2. The Cherry Ban be maintained, so that farmers get returns from reinvestment in their orchards.

3. The Coffee Manual provides the basis for post-harvest extension training for extension personnel, and be updated regularly to reflect developments in post-harvest systems understanding.
4. Sun-drying be maintained as the practise of choice.
5. Greenhouse dryers be developed into a viable support for sun-drying (for example for poor weather conditions, or wet ground).
6. Eco-processor trials continue to ensure coffee flavour is not affected when used correctly.
7. Minimal processing and sale of cherry be encouraged in farmer groups with access to roadside traders.
8. Research on solar and mechanical dryers for farmer groups be discontinued.
9. School curricula and teacher training in coffee husbandry be actively supported.
10. Funding for CRI be resourced as the sole body capable of acquiring and demonstrating scientifically new processing alternatives. This includes maintenance and provision of research equipment.
11. Coffee tasting trips be facilitated within CRI to communicate to farmer groups the effect of incorrect processing.
12. Waste management be researched by CRI as a matter of urgent national priority.
13. A longitudinal large-scale research instrument to be implemented to assess changes, to income levels, gender divisions of labour, and coffee processing (at a future date).

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11 Appendixes

11.1 Appendix 1: Overview of the Coffee Grading systems

Coffee grading is a complex but critical issue because it underpins international trade and consumer choice. The following excerpts from published information summarise some key issues.

Grading of Papua New Guinea coffee:

Source: http://www.nghce.com.pg/png_coffee
(Note the discussion that follows explains some of the terms used to describe PNG coffee grades)

Grade	Description
AA and A	Gourmet coffees produced in PNG, from the plantation sector. Bean size is greater than screen 17, uniformity is good, with max. 10 defects /kg. The raw bean is bluish-green in appearance.
X	Also plantation sector, smaller in size. Bean size is mixed, but generally over screen 14, with good uniformity and 15-20 defects per kilogram. The raw been colour is greenish.
Y1	Smallholder coffee: mixed bean size and uniformity, up to 70 defects per kilogram. The raw bean colour is greenish-grey. Nearly all small-holder coffee is classified into this grade.
SC X (Premium Small-Holder)	Between X and Y1 grades.
T (Triage)	Mixed bean size and uniformity, with a maximum of 3% foreign matter, and is yellowish to faded green in raw bean colour. It has no excessive foreign odours or flavours.

International Coffee Trading and Grading

Source: http://www.teaandcoffee.net/0504/coffee.htm

Specific regions consistently produce coffees with unique ‘cup characteristics’, for example Sumatran, Sulawesi and Java coffees are distinctive, having little in common other than all being Arabicas from Indonesia. This thought to be due mainly to environmental factors. This can be used to commercial advantage in selling the coffee.

Grading systems are fairly similar around the world, and based on the US Food and Drug Administration (FDA) and the New York Board of Trade grading systems. The percentage of coffee residing on the various grading screen sizes determines the bean size grade classification and a taste assessment will define the standard of ‘cup quality’. In order to assess the quality of a green coffee lot, one is obliged to weigh out the prescribed sample, count defects, screen the sample and actually taste the roasted coffee identifying any off tastes. After that, the importance of grade depends on whom you ask. Roasters may have a different emphasis than importers. Grade, taste and value are all interconnected in the mind of the roaster. For whole bean sales, appearance is more important. Freshness is also very important because the fresher the green beans the brighter the taste. Without a thorough knowledge of grades and cup quality, a buyer has no common language to discuss quality with suppliers.

Grading is a basic gauge of value used to assign price to the commodity. A poor showing in defect count can result in a lower price. If such a discounted coffee still has reasonably good cup quality, it can be a good value to the right roaster. Roasters of retail coffee that is to be sold as whole beans will obviously be more critical of the defect count in as much as it affects the general appearance of the roasted coffee. Roasters of ground and packaged coffee will give more weight to the actual cup quality and be less critical of the whole bean appearance because it will disappear in the grind. In fact most defects regarding appearance generally have little impact on cup quality yet this is not to say that producers who disregard appearances are paying attention to cup quality.

Information on Processing

Source: http://www.gardfoods.com/coffee/coffee.beans.htm

The two main commercial varieties are Arabica and Robusta, which differ in bitterness, quality, favour and caffeine content. Arabicas generally have caffeine levels 1.1 to 1.7% and Robusta generally is between 2 to 4.5%. The plants differ in size, shape, environmental demands, disease, and parasite resistance. Robusta plants can withstand temperatures above 30°C whereas the Arabica plants prefer cooler temperatures, so tend to be grown at higher altitudes such as the PNG Highlands.

Harvest. The bean is picked from the plant and or picked up off the ground, with method depending on labour costs – in PNG it is picked from the plant. The coffee bean is the seed inside the coffee fruit (berry or cherry). Generally the coffee berry is red when ripe, however, some are yellow, and yet, others are brown. The outer cover, called drupe, is thick pulpy skinned, called exocarp, enclosing a layer of jelly-like pulp, called mesocarp. The coffee bean, or basic seed structure, is protected by a thin protective membrane (endocarp), and commonly called the parchment. Inside that, and still covering the bean is another fine skin. The average size of the seed berry is 10 millimeters and they weigh about 15 grams each.

Sorting. The picked berries are sorted. Mostly this is done by hand, but, here are machines that can colour sort. Generally, berries are sorted by colour, size, and looks. Unripe or imperfect beans are removed. The berries may be washed and sorted by their specific gravity (whether they float or not).

Pulping. Theoretically, the beans are ripe, the pulp is soft, and the bean is easily extracted. Again, depending on where the bean is processed, this is done by hand, but there are many simple machines that do this too. One such machine is the pulper commonly used in PNG, which uses abrasion between two roughened disks spinning at different speeds. It takes about 5 kg of cherries to yield 1 kg of green coffee beans.

Fermentation. This process removes any remaining mucilage from the bean, and is an enzymatic, not a fermentation process. The beans are soaked for a period of time ranging from 12 to 36 hours. Wet processing in this way requires about 100 liter of water per kilogram of coffee beans.

The new technology of the eco-processor helps to reduce the last three steps into one.

Drying. After fermentation the coffee bean is dried on tables or plastic “canvas”. Larger processors will also have mechanical dryers. Some sorting occurs during drying.

Hulling: removal of outer hull by rotating wheels using shear stress.

The beans are often further processed by a specialised company by **blending** according to market requirements, then **roasted.**

11.2 Appendix 2: Survey Reports

Survey on Smallholder Postharvest Techniques (2006-07)

Australian Government
Australian Centre for International Agricultural Research

PNG PHT 017

Assessment of Smallholder Post Harvest Technique

Project Report

Susan May Inu

10 November 2007

This report covers the socio economic activities undertaken since November 2006 to December 2007.

1. Major survey in the three major coffee producing provinces

November 2006

2. Detail survey in EHP that includes the focus group survey

   April 2007

3. Benchmark of exportable smallholder grade for the last 3 years (2003-2005)

11.2.1 Report 1: Major survey report on Eastern Highlands Province, Simbu and Western Highlands

Introduction

The survey was done on the 27th to the 30th of November from Eastern Highlands, Simbu and Western Highlands Province covering an altitude of 1400m to 2000 m and sampling a total of 500 farmers. There were individual and group (three to five members') interviews depending on the turn out of the farmers.

The result of the survey was analysed with the current socio-economic dimensions and labour of the smallholder. The data was analysed to generate per annum production and asses all workers in the post harvest process (be they income receiving from sale of crop or receiving no payment at all) in three areas:

- General post harvest practice
- Time and labour input in to post harvest processing
- The opinion of Exporters and Roaster

Under each area stated above there are questions which provide a statistical evaluation. The discussion includes statistical and qualitative data and conclusion.

The statistical analysis shows a clear picture how many farmers' uses what methods of post harvest techniques that they know how. The discussion shows the relationship of their techniques used and the quality.

The conclusion summarizes the post harvest techniques (technology, time and labour) used by the smallholders and the level of their understanding of the methods they use and the relationship to the quality they produced.

Most farmers have a poor understanding of the relationship between the post harvest techniques used and the quality.

Statistical Analysis

These are statistics that shows the general post harvest techniques of smallholder.

When it comes to picking cherries, 44% of the farmers picked fully ripe and 56% picked mixture of ripe, unripe and over ripe cherries. About 56% use personal pulper 36% hire pulper and 8% other methods other than pulper. The use of water during pulping shows that 90% used water when pulping and 10% doesn't use water. For the foreign matter, 58% of the farmers remove foreign matters while 42% dose not remove foreign matters.

When it comes to drying 80% do the drying on the ground using canvas and 20% use beds above the ground to dry their beans. For storing 72% store their dried beans in houses where there is a fire place while 28% store their dried beans in houses where there is no fire place.

About 56% use their teeth to feel the beans to see if it is dry and ready for market, 18% used the fingers, 16% observe colours on the bean.

When it come to storing before sales, 46% store their coffee for only less than a month, 30% store for two to three months, 14% store for four to six months while 1% store more than six months.

The use of chemicals within the Smallholder can be analysed, as 94% dose not use any form of chemical and only 0.6% use chemical.

Discussion

The picking of cherry by the smallholder farmers is about picking most of the cherry once they started the harvesting seasons. They are not concern with which type of cherry to pick as they have other commitments as well.

Some farmers picked on ripe cherry during the peak season and towards the end of the seasons they tend to pick mixtures of ripe, half-ripe and overripe cherry most are half-ripe. They do this because they don't want to spend everyday picking the ripe cherry so once they are in their coffee plots they want to complete every task today or in a week.

In coffee work the farmers think it is time consuming to spend a month concentrating on coffee alone. They juggle other household commitment during coffee season such as vegetable gardening and sales to sustain them while attend to coffee.

When it comes to pulping most farmers delay their coffee for pulping because of shortage of pulper. Those who are going to hire had to wait for some days if the demand for the pulper is high. For those who just can wait had to pulp using other means such as stones or their fingers and so forth. Most farmers either cannot afford or their coffee earning have been given other priorities.

The use of water during pulping time can be attributed to the supply of water. For those who doesn't use water to pulp is due to their geographical location to the water source or seasonal problem that affects constant supply of water. The farmers who do not get rid of foreign matter are just ignorant. They think foreign matter will add extra kilogram so they can get extra toea and they usually sell the bags of coffee beans mix with foreign matter to the roadside traders (it is a cheating game). However these roadside buyers happen to sell it to the factories, which is now a serious concern to the factories.

Most farmers dried their coffee on canvas on the ground because it does not involve a lot of work. After so much work put into or harvesting, pulping fermenting and washing most farmers now go for the method that involve least work. And that is not building beds but simple spread the canvas on the ground and do the drying.

The storing of coffee depends on individual farmer most prefer to store it is the house where there is constant supply of heat and also to keep a watchful eye on it due to thieves. For the farmers who keep their bags of coffee in a store house (a house particularly built to store coffee) with no fire place either have no problem with thief or produced a lot of bags that needs to be store properly away from family house.

For storing months before sale it is common that most farmers sell their coffee beans no more than three months as most the farmers have access to the market through the highway. For farmers who sold their coffee after three months are usually the farmers with a lot of coffee bags that they tend to wait and negotiate the price when coffee supply in the local market start to drop. Those in remote area access only by plane either wait for price increase or suitable buyers or don't have the fare to transport to factories in time.

Statistical Analysis

Smallholder farmers capitalized on family labour; about 62% intensively use family labour and 38% use hired labour. For the farmer who hired labour about 10% employed one to five labour per day, 20% hired six to ten labour, 4% use eleven to fifteen labour and another 4% use sixteen to twenty labour.

For the farmers who hired labours between one to ten usually pays the rate according to the number of bags. It is usually K2.00 per bag of cheery. For the farmers who hire labour between ten and twenty are farmers who have more than a hectare of coffee. They pay group rate of K20 to K100 per day.

Most farmers, about 68% spends one to five days about 40 hours (8 hours per day) harvesting another 32% spent six to ten days about 80 hours (8 hours per day). For pulping 54% spends one to five hours and 46% spends six to ten hours. When it comes to washing 58% spend one to five hour washing the beans while 42% spend six to ten hours. For drying 30% spends only one to three days, 40% spend four to six days and another 30% spend more than six days.

When it comes to selling of beans about 7% sell cherry, 92% sell parchment and 1% green beans. For the farmers who sell parchment 22% sell one to five bags, 40% sell six to ten bags, 20% sell eleven to fifteen bags and 12% sells sixteen to twenty bags.

From the data 92% of the parchment selling farmers sells 62% sell a range of bags between one to ten bags. Their coffee gross earnings would range from K150-K750 with an average price of K2.50 p/kg class two (moisture level of 20%-15%) at factory door. Smallholder parchment is always classified as class two due to quality.

Most farmers have a poor understanding of the relationship between the post harvest techniques used and the quality. Therefore they don't pay a lot of attention to how they do their post harvest processing. However during the survey they were seriously thinking about improving their processing methods.

Farmers sells most of their coffee to roadsides traders, about 40%, 36% to factory, 14% to the exporters and 8% do their trading both with roadside and the factory.

Transporting coffee to the market cost varies depending on the distance and the number of coffee bags. About 32% pay the cost of each bag between K0.10 to K1.00 and 22% pays between K1.00 to K2.00, 24% pays between K2.00 to K5.00 and 10% pays between K5.00 to K10.00.

Discussion

Most smallholder farmers spend a minimum of three days and maximum of five days harvesting, for about two weeks in a month not consecutively and they do three to four harvesting in a coffee seasons. Their time is divided between their other household work (vegetable farming and social obligation) .On annual average of 112 hours (28 hour per week or 3.5 days) is spent on harvesting.

The pulping processes usually take an average of 7.5 hours per day. An annual average of 30 hours (4 pulping during coffee seasons). It takes an average of 7.5 hours to do washing with an annual average of 30 hours. Most farmers don't understand that the delay here affects the quality of their coffee.

When it comes to fermenting an average of 28 hours is spent. An estimated average of 112 hour per year (4 times a year) is spent on fermenting. For drying it took an average of 11 hours per day with an estimated average of 55 hours (average of 5 drying days) per year. Even farmers have some understanding of quality here; they don't clearly see the logic of quality process and price at this stage of post harvesting, to them it is a matter of quick money when coffee is dried to their satisfaction.

24% of farmers' ferment in the shade, 42% ferment in the open and 34% ferment both in the shade or open depending on the temperature.

In smallholder if labour required than it is only engage in harvesting process while all the other post harvest processing is done by the owner of the coffee gardens.

The smallholder spends 339 hours per year to do the post harvest processing.

With rate of plantation K7.50 p/day (K0.15p/kg) and the farmers usually pick 50-kg/per day. Here the smallholder who engaged labour paid them K2.00 per bag of ten kilogram bag, it is estimated that 62% of the farmers who does not engage labour subsidized labour cost of picking by K2.00p/bag.

For those who engaged labour during harvesting the labour cost range from K2.00 p/bag/day which means they subsidized their labour cost by 26% (K2 /K7.50) compared to plantation labour cost.

The overall labour cost of smallholder during post harvest processing is about K3, 051.00 (K9.00p/hr x 339 hour). Since only picking of cherry is the only post harvest process that involve labour in smallholder than about 38% of farmers who engaged labour, their post harvest cost is estimated to be on average K50.00 that is only 1.6% (K50.00/K3, 051) of the post harvest processing cost.

Most smallholders sell parchment to the roadsides traders. Their transport cost varies according to their locations.

Opinion of Exporters and Roasters

Exporters' opinion about smallholder coffee?

The Exporters all share the same opinion of poor fermenting and drying methods. Two out of five expresses concerns on foreign objects especially from roadside traders, who happen to buy from smallholders.

Conclusion

The post harvesting techniques used by the smallholder farmers vary greatly from one location to another. There are a lot of factors affecting the techniques and methods employ. Women carry out most post harvest work. As most women are also involve in other household chores they don't spent the required time in each post harvest processing areas.

The picking of cherry by the smallholder farmers is about picking most of the cherry once they started the harvesting seasons. They don't really bother with which type of cherry to pick as they have other commitments as well.

For those who does not own a coffee pulper, there are different ways and methods used to pulp cherries. Delay in pulping that affects the quality is a common problem in smallholders as well.

Fermenting process is sometimes rushed or prolongs. It is sometimes purposely done out of ignorance to quality. There are also different materials used to ferment that affect the quality. Most farmers dose a good job when it comes to washing, for those who doesn't do a good job is those who have problems with the supply of water.

Drying techniques varies. Some use tables. Beds above ground and other spread on canvas on the ground. Storing of beans during drying process is either in a family house or in a separated storehouse.

Most of the farmers involve in the survey is in access to the main highway so their storing before marketing is less than two months.

When it comes to total hours spent on different post harvest process is estimated to 339 hours per annum. For the smallholder do harvesting four times during coffee seasons. On annual average of 112 hours (28 hour per week or 3.5 days) is spent on harvesting.

The pulping processes usually take an average of 7.5 hours per day. An annual average of 30 hours (4 pulping during coffee seasons). It takes an average of 7.5 hours to do washing with an annual average of 30 hours.

When it comes to fermenting an average of 28 hours is spent. An estimated average of 112 hour per year (4 times a year) is spent on fermenting. For drying it took an average of 11 hours/day with an estimated average of 55 hours (average of 5 drying days)/year.

The smallholder labour is subsidized by K3, 051.00per year on post harvest processing. For those who employed labourers is equal to 16% of the total family labour subsidy. On average they spent K50.00 on harvesting process. The other post harvest process intensively used family labour.

The quality of smallholder is affected by the poor understanding of the relationship of the post harvest techniques used, and the quality. Most of the farmers show their concern with quality and price, however there is lack of concern with post harvest techniques used and price of quality.

Most farmers are eager to adopt new technology if and when one is develop, however their obvious constrain will be finance.

Shortfalls of this survey:

The capabilities of the farmers to adopt given their constraints:

- Are they capable with their constraints?
- How do they perceive sustainability and development of the technology?
- Do they have basic handymen skills to cut down on cost of adoption?
- What is the level of their seriousness in maintaining the technology?
- How will they contribute in terms of sustainability?

11.2.2 Report 2: Survey done in Eastern Highlands

Introduction

The survey was done on the 12th March to the 4th April covering six District of Eastern Highlands ranging from an altitude 1300 to 1700masl and sampling a total of 197 farmers. This survey was done:

- individually and with
- Focus group

For individuals farmers were asked to fill out the survey question forms, than these farmers were than grouped into three groups according to the numbers of coffee trees they have (500 less, 501 to 1000, and 1001+).The aim of the focus group is to identify the different factors that affect their decision on farm budget, Green Scale and Post Harvest.

The survey questions are structured as follows:

- Part A: Generic part covers of general coffee farming including land tenure ,farm income and labour input
- Part B: Knowledge on green scale and Pest Management Techniques
- Part C: Post Harvest techniques used by the smallholder farmers.

This report concerns only with Part A & C. The survey was analyzed according to the objectives of the projects (PHT/04/017) current socio-economic dimensions and labour input;

- Determine number of hours spent by coffee producers in specific post harvest task
- Generate per annum production
- Income receive from farm
- Level of production subsidize by family labour

The summary is the survey question with statistical answers

The statistical analysis shows farmers' income, labour input and post harvest techniques and constrains what methods of post harvest techniques they applied. The data in this report also confirm the statistics of what is the widely practice post harvest techniques.

The conclusion provides summary of the farm budget, and post harvest techniques and their ability to adopt introduce technology.

Part A:

Land tenure

55% of the farmers have been in coffee business for more than 10 years, mostly planting mixed variety of Arabica in their coffee farms.85% do farming on family inherited land and 6% on clan ownership land. About 76% of the farmers get their highest income at any one time from coffee. About 59% sell parchment and 42% sell more than 5 bags in any good seasons.79% uses coffee sales to pay their children fee and all farmers do travel when and after coffee sales.69% by highway, 10% air and 21% by sea.

Farm Income

Farm gross income range from K169 to K845 for about 58% of the farmers who sell between 1 to 5 bags of parchment. For the 42% o the farmers who sell more than 5 bags their gross income is around K1, 014 and more.

(Class 2 average price of K3.38: weekly market, May 7).

However the transport cost is K0.10 p/kg with bus fare K2.50 average.

The 58% of the farmers would now have their net income as K159.00 to K801.

For the other 42% of the farmers who produce more than 5 bags it is estimated that net income would range from K979 and more

Maximum labour cost of K50.00 (applied only to10% out of the 60% of the farmers).

The farmers are in organized groups, an organized group must have a minimum of 20 household or more. In a household, there is an average of five members who owns one or more coffee garden. A group income capacity ranges from a minimum of K3, 975.00 to K25, 350.00

It is estimated that about 65% of the coffee work is done by women and children. Women again do other domestic chores as well and this affect the time they put into coffee work.

Major social issue

Cherry theft is a major social issue. Most of the farmers here have a major problem with water. They mostly use bore water. Illiterate farmer feel left out because most knowledge about coffee doesn't get to them.

Part B: Knowledge on green scale and Pest Management Techniques

This part of the survey was presented in the report of the green-scale project.

Part C: Post Harvest

69% pick fully ripe, 51% use pulper, while only 41% own one and they all use water to pulp, 38% pulp straight after picking while 62% had to delay puling by 12 to 24 hours. The delayed cherries are packed and stored in a safe dry place waiting for the pulping process. 87% of the farmer uses bag (stock feed) to ferment and 37% allow fermenting for 48 hours while 51% do 24 hours fermenting and 5% do 52 hours.

About 51% use running river for washing. 80% remove floaters ants other rubbish. Almost 56% wash their beans till they are clean and all they put their bean in a safe and dry place when weather doesn't permit for drying. About 80% of the farmers do their drying on canvas spread on the ground.71% store their dry beans in the family house where there is a fire place.100% of the farmers feel their bean with finger or teeth taste and observe the colour.

89% are so receptive to any new technology and said would like to know more about it.

The major constrain to post harvest processing is cherry thief 75% of the farmer experience this every coffee season and 3% tribal fighting

The pulping processes usually take an average of 7.5 hours per day. An annual average of 30 hours (4 pulping during coffee seasons). It takes an average of 7.5 hours to do washing with an annual average of 30 hours. Most farmers don't understand that the delay here affects the quality of their coffee.

When it comes to fermenting an average of 28 hours is spent. An estimated average of 112 hour per year (4 times a year) is spent on fermenting. For drying it took an average of 11 hours per day with an estimated average of 55 hours (average of 5 drying days) per year. Even farmers have some understanding of quality here; they don't clearly see the logic of quality process and price at this stage of post harvesting, to them it is a matter of quick money when coffee is dried to their satisfaction.

24% of farmers' ferment in the shade, 42% ferment in the open and 34% ferment both in the shade or open depending on the temperature.

Generate per annum production

The smallholder per annum production fluctuates every year; however the production per year can be summarized according to what the farmers say a good and bad coffee season.

In a good coffee seasons the maximum and minimum production of parchment is estimated, 58% sells between 1 to 5 bags, 26% sells between 6 to 10 bags and 15% sells between 11 or more bags.

In a bad coffee season the maximum and minimum production of parchment is estimated around 76% sells between 1 to 5 bags, 18% sells between 6 to 10 bags and 7% sells between 11or more bags.

When its bad coffee season it is estimated that 16% drop from farmers who sells more than 6 bags in good coffee season

Income received from farm

Farm gross income range from K169 to K845 for about 58% of the farmers who sell between 1 to 5 bags of parchment. For the 42% o the farmers who sell more than 5 bags their gross income is around K1, 014 and more.

(Class 2 average price of K3.38: weekly market, May 7).

However the transport cost is K0.10 p/kg with bus fare K2.50 average.

The 58% of the farmers would now have their net income as K159.00 to K801.

For the other 42% of the farmers who produce more than 5 bags it is estimated that net income would range from K979 and more

Maximum labour cost of K50.00 (applied only to10% out of the 60% of the farmers).

The farmers are in organized groups, an organized group must have a minimum of 20 household or more. In a household, there is an average of five members who owns one or more coffee garden. A group income capacity ranges from a minimum of K3, 975.00 to K25, 350.00 and more.

Level of production subsidised by family labour

This table summarises the labour input of the smallholder farmers

Activities	Family Labour	Kind Labour	Hired Labour
Pruning	135	42	20
%	0.69	0.21	0.10
Drainage	131	48	18
%	0.66	0.24	0.09
Weeding	152	26	19
%	0.77	0.13	0.10
Harvesting	123	32	42
%	0.62	0.16	0.21
Pulping	182	15	0
%	0.92	0.08	0.00
Fermenting	190	7	0
%	0.96	0.04	0.00
Washing	192	5	0
%	0.97	0.03	0.00
Drying	197		
%	1.00	0.00	0.00
Storing	197		
%	1.00		

Smallholder farmers capitalized on family labour; about 80% intensively use family labour and 20% use hired labour. For the farmer who hired labour about 7% employed one to five labour per day, 5% hired six to ten labour, 4% use eleven to fifteen labour and another 3% use sixteen to twenty labour.

In smallholder if labour required than most labours are engaged in harvesting process while all the other post harvest processing is done mainly the family.

The smallholder spends 339 hours per year to do the post harvest processing.

With rate of plantation K7.50 p/day (K0.15p/kg) and the farmers usually pick 50-kg/per day. Here the smallholder who engaged labour paid them K2.00 per bag of ten kilogram bag, it is estimated that 80% of the farmers who does not engage labour subsidized labour cost of picking by K2.00p/bag.

For those who engaged labour during harvesting the labour cost range from K2.00 p/bag/day which means that they subsidized their labour cost by 26% (K2 /K7.50) compared to plantation labour cost.

The overall labour cost of smallholder during post harvest processing is about K3, 051.00 (K9.00p/hr x 339 hour). Since picking of cherry is one of the major cost in post harvest process that involve labour in smallholder than about 20% of farmers who engaged labour, their post harvest cost is estimated to be on average K50.00 that is only 16% (K50.00/K3, 051) of the post harvest processing cost.

Most smallholders sell parchment to the roadsides traders. Their transport cost varies according to their locations.

11.2.3 Report 3: Summary of Benchmarking Report

Year	Grade	Total Exported Volume	Sum(Defects)	Annual Sum	Average
2003	PSC	28785	2139		
	Y1	125089	3866		
	Y2	2240	472	6477	
2004	PSC	31889	2068		
	Y1	89600	3753		
	Y2	300	209	6030	
2005	PSC	28286	2140		
	Y1	74525	6466		
	Y2	1920	4384	12990	
Total					
	PSC	**88960**	**6347**		**2115.67**
	Y1	**289214**	**14085**		**4695**
	Y2	**4460**	**5065**		**1688.33**

Standard Measurements	Grade	Defects p/kg
1000g=1kg	PSC	35
1000kg=1t	Y1	70
60kg=1GB	Y2	150
300g=x defects		
1GB=60kg=60,000g		
300g of every 60,000g is use for physical assessment of defects		

Grade	Volumes (g)	GB bags (g)	Total grams asses for defects	Total Defects
PSC	88,960,000,000	1482667	4942	6347
Y1	2,892,140,000,000	48202333	160674	14085
Y2	4,460,000,000	74,333	248	5065
Grade	Total Exported Volume(t)	TEV(kg)	Expected Defects	Actual Defects
PSC	88960	88,960,000	3,113,600,000	6347
Y1	289214	289,214,000	20,244,980,000	14085
Y2	4460	4,460,000	669,000,000	5065

11.3 Appendix 3: Research paper on Thermophysical properties

Thermophysical properties of parchment coffee (Arabica typica)

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Abstract

Thermophysical properties of Arabica typical L. parchment coffee were determined over a range of moistures from 12 to 40% w.b. This included physical properties (unit weight, bulk density, true density and porosity) and specific heat. Linear models in terms of moisture were developed. The average parchment bean weight was 0.1565 g, bulk density was 544 kg/ m3, apparent density 764.76 kg/ m3, porosity was 29% and specific heat (at 12%) was 1.399 kJ/kg.K.

Keywords: *Arabica parchment, average weight, bulk density, true density, specific heat, porosity*

Introduction

Coffee is the leading agricultural export commodity and second highest income earner for Papua New Guinea (PNG) (Wardlow, 1993). In 2005, 1.2 m bags of green bean (GB) coffee were exported (Dambui et al.2005). However, the production fell by 32% in 2006 (Dambui et al.2006) and again in 2007 by 23% (CIC Coffee Report 2007). Decline in coffee production over the past 20 years has forced the PNG coffee industry to focus on consistency and improvement in coffee quality, as without adequate farmer incentive, industry might continue to decline.

Inconsistency in quality has been partly the result of a diversity of processing methods and machineries. It has become a major concern for the industry, particularly with regard to wet processing and drying facilities. Recently, developments have been made in the area of standardization of smallholder wet factories and drying systems (Nosare 2005).

In order to develop standards for processing equipment and simulation models for coffee processing, data characteristics of the thermophysical properties of coffee are required (Perez-Alegria et al. 2001). Coffee properties are also useful for studies related to heat transfer during coffee drying (Sivetz and Desrosier 1979). Since properties change during processing, models of properties are used, which allow updated calculation of properties as conditions change (Brenndorfer et al.1987). For example, moisture is lost during drying, which leads to a significant change in the bulk characteristics of coffee. The form of coffee during drying after wet processing consists of coffee beans covered in a thin silverskin layer plus an outer husk called a parchment. This is designated as parchment coffee, and is the form of coffee of interest in the present study.

Physical characteristics include properties such as weight, bulk density, true density, porosity and specific heat. For example, bulk density is required for estimating the capacity of the dryer. Porosity affects the pressure drop of the drying air as it passes through the product, so determines the bed pressure drop and hence the power requirement. Specific heat is important for determination of the heat energy balance across the dryer bed.

The objective of this study was to determine selected physical and thermal properties of dried parchment coffee of PNG. Properties to be evaluated were average weight, bulk density, true density, porosity and specific heat.

Literature review

Little research has been done on green coffee beans, especially on thermal properties, such as specific heat and thermal conductivity. Singh et al (1997) suggested that this is probably because the hardness and irregular shape and size of the beans that makes measurement difficult. Although some literature is available on physical properties of coffee parchment, little is known on the thermal properties of coffee. The Arabica variety studied in the present work was from Papua New Guinea. However it was expected that the properties would show agreement with Arabica values reported in the literature, as the variety (Arabica typica) grown in PNG is common to many coffee producing countries.

Studies on the dielectric properties of parchment coffee showed that the bulk density of parchment decreased with decreasing moisture content (Berbert et al. 2001) with bulk density significantly lower at lower moisture. This is in contrast to other products such as cereal grains, where bulk density increases with decreasing moisture content.

Ghosh (1968) found that the Robusta coffee variety had a faster drying rate than Arabica, and the difference was significant towards the completion of the drying process. Ghosh also determined the sizes of different bean shapes.

Vibrating trays in drying was found to improve mass transfer and increase effective moisture diffusivity (Sfredo et al. 2004). Higher temperatures reduced drying time by improved moisture diffusivity and increased heat and mass transfer. However in the same study it was found that use of temperatures higher than 45oC in produced coffee of lower physical and organoleptic quality than drying at lower temperatures.

A study on thermophysical properties of parchment coffee by Perez-Alegria et al. (2001) found that thermal properties were dependent on moisture content. Thermal conductivity, bulk density and specific heat increased with increasing moisture content. However, geometric properties such as dimensions did not depend on moisture content. The specific heat of the parchment coffee was determined using the method of mixtures.

A linear model fitted to the data determined at different moistures gave the specific heat correlation for green bean shown in equation (2):

$$C_p = 0.0535W + 1.655 \tag{2}$$

Linear relationships were used for the bulk density and apparent density of parchment as a function of moisture content as shown in equations (3) and (4) respectively.

$$\rho_b = 5.999W + 282 \tag{3}$$

$$\rho_a = 5.656W + 647 \tag{4}$$

The moisture content of coffee cherries affects their physical properties causing significant decrease of superficial area, volume and diameter of cherries during the drying process (Afonso and Correa et al. 2003). However coffee parchment does not show the same moisture dependence (Pérez-Alegría et al., 2001).

Chandrasekhar and Viswanathan (1999) determined thermal and physical properties of both cherry and parchment, testing both Arabica and robusta varieties. The bulk density of Arabica was found to vary from 400 kg/m3 at 10% up to 475 kg/m3 at 26% w.b. moisture, whereas robusta varied from 435 kg/m3 at 11% up to 515 kg/m3 at 31% w.b. The authors presented graphs of properties, but not the numerical results or regression equations.

An experiment by Varadharaju et al. (2001) on drying of coffee cherry showed that the drying rate was faster for the skins than for parchment. Quality was not affected over the range of drying temperatures studied.

The specific heat capacity of Arabica and Robusta cherries were calculated using the values of thermal conductivity k, thermal diffusivity □, and their corresponding bulk density using the following relationships (Chandrasekar and Viswanathan 1999), see equation (5):

$$c_p = \frac{k}{\alpha \rho_b} \tag{5}$$

Materials and methods

Preparation of the coffee parchment sample

Fully ripe Arabica coffee cherries were hand picked from block 1 of the CIC plantation at Aiyura, Eastern Highlands Province and pulped the same day. It was naturally fermented for 36 hours in a standard commercial processing facility. The coffee parchment was dried in the open sun for 12 days on a mesh wire drying table. The moisture was 12 % w.b. when it was removed and stored in poly-bags on tray for a week before commencing the studies. Samples extracted during drying were used to determine higher moisture properties up to 40.1% w.b.

Average weight

An empty flat metal plate was tared on an electronic balance. A sample of 200 dried parchment coffee beans was placed on the plate and the total weight was recorded. The average weight of a sample parchment coffee bean was calculated by dividing the total weight of the parchment sample by 200.The measurement was repeated 20 times.

Bulk density

A wooden cubic box with an inside measurement of 27 cm x 27 cm x 27 cm was used. The dried parchment coffee was filled to the top and leveled using a flat metal strip. The total weight of the coffee sample only was then recorded. The bulk density was determined using equation (6).

$$\rho_b = \frac{m}{v} \tag{6}$$

where m = mass (kg) and v = volume of coffee sample (m3). The experiment was repeated 10 times.

Porosity

The porosity (є) of both samples was calculated using equation (8):

$$\varepsilon = 1 - \frac{\rho_b}{\rho_a} \tag{8}$$

where ρ_b is the bulk density (kg/m^3), ρ_α is the true density (kg/m^3).

Specific heat

The method of mixtures as described by Mohsenin (1980) was used to find the specific heat of parchment coffee. A thermal flask (esky) with a lid (with a small opening in the centre to hold a glass thermometer) was used. In order to calculate the specific heat of the parchment coffee, the thermal mass (E) of the flask was found. A known volume of water was poured into the flask and left for 10 minutes to achieve equilibrium. The temperature of the water was recorded. A second known volume of water was heated to 600C. The temperature was recorded using a glass thermometer. The heated water was poured into the thermal flask to mix with the cold water. The mixing temperature was recorded at 1 minute interval for 20 minutes.

The thermal mass (E) was then determined using equation (9).

$$E = \frac{m_w c_w (T_i - T_m) + m_h c_w (T_h - T_m)}{T_m - T_i} \qquad (9)$$

Where:

E = the thermal mass of the flask (kg)
mw = the mass of the cold distilled water (kg)
cw = the specific heat of the water (kJ/kg.K)
Ti = the initial temperature of the cold distiller water (oC)
Tm = the temperature of mixture (oC)
mh = the mass of the heated distilled water (kg)
Th = the temperature of the heated distilled water (oC)

The flask was emptied, dried, then filled halfway with parchment coffee. The flask with parchment was kept in the incubator at 50oC for 12 hours, then removed from the incubator. A known volume of water (enough to just cover the beans) at a measured temperature was poured into the flask. A glass thermometer inserted in the flask was used to record the temperature of the mixture at 1 minute intervals for 30 minutes.

The specific heat of the beans was determined using equation (10).

$$c_{pb} = \frac{(T_m - T_w)(E + m_w c_w)}{m_h (T_h - T_m)} \qquad (10)$$

Where:
Cpb = specific heat of the coffee beans (kJ/kg.K)
mw = mass of the distilled water (kg)
Cw = specific heat of the water (kJ/kg.K)
Tw = initial temperature of the cold distilled water (0C)
Tm = temperature of mixture (0C)
mh = mass of the heated beans (kg)
Th = temperature of the heated beans (0C)
E = the thermal mass of the flask (kg)

Results and discussions

Average weight of coffee bean

Table 1 shows the average weight of coffee parchment beans at 12% w.b. and 40.1% w.b. moisture content.

Table 1: Average weight of a sample parchment coffee bean

Moisture Content	Average weight	Standard error
12.0% w.b.	0.156x10-3 kg	0.0112 x10-3 kg
40.1% w.b.	0.270x10-3 kg	0.0649 x10-3 kg

Table 1 demonstrates the weight loss during the drying process (about 41% of the original weight in this case).

Experimental results of the selected thermo-physical data are shown in Table 2.The table shows the values of bulk density, true density and porosity of parchment coffee between moisture contents of 12%w.b. and 40.1%w.b.

Table 2: Thermophysical properties of parchment coffee

Moisture (% w.b.)	Bulk density, ρ_b (kg/m^3)	Apparent Density, ρ_a (kg/m^3)	Porosity ε (%)
12.0	525.01	763.48	31.24
15.3	526.25	766.03	26.57
18.5	575.61	769.76	25.30
22.4	575.86	770.94	25.42
26.8	587.50	772.11	23.91
29.5	593.75	775.89	23.47
33.2	587.53	781.67	24.84
37.8	606.25	782.39	22.51
40.1	625.08	782.54	20.13

Bulk density

The bulk density of coffee parchment beans was 625 kg/m3 at 40.1% w.b., decreasing to 525 kg/m3 at 12% w.b. Figure 1 shows experimental data and a linear regression of bulk density. Bulk density decreases with decreasing moisture content. The linear model for bulk density is (equation 11):

$$\rho_b = 3.132W + 496.11 \qquad (11)$$

The coefficient of determination was $R^2 = 0.8581$, and the equation is significant at $p< 0.001$.

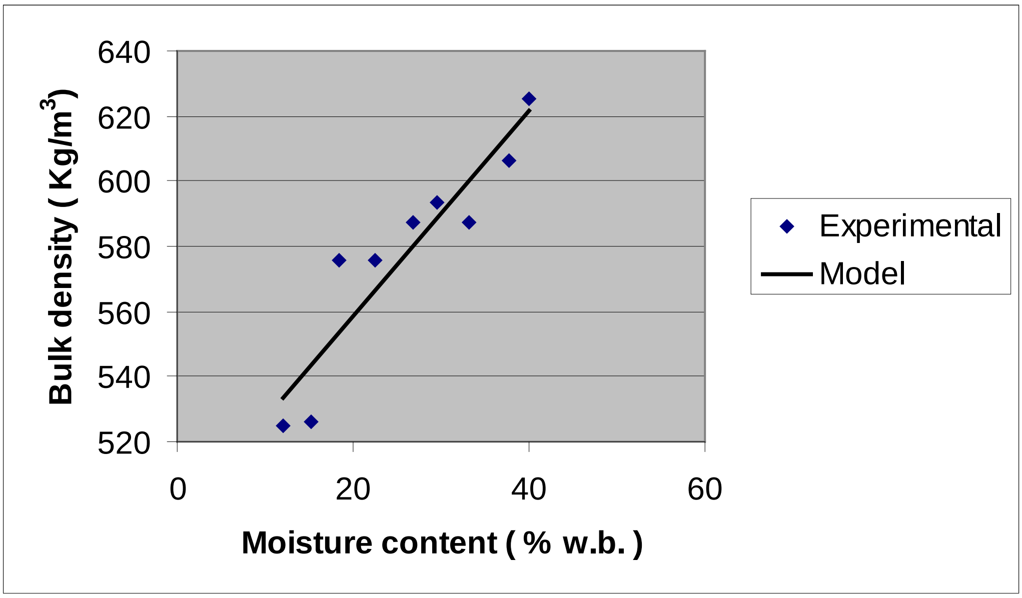

Figure 1: Bulk density and regression of coffee parchment

Apparent density

Apparent density is the density of the beans including silverskin, parchment, bean and enclosed airspace. It is called apparent density to avoid confusion with the true density of the individual components. Figure 2 shows apparent density data, linearly regressed against moisture content. The regression equation is (equation 12):

$$\rho_a = 0.710W + 755.28 \qquad (12)$$

Measured values of apparent bean density varied from 783 kg/m3 at 40.1% w.b., dropping to 763.48 kg/m3 at 12% w.b. The correlation coefficient was r2 = 0.9540, and the equation was significant at p<0.001).

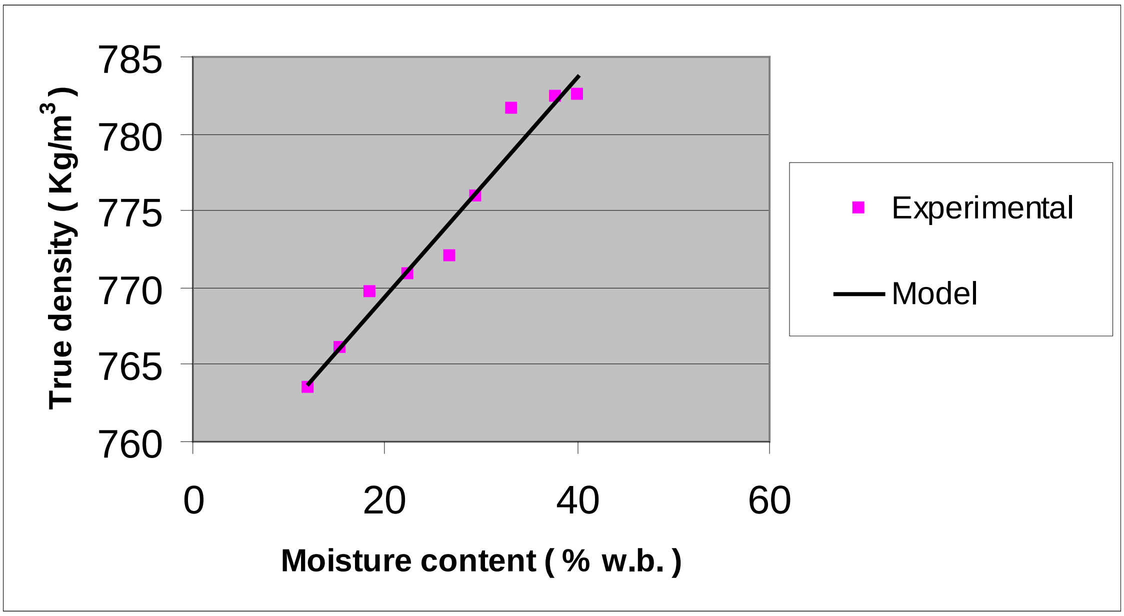

Figure 2: Apparent density and regression of coffee parchment

Porosity

Porosity was calculated using equation (8) and the density data. Figure 3 plots the calculated porosities and a linear regression of the data. Porosity was found to increase linearly with decreasing moisture, varying from 20% at 40% w.b. and increasing to 31% at 12% w.b. The linear model for porosity is shown in equation (13).

$$\varepsilon = -0.272W + 31.95 \qquad (13)$$

The correlation coefficient for this regression was r2 = 0.7430, significant at p < 0.002.

Porosity increases with decreasing moisture whilst bulk density decreases. This confirms that during a typical drying process physical changes (shrinkages) occur as parchment losses moisture while air space (porosity) increases. This improves airflow characteristics during the drying process.

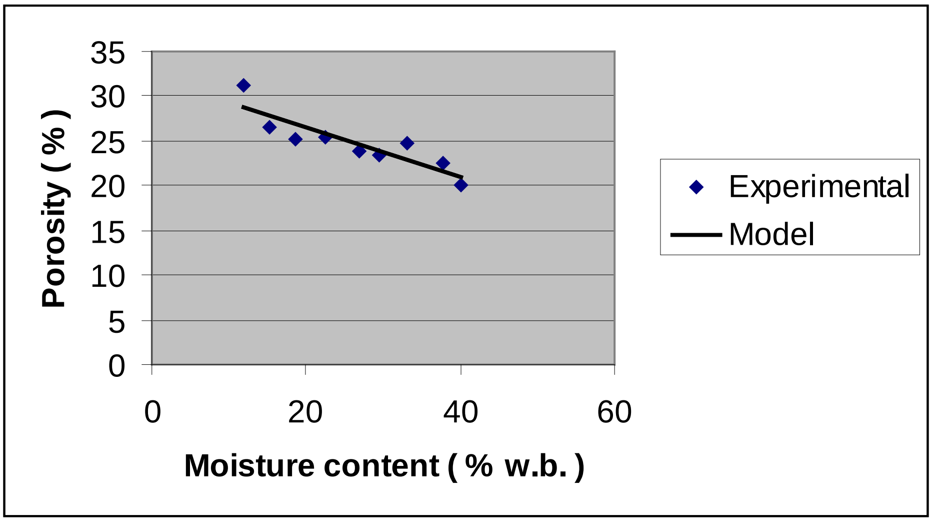

Figure 3. Porosity and regression of coffee parchment

Specific heat

Figure 4 presents experimental data and a linear regression model of specific heat. The linear model for specific heat of coffee parchment was (equation 14):

$$C_{pb} = 0.642W - 6.608 \qquad (14)$$

At a mean mixing temperature of 30.7 °C, the average specific heat capacity of parchment coffee is 1.3997 + 0.3637 kJ/kg.K at a mean moisture content of 12.48 + 0.545% w.b. By linear regression, a positive relationship between specific heat and moisture content could be established with a R^2 = 0.9245.

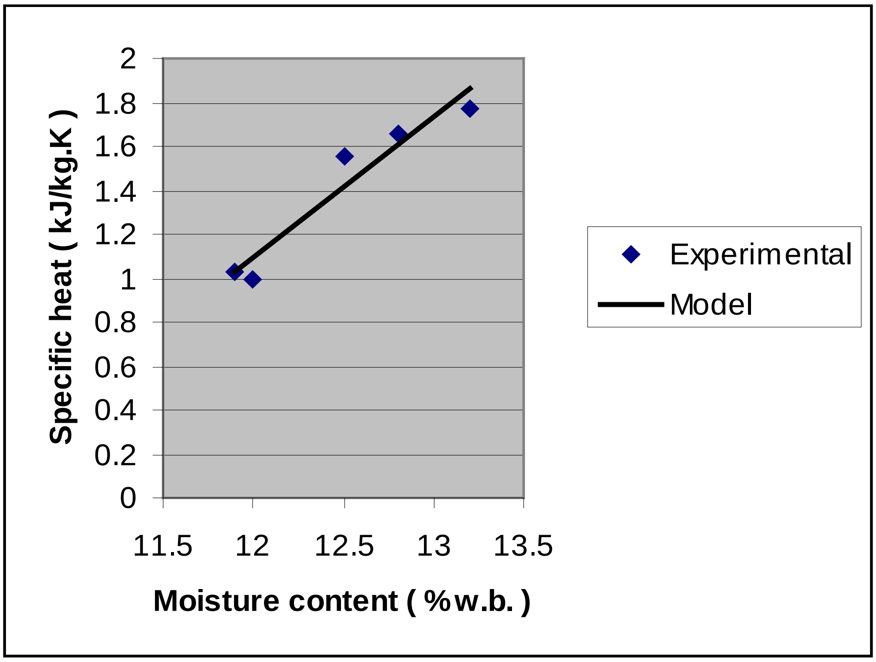

Figure 4: Specific heat capacity of coffee parchment bean with respect to moisture content

Discussion

Comparison of bulk density measurements showed that at 12% w.b., Perez-Alegria et al. (2001) predict 354 kg/m^3, Chandrasekhar and Viswanathan (1999) predict 405 kg/m^3 and the present work predicts 534 kg/m^3. The experimental values were also higher by about 70 kg/m^3 at 41% w.b.

Comparison of apparent densities showed better agreement at low moistures but large scatter between the results of different authors (715, 865 and 764 kg/m^3).

The present experiments found much lower porosity values than the literature values. For example

Chandrasekhar and Viswanathan (1999) determined values between 0.48 (high moisture) rising to 0.54 (low moisture), whereas the current experiments vary from 0.28 to 0.21 over the same range.

The specific heat values showed poor agreement with measured values by Perez-Alegria et al. (2001).

Conclusion

Selected thermo-physical properties of parchment coffee have been determined. Linear regression models were fitted to the experimental data (bulk density, true density, porosity and specific heat).

Nomenclature

ρb	Bulk density (kg/m3)
ρt	True density (kg/m3)
є	Porosity (%)
c	Constant
Cw	Specific heat of water (kJ/kg .K)
Cc	Specific heat of calorimeter (kJ/kg. K)
Cp	Specific heat (kJ/ kg.K)
Cpb	Specific heat of the coffee beans (kJ/kg.K)
E	Thermal mass of the flask (kg)
K	Thermal conductivity (W mK)
k	Constants
m	Mass (kg)
mh	Mass of the heated distilled water (kg)
mw	Mass of water (kg)
r2	Coefficient of determination
T	Absolute temperature (K)
Te	Equilibrium temperature (°C)
Th	Temperature of the heated coffee beans (oC)
Ti	Initial temperature of sample (oC)
Tm	Temperature of mixture (oC)
Tw	Initial water temperature (oC)
V	Volume (ml)
W	Moisture content in wet basis (%)

11.4 Appendix 4: Analysis of Sun-drying trials

11.4.1 Draft of Paper in Preparation.

CRI 2007 SUN-DRYING TRIALS

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Abstract

The effect of different sun-drying methods was evaluated. Different drying surfaces, stirring and shading were studied. The results indicated that the current practise of using blue ‘canvas’ performs adequately from a technical viewpoint, but raised woven bamboo beds are preferable to reduce water pooling and dust.

Introduction

About 85% of the PNG coffee is grown by smallholders. Cherry is picked from the tree, then sorted, pulped and fermented, leaving a wet bean covered by a parchment (hull) and a thin silverskin layer.

The two most important factors affecting coffee cupping quality are the harvesting and drying operations (Illy, 2002; Mburu, 1999; Mazzafera, 1998). Environmental factors during growing are less significant (da Silva et al, 2005) of which temperature is the most important. For wet processing of coffee, the most important harvesting factor is cherry maturity, as immature cherry can damage the pulpers. The most important drying method is sun-drying, which is used for drying parchment coffee from harvest moisture to a safe moisture content for storage. Traditionally this involves spreading the coffee beans to a depth of about 3 cm on blue woven plastic (called ‘canvas’). This serves to isolate the product from ground contamination, and provides a rapid method for wrapping the beans if rain is coming.

Although the method is adequate, some minor problems occur, which are accumulation of a moisture layer adjacent to the upper canvas surface, contamination by wind-born dust and debris, security of the product from theft and other similar factors, development of earthy or musty flavours from close proximity to the ground (possibly from mould), lack of consistency in the method resulting in a variable output, slow and uneven drying in inclement weather, and hull cracking during hot dry weather.

Previous studies on sun-drying indicate that the method of sun-drying has some impact on the final product (Ngoddy and Ihekoronye, 1985). Factors found to be significant included aeration through or from beneath the product, type of drying surface, stirring and shading.

Experimental trials using the typica variety were designed for the 2007 season in the PNG Eastern Highlands, with the objective of defining a best practise method appropriate to PNG conditions and the specific drying characteristics of coffee. This research was a part of an experimental program evaluating postharvest technologies, with a goal of modifying traditional practise and implementing best practise through training and outreach programs by the PNG Coffee Industry Corporation. A motivation for studying sun-drying was to provide a benchmark for evaluating other drying technologies.

Hence the objectives of the trial were:

1. To evaluate the effect of various sun drying methods in order to form a basis for comparison with alternative drying technologies.

2. To investigate possible improvements in sun drying methodology for PNG high altitude conditions.

Sun Drying

The principle of sun drying is to allow energy from the sun to supply latent heat of evaporation, which must then escape to the surrounding air and so lower the product moisture content. Weather conditions are clearly important in determining the density of energy availability during the day, and at ground level, direct solar irradiation in the Highlands is about 20 $MJ/m^2/day$ (NARI Weather Station, 2007 data), and sky radiation adds a further 30% to this. Only a small proportion of this is effective for evaporation, depending on the absorptivity of the beans and the drying surface, dissipation of heat from the bean to its surroundings, the surrounding air flow, moisture and temperature. Beans near the top surface will receive most of the radiation energy.

This suggests that the drying surface, elevation above the ground (to catch air movement above the ground boundary layer, but also to allow moisture drip), orientation to wind, shading and degree of mixing will be important factors.

Methodology

Experimental design overview: six surfaces tested against raking/non-raking and shading/non-shading, with duplicates. So six different surfaces were tested for various levels of shading and mixing.

The existing method as used by smallholders and farmer groups in PNG (blue canvas) was adopted as the control. Raised platforms for the drying beds were constructed on a north-facing hill, spaced (1m) to allow ventilation. Each platform was 70 cm high. One meter by one meter trays were constructed for holding the product. These trays were placed on the platforms, but could be lifted and weighed separately using a hanging balance. The trays consisted of an outside wooden frame supporting the drying surface. The product was spread uniformly over the drying surface to a depth of 3cm, approximately 15 kg of wet parchment beans. The materials chosen for the drying surface were:

1. Blue woven polypropylene (‘canvas’), as a direct comparison with the control placed at ground level.
2. Metal mesh, spacing 4 mm.
3. Metal plate (iron).
4. Plastic mesh, spacing 4 mm
5. Woven bamboo, coarse weave to allow water runoff but not allow significant aeration from below the sample.

The two co-factors chosen were shading (originally intended as 2 hours per day but later modified to complete shading) and stirring at designated intervals.

Sufficient platforms were designed to allow a randomised block design. This resulted in 5 platforms with 5 insert trays each plus one control tray one the ground (representing the current industry methodology), with a duplicate set of 5 platforms for shaded trials. The grouped platforms were placed under timber frames which allowed coverage by canvas during rain and at night, and protection for the trials was provided by a local security company.

The base sample size was chosen as 2.4 t of parchment coffee as this was a standard processing batch size for farmer groups, and was also of sufficient volume to minimise boundary effects during pulping and washing.

Testing was as follows.

1. Ambient conditions: ambient temperature, relative humidity and solar radiation were monitored during the trial.
2. Trays were assigned as randomised blocks to each platform, so that one of each surface type was placed on each platform.
3. Sufficient fresh cherry was picked for a single experimental block. This was approximately 2.4 tonnes, based on 15 kg x 5 trays per stand x 6 treatments. It takes 5.2 tonne cherry to produce 1 tonne of wet parchment coffee.
4. The cherry was hand-sorted to meet the following quality standard: coffee is well-mixed and fully matured, having a maximum of 2% immature cherry and 3% overripe.
5. The cherry was processed using a standard coffee processing plant for commercial production located at the research station at Aiyura. This resulted in a standard batch of approx 450 kg fermented and washed *typica.* Two samples were obtained for initial moisture measurement. The procedure for moisture measurement was the standard AOAC method (200 g at 108 ^{o}C for 7 hours).
6. The batch was then separated into 6 groups of 75 kg wet parchment coffee. These were placed into the trays, levelled to 3 cm, then initial weights determined.
7. Samples were raked and covered as per experimental schedules, with the same treatment applied to single platforms, so that all trays on a platform received the same schedule.
8. Moisture measurement: Trays were lifted from the platforms and weighed twice daily. Given the number of trays, the weighing process typically took about an hour to complete.
9. Final moisture: after the drop in weight of the trays indicated that the target moisture of 11% wb had been reached, total drying time was recorded and samples were taken for final moisture measurement. The remainder of the dried beans was stored for triangle testing of differences and cupping trials. Average drying rates were then calculated from this data. (was moisture meter used instead? Why are final moistures so high?)
10. Triangle testing: samples were roasted immediately before testing. Two similar and one different coffee brews were made and a blind panel test used to test differences between the methods.
11. Cupping tests: local expert cuppers assessed and graded the different samples.

Treatments

Treatments were allocated randomly to the five platforms as follows:

1. No shading and mixing.
2. Shading no mixing.
3. No shading and few mixing (twice per day).
4. Shading and few mixing (twice per day).
5. Shading and many mixing (at 9 am, 12 am, 2 pm and 5 pm).

Operators recorded details in a logbook (weights, temperatures and ambient conditions) and conducted daily inspections of the equipment for condensation problems

Analysis

1. Weights were converted to moisture contents and plotted against time.
2. Comparisons were made between average drying rates over the time.
3. Results of quality tests were analysed.

Results (Unshaded trials)

All surfaces tested were able to dry within the period required. The average drying rate (in kg/hr) over the first 10 days of drying was selected as the best measure of drying efficiency. After ten days, the beans were sufficiently dry that day to day variations in weather conditions obscured the effects of the drying trials.

Figure 1 shows the results for the first trial replication for each surface, averaged over the stirring regime used.

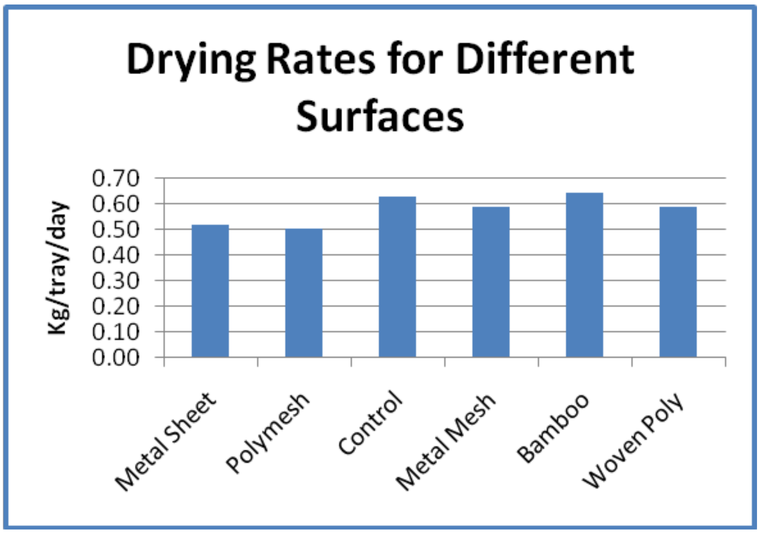

Figure 1: Average Drying Rates over First Ten Days: Effect of Surface

Based on a two factor analysis of variance, the differences due to drying surface were significant at ten days to a 98% confidence level, whereas the differences in drying rate due to method of raking were insignificant. Interactions between raking method and drying surface were not detected by the analysis.

The results were unexpected. Firstly the control performed very well, indicating that current practise can dry as well as other methods tested. The three surfaces which performed best were the bamboo mesh, control (canvas on ground) and the woven polypropylene (canvas on platform). The metal sheet and polymesh were the least successful, about 25% slower than bamboo.

Secondly the effect of raking was expected to be significant, but proved to have no effect. Despite this, bean stirring would still be recommended to prevent local moisture build-up which may cause mould.

Cupping

Cupping trials were performed in Lae at the Coffee Export Office by professional cuppers. Three cuppers were used to test samples across all trials. The accuracy of the cupping score was determined statistically (analysis of variance) as within 10% on a maximum score of 100. In addition cuppers rated attributes of the aroma and flavour. The cupping tests showed a preference for the samples from the first trial run (see Figure 2).

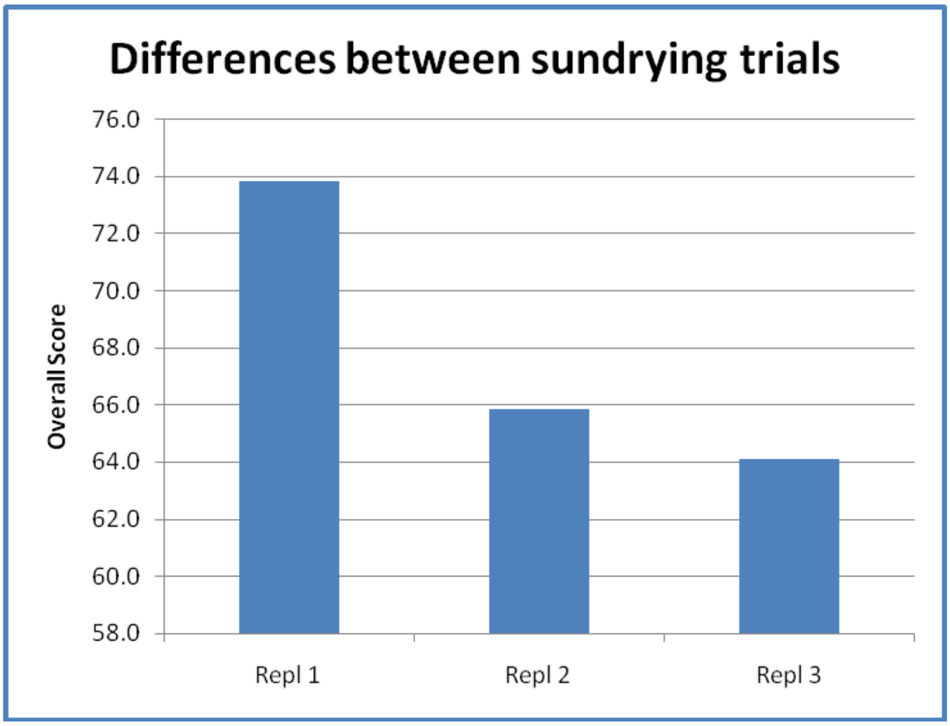

Figure 2: Differences between replicate trials based on overall score.

Conclusions

The control treatment on blue woven polypropylene ('canvas') and woven bamboo were the most successful treatments in terms of drying performance. The stirring did not show a significant effect.

Recommendations

The existing sun-drying method using blue woven polypropylene ('canvas') should be maintained and in-spite of the lack of significance, stirring is also a useful technique that should be continued.

11.5 Appendix 5: Greenhouse Dryers

11.5.1 Draft of paper in preparation.

Application of Greenhouse Dryer for Partial Drying of Arabica Coffee in PNG

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Introduction

One of the crucial steps in coffee postharvest processing is drying the parchment coffee from about 54% wet basis (wb) to a moisture content of about 10-11% for storage. Throughout the world, the most common drying method is sun-drying, which can give good quality product if managed correctly. This is also the main drying method in the Eastern Highlands of Papua New Guinea (PNG), but low temperatures and high cloud cover reduce the availability of solar energy making the method less dependable. For the same reason, solar dryers are not a reliable solution, requiring large collector areas to provide sufficient energy. Mechanical dryers are not suited to the small scale “smallholder” production common in the region, working best when economies of scale can offset the high capital cost. For this reason, a new alternative, the greenhouse dryer, was investigated. The term greenhouse dryer is not used consistently in the literature, and is often used to refer to aerated solar collection dryers. However the greenhouse effect which is of interest here is independent of airflow, and so used in the context of this paper, “greenhouse dryer” refers to a dryer where external airflow is eliminated, and only internal natural circulation currents are assumed to occur.

As a result, the primary mechanisms for moisture movement are internal product diffusion, surface evaporation, natural circulation of moist air, condensation on cold surfaces, coalescence and run-off to ground level. The thermal advantage of this method is that instead of the latent heat of evaporation being convected away from the dryer, heat is partially recovered when water condenses from air as it cools.

For this mechanism to be a significant transport mechanism, a few factors need to be in place. The internal air temperature must be significantly hotter than the outside air temperature, the inside air humidity must be high (but not necessarily saturated), and the airspace sufficient for buoyancy forces to drive the air circulation. These conditions are easily achievable in PNG. However the internal temperature must remain below 45^{o}C to prevent killing the germ and so affecting enzymatic development of flavour precursors. This air target temperature will deliver the maximum rate of internal moisture diffusion within the bean and the maximum rate of condensation possible without affecting final quality.

Introduction of external air (such as in so-called greenhouse dryers where air inlets and even fans are added destroys this natural circulation, keeping the internal air too dry to allow the condensation mechanism. To avoid this, the greenhouse dryer should be as airproof as is convenient, much like a greenhouse for growing plants.

The maintenance of a temperature differential is necessary to allow condensation as moist internal air reaches ambient-cooled surfaces, and the driving force required is solar. However the greenhouse dryer requires far less solar energy than a conventional solar dryer, since the condensation mechanism recovers a proportion of the latent heat of evaporation. This heat recovery allows greater energy efficiency.

In most dryers, heat losses through the sides of the dryer are typically a loss in efficiency. For a greenhouse dryer, they work to its advantage. Clear thin plastic allows a broad spectrum of solar energy into the unit, but re-radiated heat with a different spectral range is trapped, so that radiation losses are reduced. Without the conduction/convection heat losses through the side walls, internal temperatures would become excessive and damage the product quality. So for an ideal greenhouse dryer, the rate of energy input by radiation would balance the energy losses by conduction/convection through the dryer walls. Ideally this would balance at a temperature just below the product maximum temperature.

Coffee is reasonably high in oils (16% d.b.), so fast drying is to be avoided in order to avoid case-hardening, in which an external hydrophobic oil-rich layer prevents moisture migration from the centre, trapping water which creates a region of higher water activity, leading to microbiological problems. Ideally the parchment coffee would dry in about four days, and the rate of drying should be matched between sun drying with ideal conditions and greenhouse drying. The advantages required for adoption of greenhouse dryers should not then be rate of drying, but in terms of capacity per unit ground area, reliability in terms of independence of weather conditions, and prevention of contamination, for example dust and ground moisture.

On this basis, a project was commissioned to design and test a greenhouse dryer suitable for Highlands PNG parchment coffee drying. This was a component of an ACIAR-funded project analysing post-harvest systems in the Highlands of PNG.

Methodology

The initial prototype was designed purely to test the concept, and consisted of a wooden frame with an angled roof (see Figure 1), to which was fitted internally plastic sheeting (polyethylene, heavy gauge). Polyethylene was chosen as a cheap, easily replaceable plastic which could be used for a season and then discarded. There are many plastics with better sun-resistance, but previous work on solar dryers in East New Britain had convinced the authors that in practise it is difficult to keep plastics from becoming hazy over time due to microbial activity in humid climates. The back (highest wall) of the dryer was made of black plastic in order to increase temperature differences within the dryer, although this was later found to be ineffective. The dryer is oriented with the shortest face towards the sun at noon, giving maximum solar radiation input over a day.

Two 1 m2 drying trays were constructed and fitted into a frame which raised them 1 m above ground level. The trays could be separately weighed.

The prototype was constructed by ATP Projects, Goroka for the Coffee Research Institute. TinyTag loggers were used for recording temperatures and relative humidities hourly for a week. Three loggers were used, one suspended in the shade to measure ambient conditions, one close to ground level at the back of the dryer, and the other placed on top of the product on the trays.

A plastic pipe fed condensed water to a bucket, and a measuring cylinder was used to determine the amount of water collected.

Logging was started on the morning of the experiments. Approximately 200 kg of harvested cherry was procured and processed, giving 40 kg of parchment. Two 200g samples of parchment coffee were placed in plastic bags for initial moisture content determination, using the AOAC oven dry methodology. The remaining parchment was spread to a depth of 3 cm on the two trays, and the dryer was sealed. This gave an initial tray loading of about 15 kg. At hourly intervals, the dryer was entered and the product weighed, then mixed.

After five days the experiment was closed down, with two 200 g samples of the dried parchment taken for final moisture determination. The quality of the coffee was determined by a physical inspection.

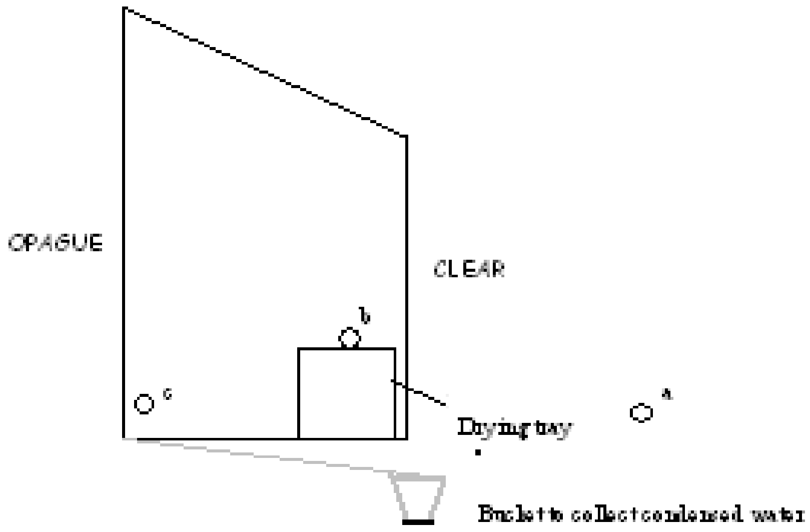

Figure 1. Schematic of the greenhouse dryer

Results and Discussion

Figure 2 is a plot of a typical daytime temperature profile of the green house. Temperatures above and below the bed are compared with the ambient temperature.

The temperature difference between ambient and the greenhouse dryer is about 12 to 15 °C. This provides a suitable temperature for condensing moist air. From a standard psychrometric chart, if air at 40 °C and 50% RH is cooled to 28 °C, condensation will occur. From the experimental data, the air relative humidity during the middle of each day drops to about 50%. So conditions in the dryer are suitable for condensation for a period of time in the middle of the day. In practise, condensation was observed from early morning onwards. However most condensation occurred directly above the bed, with little on the back of the dryer. This suggests the back half of the dryer does little effective work, and that it could be used for additional trays.

Hot air rises, so if the below bed temperature is higher then air will rise through the bed. But in this case, the bed temperature is hotter than the floor temperature, so no circulation currents through the bed can be occurring. The bed is therefore being heated by radiation only, both from sunlight on the bed and from the heated air above it. Thus there is an air circulation cell above the bed only (as evidenced by condensation), but not one through the bed.

Equating the heat losses by convection with the input radiation energy gives the following equation:

$$Q_{rad}A_{roof} = hA_{all}(T_{in} - T_{amb})$$

Solving this equation for the dimensions used in the prototype, assuming h=10 W/m2.K, gave a temperature increase of about 10 °C, which is adequate to drive the evaporation – condensation cycle required. Since the actual area for solar energy input is more than the roof size, the actual temperature rise would be greater than this. This is confirmed by the experimental results, where the observed temperature difference varied between 10 and 15 °C.

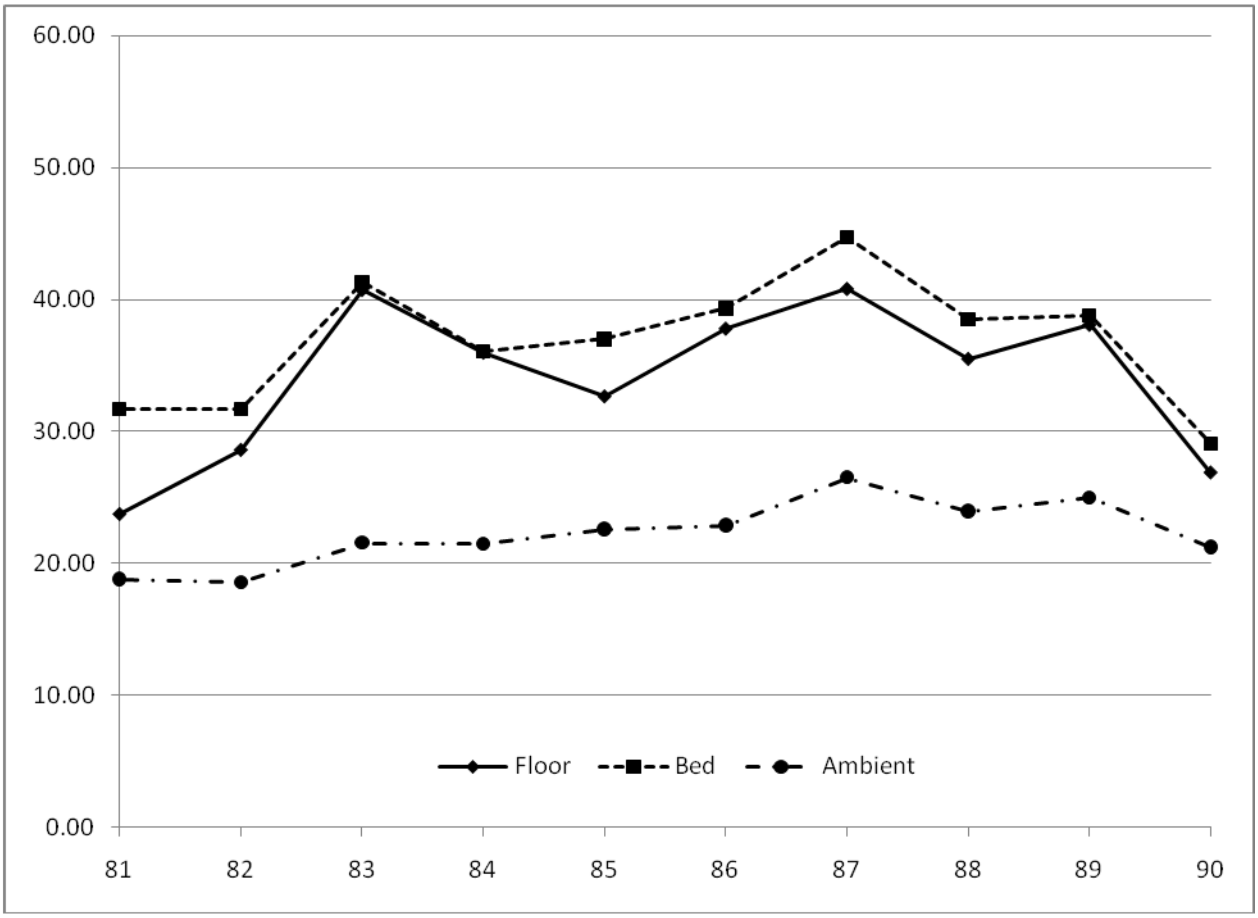

Figure 2: Comparison of Ambient, Bed and Floor Temperatures.

During a subsequent run of the equipment, temperatures were monitored at five points within the dryer, and three of the temperature traces are given in Figure 3 for a 72 hour period. Again it can be seen that no circulation occurs through the bed during the day, but there is evidence for a circulation cell above the bed (bed temperature slightly higher than the temperature of the air at the top of the dryer). Interestingly, during the night there is a temperature reversal, which would generate some air movement through the bed.

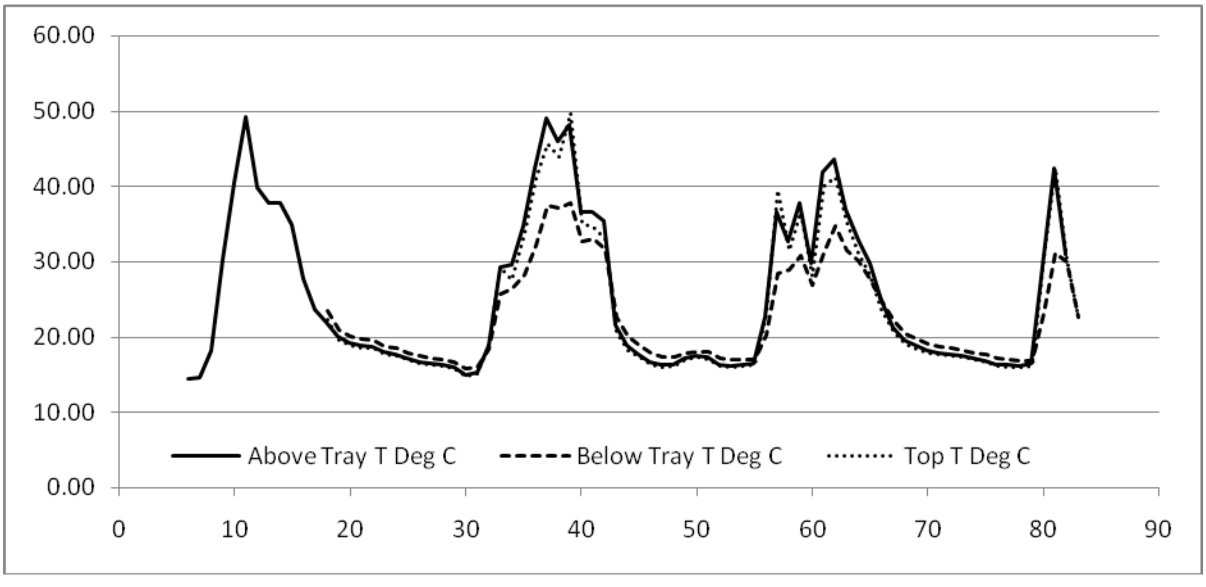

Figure 3: Plots of temperatures over typical days of operation

A plot of moisture contents for the first run is given in Figure 4.

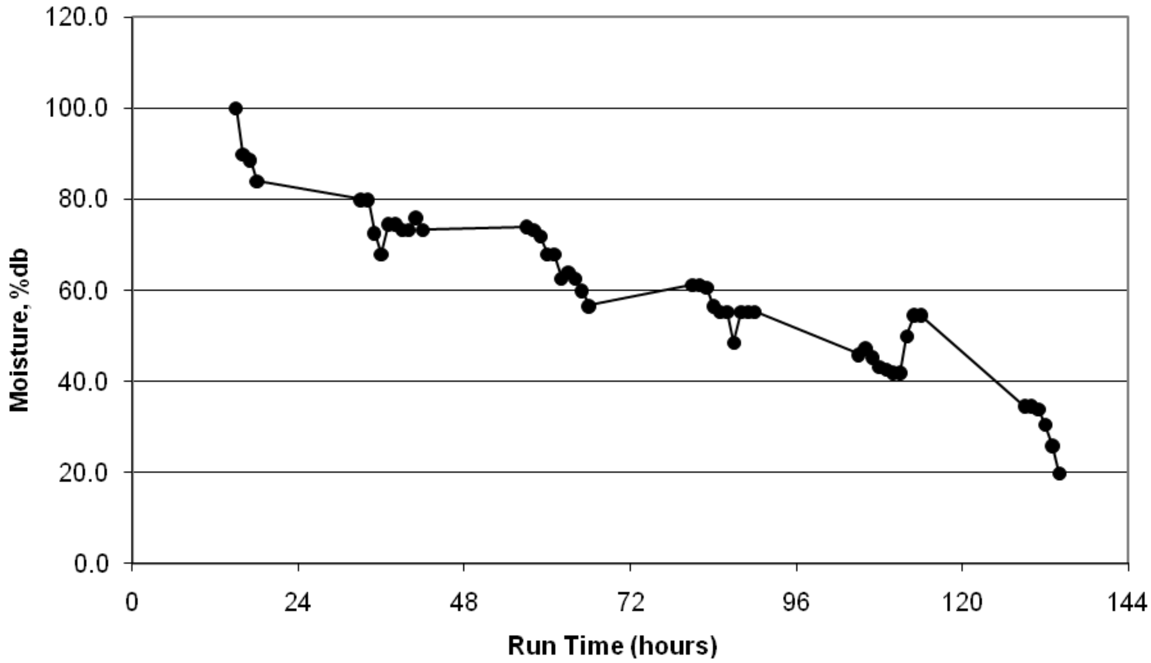

Figure 4: Plots of moistures from the first experimental run

Conclusion

The experimental results look promising and the experiments are continued by the CRI team beyond the completion date of the project.

11.6 Appendix 6: Paper on Evaluation of Wet Processing Systems

11.6.1 Evaluation of Wet Coffee processing Systems in PNG

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Abstract

Three wet processing systems were evaluated at the Coffee Research Institute of the Coffee Industry Corporation in Aiyura, EHP during the 2007 coffee season. Two systems produced parchment with mucilage, while the Eco processor (depulper+demucilager) was without mucilage. The Eco processor proved to be suitable in terms of ease of operational time, however it was not fully washed mucilage it was pose some risks in terms of quality deterioration. It a also most suitable in terms of short processing time. However it had high percentage (7.20%) of skin mixed with parchment.

The commercial wet system produced fully fermented and washed coffee and produced high quality coffee but had high processing time and high labour and operational inputs. The small holder wet process used a hand operated drum pulper. It produced clean parchment coffee wit less skins (2.83%) but had longer processing time including drying time.

Although there was some difference in their cup taste when demucilager was compared with commercial and small holder wet processes, the differences was not very significant. This observation is however subject to much deliberations by wider views especially those involved in the cupping assessment.

Background

Arabica coffee is the main coffee grown usually in the highlands of PNG, which is grown at an altitude of 600-1800masl. Harvesting periods usually coincides with rainy and wet conditions (the daily average is at 7mm) and for drying it is usually wet.

Wet processing systems are commonly recommended for producing higher quality coffee, however is suitable in areas where is high labour force, larger processing facility and drying area. Wet process in rural area is the cheapest and commonly used systems but there is a lot of in consistency to quality due to peoples ignorance in controlling fermenting and drying time.

Coffee is usually wet pulped with mucilage intact, and after fully washed, it is dried on canvas in direct sunlight. The fermenting infrastructure and methods is sometimes manipulated by many farmers for quick money thus results in an inconsistent stage. As a result coffee output is usually of poor quality classified as Y grade. A survey of farmers showed that 887% of farmers are not consistent with the recommended 36 hours of fermenting and as results poor fermenting process is the major cause of tainted parchment coffee. Another study on bench marketing done in this project indicated that Y grade coffee predominantly from smallholder coffee has a high defect of 80%. Thus; the coffee is usually sold at a discount price which is currently at 15 cents/tonne at NYC market.

The purpose of this ACIAR ASEM/2004/017 project to seek appropriate ways to address the problem of poor fermenting and drying problems through wet processing and drying trials. A wet processing trial was conducted at CRI- Aiyura, to evaluate three wet coffee processing process namely; Commercial smallholder and the imported Eco processor. The processing systems were trialled to evaluate the physical and cupping features of the processing systems and the coffee produced.

Introduction

The ACIAR Post Harvest project was design to look at a range of post harvest issues in the coffee industry. Activities include field surveys of post harvest practices employed by small farmers, wet processing, drying and storage trials. One of the initial trials conducted under wet processing was the Eco processor trial. Eco processing was identified as a potential opportunity to investigate.

The aim of the Eco processing trial was to reduces variables affecting coffee quality and to test the effect of processing on coffee flavour. Coffee cherries used for this trials was sourced from one block of typical variety from CIC research plantation at Aiyura. The coffee was produced through three different processing facilities (treatment), CIC commercial factory (Treatment A), new Eco processing technology (Treatment B) and small holder wet factory (Treatment C). The trial was repeated five times through out the coffee seasons to produced 15 samples.

All samples processed through the three facilities were sun dried and prepared for quality assessments. Drying times were monitored carefully and moisture checks were maintained throughout the drying process. All samples dried to the required moisture level were brought into store for quality tests.

Rationale

The recommended method for processing of the fresh coffee cherry is to pulp, ferment for 36 hours and then wash the parchment ready for drying. It is termed “Full-Washed” method. The full washed method uses 4 to 10 litres of water per kg fresh cherry and creates large volumes of wastes. The fermentation step in this process can create quality problems if not managed well. Machinery which pulps and then mechanically removes the mucilage is now available. These machines use 0.2 to 0.5 litres of water per kg of fresh kg and create wet parchment ready for drying without the 36 hr fermenting and washing step.

A Penagos UCBE 500 M Pulper Eco processor or Demucilager which creates “Washed” coffee will be tailed against standard “Full-Washed” coffee methods to determine if there is any significant difference in quality of the resulting coffee. Two full washed treatments will be used for comparison

1. Smallholder wet factory at CRI
2. Commercial wet factory at CRI

The objectives of this quality assessments is to evaluate the coffee quality resulting from Pulped and Eco processed “Washed coffee” from the Penagos Machine compared to “Full-Washed” Coffee produced by the small holder and commercial wet factory processes. Then assess the physical and cup qualities of the samples at CRI Aiyura, and CIC Lae. The samples were then provided to the commercial coffee industry to assess the quality and the market potential of the various processing options.

Materials and Methods

These topics are addressed in two sections:

1. The first section (A) covers the processing aspects of the trial while
2. The second section (B) covers the quality assessments aspects of the coffee produced.

11.6.2 A) Processing Trial

Description of the processes

Three wet process (Treatment A,B,C) were tested at the CRI-Aiyura in five replicates from May 2007 to August 2007. The processes tested were as follows:

Commercial wet process – Treatment A

It is large commercial wet processing unit where cherry is pulped and then naturally fermented and fully washed. It is comprised of 3 disc pulper with a capacity to process 3000 kg cherry per hour and used 1500 L of water per tonne of cherry. The disc pulper in today's value is worth K30,000 (AUD12.000). It is pulping capacity of 4400 kg/hr. Fermenting is done naturally for 36 hours and is washed fully afterwards in flush of water until all mucilage is removed.

Eco processing:- Treatment B

The eco-processor is a Penagos product imported from Colombia through CAPE Ltd, an Australian agent at a cost of AUD6,000. It has three functions in one single operation; a rotational cleaning screen and a vertical eco processing component. It has a capacity of 500 kg cherry per hour and utilities very little water (0.3L/s per kg cherry removed). The eco processing component is a vertical screw and removes mucilage, during a rotational motion whilst wet parchment with mucilage enters vertically and discharges without mucilage at the top chute. It is powered by two three-phase motors and utilizes 0.55 kw hr of electricity on average with processing average time of 0.39 hours for processing 200 Kg cherry. The separated skins mixed with mucilage from eco processing are removed by a horizontal rotational rotor. The wet dry parchment from the eco processor is put to direct open sun drying.

Smallholder wet process – Treatment C

Wet process is another naturally fermented and fully washed system but a smaller version. It comprises of a small hand- driven drum pulper and with a capacity of 200 kg cherry/hour which utilizes small amount of 0.8 L of water/kg cherry. The unit consists of a hand pulper, fermenting infrastructure including three fixed fermenting cement boxes and a small washing channel with a capacity to store 75 kg wet parchment. The total processing time is 36 hours.

Materials and Methods

Some renovations were done to pulpers in the commercial unit and fermenting boxes were cleaned. Hand revolution for the hand pulper was fixed at 10 rev per minute so there was less fluctuations in hand rotation. Eco processor was given minor cleaning prior to commencement of trial. Water rate testing were done and fixed at full opening because it still gave a small flow. Fully ripe coffee cherries picked from the same typical block at the CRI plantation was hand sorted to give clean, fresh, cherry coffee. 200 kg each was fed to the eco processing and smallholder processes while 1000 kg cherry was used for the commercial unit. Cherry quality for the three trial runs was assessed by selecting a 1 kg sample from each process lot and sorting ripe (red), immature (green) and overripe, then weighing each group and calculating final percentages. (See table 1). The conducted was five times during the season from May 2007 to August 2007.

The fermented parchment was washed in clean water by hand until free of mucilage and spread to dry at 15 kg/m2 on the drying trays. The wet dry parchment from the eco processor is put to direct open sun drying without further washing. For each treatment process, a total of 75 kg wet parchment were dried thus requiring a total drying table area of 5 m^2 at a batch thickness of 3 cm.

Parchment was raked four times per day at 9:00 hr, 11:00 hr,13:00 hr and 15:00 hr. Trays was left open to sun during sunny days but were covered with tarpaulins during times of rain and night and then uncovered in the morning. When each treatment reached 11% moisture it was weighed and bagged in clean, new and odour-free poly sack (Approximately 35 kg dried parchment). Sacks of samples were stored on pallets in the dry storage room of the new post harvest building. The dried parchment was stored between three to eight weeks before hulling for a quality assessment.

Data collected

i) Water usage of each machine (litres/kg of fresh cherry processed).
ii) Energy consumption of each machine (kWh)
iii) Speed of processing of each machine (h)
iv) Clean parchment produced (% weight)
v) Damaged parchment (% weight) determined from a 1 kg sample from each machine output.
vi) Skin in final parchment (% weight) determined from a 1 kg sample from each machine output.
vii) Mucilage loss (% weight)

11.6.3 B) Quality Analysis

Description of the Cupping Process

All the parchment samples were hulled and evaluated in the CRI cupping tasting lab from the 22nd August 07 to 10th October, 2007 by a team of cup tasters at three locations. The panels were made up of representatives from exporters, processors and CIC offices.

The main conventional cupping tests were done in the CIC office in Lae and Goroka. There were nine cuppers in Lae but the number diminished gradually and became inconsistent in Goroka.

Triangle testing was done in Goroka only. Parchment was hulled, roasted and cup tasted using the CIC standard quality assessment method. For the triangle testing only the difference between the three treatments were established which was quite simple. CIC standard method was used to establish physical and cupping characteristics of the green bean samples.

All materials and procedures followed in quality assessment of the wet processing samples to the ICO standard procedures.

Parchment Moisture Checks

Dried parchment was placed in store after drying were checked for moisture. Three 170 g samples were taken at random from each replicate and moisture content measured using a Sinar AP grain moisture meter. Samples exceeding 13% moisture were re-dried in the sun and oven drier on wet days before hulling.

Hulling of Parchment Samples

Dried parchments from the three treatments were hulled to green bean using a McKinnon sample huller with a hulling capacity of 18 kg of parchment per hour. The recovery ratio is 80%. The hulled samples were cleaned of dust and excess husk using a sample catador with a cleaning capacity of 5 kg per hour.

Weight Checks

The green bean samples were cleaned using a sample catador and weight of green beans for all 15 replicates taken using a 1-tonne capacity ‘Salter’ scale. The green beans for each of the 15 reps were divided into five samples each for distribution to five tasting facilities as indicated below.

- 1 x set of 15 x 5 kg sample lots tasted in Lae
- 1 x set of 15 x 5 kg sample lots tasted in Aiyura
- 1 x set of 15 x 5 kg sample lots tasted in Goroka
- 1 x set of 15 x 5 kg sample lots sent to exporters for independent evaluations.

- 1 x set of 15 x 5 kg sample lots distributed to exporters to send to their buyers for feed back.

Grading

The green bean samples were screened manually using a Paul Kaack shaker sieves fitted with perforated screens of different sizes. Bean sizes are determined by its width and not its length. The sizes of the holes in the screens are usually measured in sixty-fourth of an inch. The following table gives the equivalent sizes and grades.

Table 1. Screen and prescribe grade for green bean.

Grade	Metric size	Imperial size	General comments
AA	7.24 mm	No. 18	The largest prescribe grade
A	6.75 mm	No. 17	The largest normal grade
X	5.56 – 6.35 mm	No. 14 to No.16	
PB		PB	
T			

Note: Only A grade beans were used in the following quality assessments.

Defect Assessment

300 g sample of A grade for all 15 replicates for the three treatments were weighed and defect assessment carried out of the sample. Defects are bad, non-usable parts of or whole beans that contribute to the lowering of the final quality of product. The total defect per 300 g sample for the A was compared for the A was compared against the PNG Standard Green Bean Specification.

Table 2. Common Defects, their cause and Effects on Liquor

Defective Beans	Cause	Liquor flavour
Blacks	Pods dried on the tree, dead beans which have reached the final stage of aging process. Beans under water for long period.	Stinker, Foul and unclean taste.
Sours	Over/under fermentation, natural deterioration process.	Fruity, sour and fermented.
Mouldy Beans	Storage in stale conditions-lacking sunlight and ample ventilation, under-dried beans.	Stale, Earthy, Musty
Water Damaged beans	Processed in unclean water, beans collected from waterways of vats	Earthy, Stinker and Unclean.
Immature	Not fully developed beans	Harsh, hardish, greenish
Whites and olds	Aged by lengthy storage-passed use by date, loss of green pigment by chemical vapours.	Woody and lacks body

Roasting

A probat 4- barrel gas roaster was used in roasting of samples for cupping. The probat coffee roaster was heated to 190-200 ^{o}C. 150 g of trial samples were placed in each barrel using a standard scoop. The roasting temperature was maintained at 150^{o}C until the second popping when air vents were opened and the roasted bean removed from the roaster. It took about 8 minutes to roast a sample. A good medium roast was prepared for all samples.

The roasted beans were poured onto perforated plates and cooled to about 30oC and ground using a coffee sample grinder. The control on the grinder was set at fine grid as there were so many samples to taste and the brewing and extraction periods are shorter with fine grids.

Conventional Cupping

This method was used in both cupping locations in Goroka and Lae. A standard cupping form for Specialty Coffee association of America (SCAA) was used to assess all quality attributes of the wet processing trial samples. Blind tests were conducted on all samples. Blind tests were on all samples. Conventional cupping procedures prescribes by ISO were used in the quality evaluation of the wet processing trial samples according to quality assessment procedures prepared in the project document. Two of the tests that were carried out using standard/conventional cupping methods were; (1) checking for variations within each replicates and (2) checking for variations between the three wet processing treatments.

Variations within replicates

The five replicates for each treatment were compared for any major differences. Within the replicates, slight variations were expected as samples were harvested at different times throughout the coffee seasons. Eg: Rep 1A, Rep 2A, Rep 3A, Rep 4 and Rep 5A.

Variation within treatments

The three wet processing methods tested: (A) Commercial Processing, (B) demucilager, and (C) Small holder processing, were then compared between the treatments. For example Rep 1, A, B, C then Rep 2A, B, C etc.

Cup preparation

A 14 g sample of ground coffee was placed into ml 200 ml capacity white ceramic cups as per ISO recommendations (70#0.1grams coffee 100 ml). All panellists were asked to assess aroma and fragrance at dry. Boiling water of 95o was poured into each cup and aroma and fragrance assessed at break. Four cups for each replicates were prepared as two panellists were allocated to a cup for all assessments. There at least eight people in the panel.

Rainwater collected in galvanized tank was pumped to an overloaded tank (tuffa tank) and used inside the laboratory for cup preparation.

A 2 x 1 litre samples of the water were collected and sent to the National analysis Laboratory in Lea for testing. Following are the properties of the lab water.

Table 3: Coffee quality laboratory water properties

	Water parameter tested	**Concentration (ml/L**
Water sample 1	Calcium	0.6 mg/L
	Hardness (Calculation)	2.0 mg/L as Ca CO3
	Magnesium	0.1 mg/L
	pH	6.9 pH units
	Total Alkalinity	3 mg/L as CaCO3
	Total dissolved Solids	14 mg/L
Water sample 2	Calcium	0.7 mg/L
	Hardness (Calculation)	2.3 mg/L as Ca CO3

	Magnesium	0.1 mg/l
	pH	6.3 mg/L units
	Total Alkalinity	10 mg/L as CaCO3
	Total Dissolved Solids	32 mg/L

Brewing and Tasting

The cups were cleaned of excess mousse and floating solids and were left to cool down to 50-55^{o}C before tasting. It takes approximately 7-10 minutes from time preparation to tasting temperature.

Recording

The SCAA coffee cupping forms were used for each panellist assessments of all quality attributes. Scores were given according to each panellist assessment. A sample of the form is attached in the Appendix.

Triangle Testing

Composite samples were prepared by blending equal qualities of green from the fine replicates for each treatment to make Composite A, Composite B and Composite C. these composite samples were used for the triangle testing only in Goroka. From the Lea cupping results we realized that three and four of the Eco processor (B) treatment were inadequately processed. The samples were brought into store too soon when the moisture was still high therefore became mouldy. These samples were removed when composites were prepared. Triangle tests were conducted in Goroka only. Ten panellists took part in this test. Each panellist was presented with three sets of samples; two like samples and one odd sample. The panellists were asked to identify the odd samples.

Sample preparation

5 kg of ‘AA’ were taken from each replicates for the three treatments A,B and C and blended to make 15 kg each of treatment A,B, and C. Three composite samples of A,B and C were prepared.

Roasting and Grinding

The roasting and grinding procedures in sub-section XXX and XXXX were used for preparation of samples for the triangle test.

Brewing

42 g of fine ground coffee were measured into a 1 litre capacity coffee plunger. 600 ml of boiling water of 100-105 °C was poured into the plunger and stirred with a spoon. The coffee was left to stand for 5 minutes to brew before the plunger’s strainer was pushed down to the bottom to separate the solids from the liquor. The same ratio of coffee to water recommended by ISO was used (7#0.1 to 100 ml hot water).

Cups preparation

Cups for the triangle test were prepared using capacity white ceramic espresso cups. A panellist was presented with three samples sets with different combinations of the three tests treatments A, B, C. See Table 4. Of the three cup presented, two cups were same and one was different. The panellists were asked to identify the different sample.

Table 4 Combinations of the three treatments (A, B, C) given to each taster

	Panellists									
	001	002	003	004	005	006	007	008	009	010
Sample Set 1	BAA	ABA	BAB	AAB	ABA	BAB	ABB	BAA	ABA	BBA
Sample Set2	BCB	CCB	BCB	BBC	CBC	CCB	CCB	BBC	BBC	CBB
Sample Set 3	ACC	ACA	CCA	ACC	AAC	ACA	CCA	CAC	CCA	AAC

Tasting

The samples were coded and presented to each panellist to blind test. A triangle table was used for this test. Samples were prepared on the other side of the table and passed to the other side through a slot in the table wall. This was done so that the taster does not see how the samples were prepared.

Recording

A triangle test form was developed and used for recording of panellist's choice.

Results and Discussion (Processing trials)

Table 5 shows the percentage of fully ripe cherry, green cherry and overripe cherry used in the trials. Replication three had more overripe and green cherry, as there were fever cherries at the time of picking in the typical block. However, a high value of 92.36% indicates that most of the cherries used in the trial were fully ripe (Figure 3) as shown in Table 2.

Table 5. Coffee cherry used in 5 reps.

Trial date	14 June 07	27 June 07	06 June 07	20 July 07	04 August07
Fully ripe cherry %	90.4	94.4	88.96	93.64	94.19
Green cherry %	6.2	3.7	5.54	1.55	1.71
Overripe cherry %	3.4	1.9	5.50	4.81	4.10

Table 6 cherry Quality (Mean value for the 5 reps)

Rep			
	Fully ripe (Red) cherry %	Green cherry %	Over-ripe cherry %
1	90.4	6.2	3.4
2	94.4	3.7	1.9
3	88.96	5.54	5.5
4	93.84	1.55	4.61
5	94.18	1.72	4.1
Average	**92.36**	**3.74**	**3.90**

Table 7 Performance of Processing Systems (Main data from 5 replications)

Process/ Machines	Output Products	Purchase price (K)	Processing rate (kg cherry/hr)	Water usage (L/kg cherry)	Operational hours (h)	Electricity consumption
Commercial (Treatment A)	Fully fermented & fully washed	30,000	4458.13	1.57	0.39	1.83
Eco processor (Treatment B)	Unfermented & unwashed eco processed	20,000	521.62	0.33	0.37	0.55
Smallholder (Treatment C)	Fully fermented & fully washed	1,000	233.92	0.86	0.81	-

The commercial and smallholder process used different set ups but both produced fully washed parchment coffee from a fully fermented process. Eco processor used a different unit (mechanical processor) and produced unfermented and eco processed parchment.

Important processing specifications were established in (Table 3). Although the commercial unit has a high pulping rate, the amount of water is quite reasonable. From earlier assessment it was found that water usage to be up to 5 L per kg cherry. Operational hours for the three processing systems various between 0.81- 0.39 hours which was quite low. The eco processor had a lower rate of power consumption.

Table 8 Processing Outputs (Means from 5 Reps)

Machines/Process	Outputs Products	Clean Parchment %	Parchment mixed with skin %	Damaged parchment %	Mucilage loss %
Commercial	Fermented and fully washed	93.94	4.06	2.00	29.21
Eco processor	Unfermented and unwashed eco processed	91.56	7.20	1.24	14.59
smallholder	Fermented and fully washed	96.23	2.83	0.94	29.48

Table 4 data shows different results from the three processes being trialled. Although three processes were used, the comparison were made mainly between the two outputs namely, 1) Fully fermented and washed parchment 2) Eco processed parchment.

The amount of clean parchment was high for the three processes ranging from 91.56% to 96.23%, however eco processor had relatively high percentage (7.2%) skins with a parchment which was a result of less skin separation time due to high speed of pulping process. Bean damaged for all the three processes from 0.9 to 2.0% which is relatively a low value and acceptable. The mucilage loss ranges from 14.59% for eco processor to 29% for the fully washed process which are acceptable values. A value of 31% mucilage loss would indicate that mucilage has been fully removed by 100%.

Results and discussion (Processing Cupping Assessment)

The results presented below covers both physical assessment i.e. defects assessments and cup assessments. Only 'A' grade green bean was used for all quality tests.

Physical Assessment

The most dominating defects recorded for the three trialled processes were black, sour and nipped/broken beans. Other types of defects that occurred in the samples were pod, shell and immature beans (Figure 11.0).

Black beans were results of harvesting immature beans or gathering beans that have been dropped on the ground. Black beans also results from pulper nipped beans which have partly oxidized. Sour or brown beans may be caused by faulty fermentation, improper washing or over drying.

Samples from the new ecoprocessor machine produced excessive black beans as recorded compared to the other two processes. This could results from immature beans harvested and not removed properly during cherry sorting before processing. It could also result from beans injured by screws inside the machine in the process of mechanically removing the mucilage. The injured beans were oxidized during the drying process resulting in black beans.

Conventional cupping

The results for the conventional cupping are based on comments from the panellists. Scores collected from tasters have been subjected to statistical analyses and will be reported in the next draft. All comments from tasters from the two cupping locations are summarized below.

Treatment A

Comments from most panellists were not all five replicates were generally uniform with slight variations. The cups were well balanced with sharp acidity and full body and smooth aftertaste indicating good quality cups. Two panellists' comments were different because they were used to tasting coffee at much lighter roast. The samples were considered to be dark roasted. For these panellists, this test was repeated with much lighter roast. Their responses were similar to the other panellists as reported above.

Treatment B

All panellists identified replicates three and four to have unclean aroma, slightly fermented, more fruitiness and sourness and had a winy taste. The two samples were traced back and found to have been stored wet. Samples from the two replicates had mould problems. The off-flavours detected in the cup were defective due to improper drying and storage i.e. samples brought into store at higher moisture content. The problem was considered with the cups. All replicates weren't uniform with slight variations in acidity and body.

Treatment C

Generally the cups and typical PSC characteristics with high acidity medium body with chocolate caramel and floral aroma. Scores reveal uniformity in all cups. Fairly average coffee with good character and finish.

Triangle tests

The triangle test was only conducted in Goroka. A total of ten tasters participated in these tests. Exporters representatives and CIC officers participated. One panellist did not submit the form therefore only nine judges results were assessed.

Table 9 Triangle tests results

	Total judges	Correct answers	Comments	Level of significance at 5%
Sample set 1	9	5		No significant differences
Sample set 2	9	4		No significant difference
Sample set 3	9	7	Sample C fruitier sample A balanced cups	There is significant difference in sample A and C.

Note: Number of correct answers necessary to establish level of significant for nine panellists is 6 at 5% confidence limit.

Sample Set 1:

(Comparing samples on treatment A (Commercial processing) and Treatment B (Eco processor).

Of the nine judges five were able to pick the odd sample. Number of correct answers required to establish level of significance is 6. We can therefore say there is no significant difference in the two samples.

Sample Set 2

(Comparing samples from treatment B (Eco processor) and Treatment C (Smallholder processing).

Of the nine judges only three were able to pick the odd sample. Number of correct answers required to establish level o significance is 6. We can therefore say there is no significant differences in the two samples.

Sample Set 3

(Comparing samples from Treatment A (Commercial Processing) and Treatment C (Small holder Processing).

Of the nine judges seven picked out the odd sample. Number of correct answers required to establish level of significance is 6. Therefore at 5% confidence level there is a significant between the two samples.

Coffee Exporters Evaluation Report

Letters were sent with green bean samples of the three wet processing trials to eight coffee exporters for independent evaluation. To date only exporter, W R Carpenters responded back. Following are results from the exporter's evaluation (ADD Joh Edwards).

Table 10: Quality evaluation report of the wet processing samples from WR carpenters.

Estate	Grade	Marks	Green bean	Liquor	Remarks
CIC Aiyura -	A	Sample A- Commercial Sample	Rather light in colour, bean centre ,either brownish/yellowish in appearance.	Unclean ferment in cup.	Note: Sample A centres are slightly cleaner than sample B and C.
CIC Aiyura -	A	Sample B Eco processor Sample	Inferior in appearance to samples A. Paler beans, dirtier centres and appears of bean washed in unclean water. Over dried and gives an even roast.	Unclean taste, touch of ferment.	Note: Totally unsuitable of plantation coffee.

CIC Aiyura -	A	Sample C Small holder Sample	Better bean appearance than sample B, still contains unclean centres. Evenly dried coffee. Good even roast.	Best of the cups with good acidity and body. 1 cup Quite unclean and unpleasant in taste.	

Samples that were sent to exporters for independent evaluation were prepared by getting equal quantities from the five replicates and combined to get a composite sample for the three wet processing treatments. Replicates three and four for the demucilager trial were eliminated from the composite samples because of the mould problem mentioned earlier in the report. All composites were dried down to 12% before delivers were made.

Samples A was reported to have unclean ferment taste associated with liquor. This was not indicated by panellist in the Lae and Goroka tasting sessions. This taste may be attributed to excessive skin in the fermentation batch or discoloured pulping nipped beans. If this were the case, it would have been picked up by other cuppers.

Liquor report from the ecoprocessor samples (Treatment B) were similar to those reported by the panellists in the Lae and Goroka cupping sessions. There was sour, winy and unclean, ferment taste associated with the cup. The taste may be attributed by some fresh mucilage still attached in the centre cut of the beans during mechanical mucilage removal. Sour taste in the liquor is an unpleasant flavour suggestive of rotting coffee pulp. It is caused by improper fermentation resulting in a continuation of the fermentation process during early stages of drying. As suggested the attributed taste in samples B may be related to the adhering mucilage from the ecoprocessor.

Samples preparation and liquoring procedures used by the exporter is not known. Differences in such procedures will alter certain flavour attributes in the liquor.

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Conclusions

The three processors appear to have a good rate of pulping and eco-processing. There was no cost of electricity for the small holder process as it was manually operated but high processing time whilst ecoprocessor had the lowest processing time.

In terms of quality output, fermented processes produced high quality out put compared with ecoprocessor. Eco-processed quality was also good quality in general although the cup features were non traditional and thus creating a new market opportunity for PNG coffee.

Fermented systems had low defects compared with ecoprocessor.

All the three systems have a high potential to fetch a top premium and exchange grade according to the SCAA classification based on their level of defects and cup characteristics.

Quality results from cupping sessions conducted at the two locations as well as those submitted by one exporter for the wet processing trial conducted this season can be summarized in Table 11.

Table 11: Quality attributes of coffee processed under the three wet processing facilities.

Wet Processing Treatment	Export grade	Defect level recorded	Physical attribute	Cup quality attribute
Commercial	A	9	Light green in colour with brownish/yellowish centres	Sharp acidity, full body and smooth aftertaste. Well balanced cups.
Demucilager	A	15	Pale beans with inferior appearance and dirty centres.	Harsh, flat cups with strong astringent, pungent taste slightly lacking body and acidity. A hint of sour, winey and ferment taste.
Smallholder	A	10	Light green in colour with brownish/yellowish centres.	High acidity, medium body with chocolate, caramel and floral aroma. Fairly average coffee with good character and finish.

The three processors trialled produced three different coffees with different cup characteristics. There was however changes of improper drying and storage resulting in mouldiness in other replicates. The quality characteristics identified for each product were different however not detective.

The triangle test (test of difference) confirmed that coffee produced from the three processes were different and had different cup characteristics.

Recommendations

On the basis of favourable processing specifications (less processing time and consistency), ecoprocessor is recommended although there was a non traditional flavour. We are hopeful that the unique quality can be a marketing opportunity for the PNG farmers because it shared some common features of coffee from major coffee growing countries.

It is suggested that the three treatments be repeated next coffee season with proper attention on processing. A new moisture meter is required to replace the existing one as it is not functioning at present. Following are some recommendations made at the Exporters Council Meeting in Lea.

1. Storage studies followed by quality evaluation to be undertaken on ‘ecoprocessed’ coffee. This concern was raised as from the conventional processing methods, coffee can hold for up to eight weeks in containers during exports. Need to established storage life of ‘ecoprocessed’ coffee during exporting.
2. Studies of ‘ecoprocessed’ coffee being washed prior to drying.
3. Underwater soaking of ‘ecoprocessed’ coffee for at least 8 hours before washing.
4. Test other brands of ecoprocessor on the market