FOOD QUALITY AND SAFETY OF SOLAR DRIED FRUITS AND VEGETABLES IN THE BUTHA-BUTHE DISTRICT, LESOTHO

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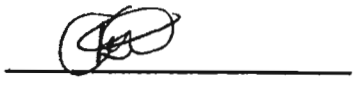
Declaration

I hereby declare that the research in this dissertation is of my own investigation. Where use was made of the work of others, this has been duly acknowledged in the text.



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ABSTRACT

This study investigated the quality and safety of solar dried fruits and vegetables produced by households in three locations in the Butha-Buthe district of Lesotho from November 2002 to March 2003. The aim of the study was to enhance year round availability of fruits and vegetables and reduce post-harvest losses, contributing to increased food availability and accessibility in the district.

The study analysed the quality and safety of dried fruits and vegetables by assessing the processing techniques applied by the respondents during the production of dried fruits and vegetables, analysing the quality of dried fruits and vegetable samples produced by the study respondents using Appropriate Technology Section (ATS) solar driers, and by identifying the constraints that hamper the improvement of quality and safety of solar dried fruits and vegetables in the study area. Data was collected through focus group discussions, interviews, and laboratory food quality analysis of dried fruit and vegetable samples provided by the respondents.

The dried fruits and vegetables produced by the respondents were of low quality due to poor processing techniques and unhygienic practices that increased chances of contamination and deterioration during processing and storage. Lack of processing skills and information, particularly on quality and safety standards, and weak extension support contributed to poor product. For the respondents to improve the quality and safety of dried fruits and vegetables, they need training and support with respect to quality and safety that includes training on the importance of food safety, best processing and storage practices and marketing of dried produce.

ABBREVIATIONS

ATS	Appropriate Technology Section, Ministry of Local Government
FAO	Food and Agriculture Organisation
FNCO	Food and Nutrition Cooordinating Office, Lesotho
GMP	Good manufacturing practices
GoL	Government of Lesotho
HAACP	Hazard Analysis Critical Control Point
IFPRI	International Food Policy Research Institute
ISO	International Standards Organisation
ITDG	Intermediate Technology Development Group
LVAC	Lesotho Vulnerability Assessment Committee
MOLG	Ministry of Local Government
NRI	Natural Research Institute
NGO's	Non Governmental Organisations
UN	United Nations
UNAIDS	United Nations Aids
UNCEF	United Nations Children Emergency Fund
UNDP	United Nations Development Programme
UNIFEM	United Nations Development Fund for Women
WFP	World Food Programme
WHO	World Health Organisation

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CHAPTER 1
THE PROBLEM AND ITS SETTING

1.1 Importance of the study

The majority of rural Lesotho households rely on agriculture for food (Sechaba Consultants and CARE Lesotho 2001). Recently, agricultural production has declined due to soil and land degradation, poor crop husbandry practices, erratic and unreliable rainfall, and almost non-existent extension services (FAO and WFP 2002). Lesotho's food shortages are further compounded by limited and seasonal availability of crops and absolute shortages of food in the 'hungry period' preceding harvests (LVAC 2002). The country is prone to natural disasters, the most serious being drought that occurs on average three years per decade (Cook 2002). Post-harvest losses due to poor processing and storage also exacerbate the problem of food shortages in Lesotho (FNCO and Multi-Sectoral Taskforce 1997).

According to United Nations Development Programme (UNDP) human development report for 2002, 43.1 percent of Lesotho's total population live below US$2 a day (UNDP 2002). An assessment on crop and food supply in Lesotho, by Lesotho Vulnerability Committee (LVAC) in 2002, estimated that 450,000 people in Lesotho (21 percent of the population) required targeted food aid to maintain acceptable nutritional levels over the period 2002 to 2003 (LVAC 2002). According to a rapid assessment survey on nutritional status of under-fives in Lesotho by the Food and Nutrition Coordinating Office (FNCO) and UNICEF in 2002, 15.4 percent of children aged 0-59 months were found to be underweight, 8.9 percent of children aged 6-59 months needed vitamin A supplementation, 30.7 percent of children aged 0-59 months were stunted and the rates of wasting were found below the 15-20 percent levels which are considered by WHO to be a nutritional emergency (FNCO and UNICEF 2002). The findings from the assessments above show high levels of food insecurity in Lesotho. Sustainable interventions to alleviate the worsening food security situation are urgently needed.

Access to stable and sustainable food supplies is a precondition to the establishment of food security at household level (FAO 1997). Food self-sufficiency in Lesotho cannot be achieved only by increasing agricultural production but also by reducing crop post-harvest losses through processing and proper storage (FNCO and Multi-Sectoral Taskforce 1997). It may be possible to improve household food security in Lesotho by increasing food availability and

access through promoting food preservation activities among poor households (FAO and WFP 2002). Increasing food processing through the establishment of appropriate and improved technologies for home preservation such as solar drying of fruits and vegetables can ensure year-round availability and variety of micro nutrient rich foods (FAO 1997).

Preserving seasonal foods by solar drying is an effective and cheap method of processing and preserving foodstuffs until the next crop is harvested because it uses the natural resource, sunlight, and simple equipment (solar drier) to increase the efficiency of the sun's energy to dry food (UNIFEM 1995). Foods preserved by drying can be kept at ambient temperatures for long periods and provide nutrients when fresh produce is not available (FAO 1997). Solar drying transforms highly perishable fruits and vegetables into products that can be transported for long distances and can be stored (FAO 1997).

In Lesotho, vegetables are traditionally grown in small garden plots and fruit trees are usually planted around the house to provide shade and wood (FNCO and Multi-Sectoral Taskforce 1997). Still, Lesotho suffers from shortages of fruits and vegetables since the country relies largely on imported produce (Moletsane and Wyeth 1994). According to Moletsane and Wyeth (1994), Lesotho produces only 40 percent of its total annual consumption requirement of fruits and vegetables. The remainder is supplemented by importation, mainly from the neighbouring Republic of South Africa (Lesotho Bureau of Statistics and FAO 2002). This seasonality of production of fruits and vegetables in Lesotho impacts negatively on availability for households throughout the year (Mofubetsoana 1995).

In Lesotho, the sun shines almost 300 days in a year and summers are usually hot (Lesotho Meteorological Services 2003). Despite the abundant sunshine, Lesotho's Food and Nutritional Coordinating Office (FNCO), has indicated that fruits and vegetables that are available during November to March go to waste each year because of lack of knowledge on how to preserve them (FNCO and Multi-Sectoral Taskforce 1997). This could be attributed to using traditional methods of processing, which are largely inadequate, particularly with respect to food quality and safety (Mofubetsoana 1995). Most small-scale food processors have limited technical and managerial skills, coupled with inadequate business premises and infrastructure (Ammorigi 1999). Little research has been carried out in Lesotho with regard to small-scale solar drying of food. Therefore households lack access to information about relevant and appropriate technologies (Mofubetsoana 1995).

This study highlights the potential contribution household processing of fruits and vegetables by solar drying can make to the overall development of Lesotho's agricultural sector and food security. The study is very relevant in Lesotho in view of the current famine faced by the country and declining agricultural production. The study also provides information to policy makers and extension workers in promoting the importance of preserving fruits and vegetables among households in order to enhance household food security through improved nutrition, increased household income and increased dietary diversity.

1.2 Statement of the problem

Investigation of the quality and safety of solar dried fruits and vegetables produced using the Appropriate Technology Section (ATS) solar drier in the Buthe-Buthe district, Lesotho.

1.3 Sub-problems

Sub-problem 1: To assess the processing techniques applied during the production of dried fruits and vegetables by selected households in Butha-Buthe district, who have purchased ATS solar driers following training in using them by ATS dissemination officers.

Sub-problem 2: To analyse the quality and safety of solar dried fruits and vegetables produced by households using ATS solar driers against Joint FAO and WHO codex alimentarius food quality standards for processed fruits and vegetables in Butha-Buthe district.

1.4 Hypothesis

The production of quality and safe dried fruits and vegetables using a solar drier, is an efficient and sustainable way of extending the shelf-life of fruits and vegetables, thus increasing the availability of fruits and vegetables in the Butha-Buthe district, Lesotho.

1.5 Conceptual frame work

Figure 1.1 illustrates the conceptual frame work for this study and the relationship between the various parameters that were investigated. The study investigated various parameters that influenced the quality and safety of dried fruits and vegetables in Butha-Buthe district. These parameters included: preparation of fruits and vegetables for drying, processing steps such as slicing, treatment of fruits with preservatives and salts, vegetable blanching, drying,

packaging, and storage of the dried products. The study also investigated quality assurance and control during the processing stages such as application of good manufacturing practices (GMP), and inspected the quality and safety of the final dried products through laboratory quality control tests. Socio-economic and environmental constraints that impact negatively in the quality and safety of the dried fruits and vegetables were investigated as poor quality products result in products with a short shelf-life due to poor storage properties (figure 1.1).

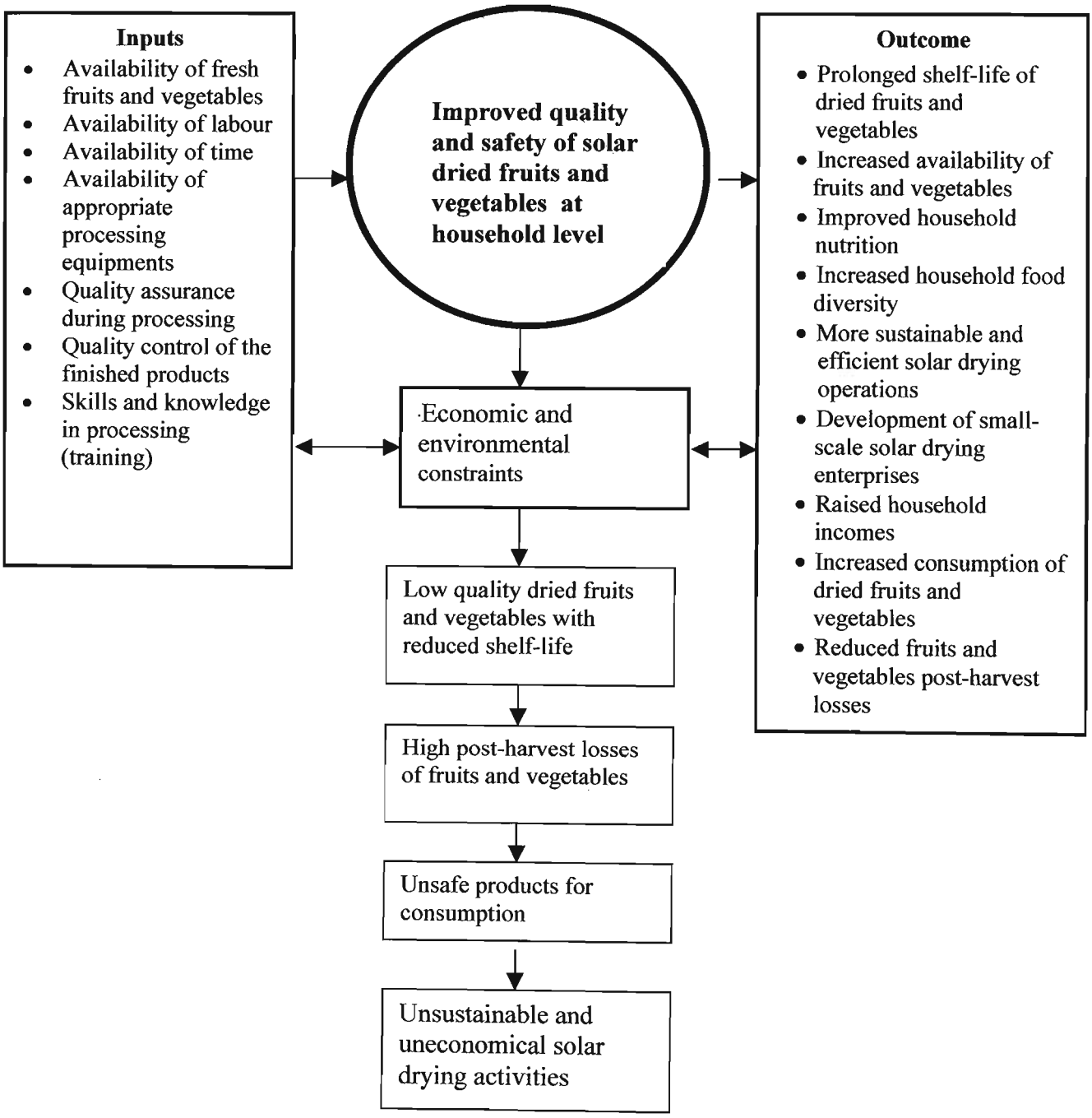

Figure 1.1: Conceptual framework

1.6 Study limits

First, the nutrient composition of the dried fruit and vegetable samples was not analysed. Second, market research to establish the market potential for the dried fruits and vegetables was not carried out. Third, the study did not compare the quality and safety of fruits and vegetables dried using other methods of drying such as open air drying and mechanical drying. Fourth, the study did not assess the practices of cultivation of fruits and vegetables even though the quality of raw material for processing influences the quality of the finished products. Lastly, the study did not investigate the solar drying of other products such as tubers, herbs and meat for the purposes of comparison.

1.7 Study assumptions

It was assumed that the respondents were willing to donate dried fruit and vegetable samples for laboratory quality analysis. It was also assumed that the respondents had sufficient produce to dry, that is, had surplus produce. The data collection tools were designed in English, then translated into Sesotho for data collection and translated again in English for data capturing. It was assumed that the translations were accurate.

1.8 Organisational structure of the thesis

The background and purpose of this study has been outlined through the description of the problem, conceptual framework, hypotheses, study limitations and, assumptions in Chapter one. Chapter two presents a review of literature on solar drying, its impact on household food security and factors that affect the quality and safety of dried products. The description of survey area and characteristics of the sample are given in Chapter three. The methodology of the study is given in Chapter four, which describes the sample selection and research design. Chapter five presents the results of the study, from the process and environmental conditions influencing the quality and safety of solar dried fruits and vegetables by respondents such as raw material, production process flow such as selection, preparation, storage, quality assurance and constraints. Chapter six presents results from laboratory quality control tests on the dried fruit and vegetable samples from the respondents. Lastly, Chapter seven presents the conclusions and recommendations for the study and implications for further research.

CHAPTER 2
REVIEW OF RELATED LITERATURE

Agriculture is the cornerstone of most developing country economies (Azam-Ali *et al.* 1996). Unfortunately, agriculture alone is often unable to provide sustainable livelihoods for growing populations in these countries (Anon 1996). Alternative or additional food and income generating opportunities are needed to support millions of poor families who cannot longer support their livelihoods from agriculture production alone (Anon 1996). Increased and diversified production of food for family consumption or as a source of income is a basic prerequisite for improved household food security (FAO 1997).

With the right processing, fruits and vegetables have the potential to assist rural households in developing countries enhance food security (Anon 2004). In Sub-Saharan Africa for example, fruits and vegetables are the most accessible agriculture products and natural solar energy (the sun shines consistently for most of the year in these countries) can be utilised (Azam-Ali *et al.* 1996). However, the availability of many fruits and vegetables is seasonal, creating cycles of abundance and scarcity (FAO 1997). When harvested, fruits and vegetables undergo rapid deterioration, especially in humid climates where prevailing conditions accelerate post harvest deterioration (Anon 1996). For example, the post-harvest losses of fresh fruits and vegetables have been estimated to range from 20 percent to 60 percent in the developing countries, limiting availability and consumption (UNIFEM 1995).

Fruits and vegetables are therefore not seen as important livelihood opportunities by rural communities, due to seasonal availability, poor keeping quality, long distances to markets, and poor conditions of many rural roads (Azam-Ali *et al.* 1996). This makes it impossible for most rural communities to use fruits and vegetables as sustainable sources of food and income (FAO 1997). The processing of fruits and vegetables can reduce post-harvest losses and extend shelf-life, improving availability (Mircea 1995).

There are several methods for preserving fruits and vegetables, such as freezing, canning (pickling, chutneys, jams/jellies, and juices), vegetable fermentation (sauerkraut), fruit

fermentation (wines, vinegar) and drying (sun and solar drying) (Mircea 1995). However, many methods are inappropriate for use at household level especially in the developing countries (Azam-Ali 2002). For example, canning of vegetables at household level may have safety implications such as contamination with pathogenic microorganisms resulting in diseases such as botulism (Marina 1991). Many vegetables are not acidic and many spoilage and pathogenic microorganisms can grow in alkaline conditions (UNIFEM 1995). On the other hand, canning of fruits involves more expensive equipment and skills than most processing methods (Anon 2004). Freezing may not be possible at household level, especially in developing countries, due to of lack of electricity and freezing equipment (Azam-Ali *et al.* 1996).

Solar drying is possibly the most appropriate way of preserving many fruits and vegetables (UNIFEM 1995). It has the advantage of being a traditionally understood technology, equipment costs are low, and it is well accepted in developing countries as it uses technology similar to traditional sun drying (a very old method of preserving food) (UNIFEM 1993). Solar drying is carried out to preserve fruits and vegetables by reducing their water content below that which supports the growth of microorganisms and the action of oxidative and hydrolytic enzymes and biochemical activity (Fellows 1997). In solar drying, fruit or vegetable slices are spread over stainless metal trays or screens, which are placed in the sun to dry (Gustavo *et al.* 2003). The dried fruits and vegetables products are then packaged in plastic bags, glass or bottles. When packaged this way, their shelf-life can extend for 6-12 months and beyond substantially reducing the weight and volume of produce, minimising packing, storage and transportation costs and enabling storage under ambient temperatures (Mircea 1995).

2.1 Solar drying of fruits and vegetables in promoting household food security

Preserving foods expands the utility and productivity of farm produce, which may be surplus during peak seasons but scarce during off seasons and helps smooth availability and access (Anon 1996). For example, in developing countries, fruit trees tend to produce in flushes and fresh fruits are highly perishable (UNIFEM 1993). This is especially true of mangoes, pineapples, peaches and bananas (UNIFEM 1995).

An important aspect of food processing is that it permits greater dietary diversity, giving households access to a wider range of vitamins and minerals than they would otherwise

consume (FAO 1997). When included in household's diets, dried fruits and vegetables can contribute significantly to household nutrition (Azam-Ali 2002). Dried fruits have a higher concentration of sugar than their fresh counterparts as most water is removed in drying (Proudlove 1992). Therefore, there are more calories in dried foods than in fresh foods on a weight for weight basis (Gilbert 2004). Dried fruits are rich in riboflavin and iron (Proudlove 1992). Dried vegetables are a good source of minerals, B vitamins, riboflavin and niacin (Judy 2000). Both dried fruits and vegetables provide useful amounts of digestive fibre (Proudlove 1992).

Processing fruits and vegetables offers many income generating activities for rural households that directly improve their food security status (FAO 1997). Agro-processing can also stimulate demand for farmers' crop and products and give consumers additional choices (Azam-Ali 2002). Agro-industries convert commodities into processed foods that are usually more stable and fetch higher prices in the market than the raw untreated commodity (Anon 1996). In sub-Saharan Africa, it has been estimated that 60 percent of the labour force finds part of its work in small-scale food processing (Anon 1996). An example of a successful application of solar drying is the production of desiccated coconut in Bangladesh (Azam-Ali *et al.* 1996). One enterprise is owned by a group of women who use cabinet solar driers to dry grated coconut, which is sold in Dhaka (Azam-Ali *et al.* 1996). The growth of solar drying enterprises can thus generate employment and contribute to diversifying the economy through reduction of fruit and vegetable imports and adding marketable products to local markets (Marina 1991).

2.2 Use of solar driers in improving the quality and safety of dried fruits and vegetables

Drying foods by traditional approaches where the produce is simply spread on mats on the ground, stone surfaces or house roofs to dry, have many limitations (Mircea 1995). Such drying is slow, irregular and can increase the risk of spoilage (Marina 1991). Traditional sun-drying can also give rise to a number of hazards such as natural decay as a result of exposing the food for a long time in warm moist conditions, ideal for the growth of destructive and sometimes toxic moulds (Fellows 1997). Exposing the food in this manner makes it difficult to prevent theft. Sudden rainstorms can soak the produce (Azam-Ali *et al.* 1996). Traditional open sun drying exposes produce to animals, insects, dust, dirt and many forms of

contamination (Marina 1991). Open drying exposes the produce directly to solar radiation, that can cause darkening (colour changes) and loss of vitamins and flavour (UNIFEM 1995). Also, large areas of land are required for spreading the product out to dry (Ammorigi 1999). Produce dried in traditional open sun drying may be of low quality and cannot be expected to keep well during storage, because there is minimal control over hygiene and little control over humidity, temperature and the speed of drying (UNIFEM 1995).

Solar driers have been developed to overcome the shortcomings of traditional methods of drying and involve the use of some structure to collect and intensify the sun's heat (UNIFEM 1995). Solar drying is based on the principle of absorption of heat from solar radiation by a black surface (UNIFEM 1993). Solar driers raise the internal chamber's temperature by between 10^0C and 30^0C above room temperature (Marina 1991). For example, using the solar dryer, 80 to 90 percent of the moisture content of the drying produce, will be evaporated in 10 to 40 hours, (depending on the moisture content of the food item and the atmospheric temperature) while it takes more than 100 hours to dry the food in the conventional, open air method (Kerr 2004). The temperature inside the solar drier can be maintained at 60^0C to 70^0C, which minimises the damage to the vitamins and other nutrients (ITDG 2002). The higher temperatures generated inside the drier also act as a deterrent to insect and mould growth (Fellows 1997).

Solar driers offer a considerable degree of protection from rain, which reduces the need for labour to bring drying produce in if the weather should change (Kerr 2004). The product is also protected from dust and insects within the drier (ITDG 2002). Drying is quicker, and if racks are used to increase the capacity for drying inside the drier, less space is needed for spreading the produce (Azam-Ali *et al.* 1996). On average, five kilograms of food can be dried in a drier of $1m^2$ x $0.5m^2$ (UNIFEM 1995). Solar driers are comparatively cheap to build, do not require skilled labour and do not require sophisticated building materials i.e. they can be built of locally available materials (UNIFEM 1995).

The Danish Association for International Cooperation, Uganda's Hoima Nursery Schools Development Association, and Gukvatamazi Farmers' Association have introduced locally made solar driers to small-scale and community-based farmers (Arfaoui 2001). The solar drier is designed from basic material found in the community and it is constructed by local craftsmen (figure 2.1).

Figure 2.1 A solar drier developed and promoted by Uganda Hoima Nursery Schools Development Association (Arafoui 2001 p.4)

The sun shines through the clear polythene onto the fruit, heating the interior of the drier and the air moves upward by convection, carrying moisture away from the trays and out of the drier (Arafoui 2001). In Burkina Fasso, the Cercle Des Secheurs, a small co-operative in Ouagadougou, have designed simple solar driers with the help of Centre Albert Schweitzer (Azam-Ali *et al.* 1996). The driers are covered with plastic resistant to damage by the sun (Sebag and Tougoma 2002). Mangoes have been successfully dried in these driers and have been exported to the United Kingdom (Sebag and Tougoma 2002).

When considering solar drying, it is important to encourage technical specialists, extension workers, and food processors to field test, adapt and transfer this technology to the rural communities and ensure that local technical institutions are able to provide continuing and local long-term support (UNIFEM 1995). Golletti and Wolf (2004) argue that solar driers must be adapted to suit local climatic conditions, local crops to be dried and construction materials should be locally available (Golletti and Wolf 2004). Also, correct processing of the product to be dried, followed by correct storage of the dried produce, is required for improved quality and safety (Fellows *et al.* 1995).

2.3 Processing of fruits and vegetables by solar drying in Lesotho

In Lesotho, fruits and vegetables make good relishes for staple cereals, namely maize and wheat (FNCO and Multi-Sectoral Taskforce 1997). Most fruits are eaten fresh when in season as appetisers, snacks, or desserts (Mofubetsoana 1995). Vegetable varieties include those grown in home gardens such as Swiss chard, pumpkin leaves, onion tops, turnip leaves, beetroot leaves, cabbage and wild vegetables (*sepaile, theepe, papasane, lishoabe) (*Moletsane and Wyeth 1994). Fruits include wild peaches, prunes, apricots, and cultivated apples, peaches and apricots (Moletsane and Wyeth 1994). The availability of fresh fruits and vegetables is seasonal. For example during winter, vegetable and fruit cultivation is curbed by the harsh cold winters and scarcity of fresh fruits and vegetables is experienced (FNCO and Multi-Sectoral Taskforce 1997). Not only are fruit and vegetable imports increased during this time, but prices rise considerably, restricting access to their purchase for most households (Moletsane and Wyeth 1994).

An assessment of the technology needs for Lesotho by the Appropriate Technology Section (ATS), of the Ministry of the Local Government (MOLG) showed that preservation of fruits and vegetables is the most widely practised food preservation activity carried out in Lesotho (table 2.1). Households in Lesotho preserve small amounts of leafy vegetables and fruits (MOLG 2000). This has little impact on improving the availability of fruits and vegetables during the scarce seasons (FNCO and Multi-Sectoral Taskforce 1997). Traditional solar drying practices employed by households in Lesotho are largely inadequate to produce high

quality products. Preserved fruits and vegetables have a short shelf-life (MOLG 2002). Most dried fruits and vegetables sold in shops in Lesotho are imported from South Africa (Moletsane and Wyeth 1994).

Table 2.1 Methods of food preservation used by households in Lesotho, n=1510 households (MOLG 2000)

Food	Preservation method used by households			
	Drying	**Bottling**	**Fermentation**	**Freezing**
Meat	486	0	0	55
Milk	0	0	501	38
Fruits	533	281	0	0
Vegetables	673	0	0	14

There are projects in Lesotho to increase the productivity and availability of fruits and vegetables. One example of such a project is a project focusing on encouraging orchards and vegetable gardens in Lesotho (FNCO and Multi-Sectoral Taskforce 1997). This project is intended to improve fruit quality and varieties and address environmental concerns such as soil erosion. It is hoped that increasing awareness of the value of food processing, and information on solar drying technologies, will reduce prevailing deficiencies in micro-nutrients, contribute to improved household food security and reduce soil erosion (FNCO and Multi-Sectoral Taskforce1997).

2.4 Quality and safety improvements to dried fruits and vegetables during processing

Food safety and quality control ensure that desirable characteristics of food are retained throughout food production, handling, preparation, processing, packaging, and distribution (FAO 1997). This in turn can promote healthy diets, reduce food losses and encourage domestic and international trade (ITDG 2002). For example, to produce good quality dried fruits and vegetables that are acceptable for both home consumption and markets, there are several factors to consider including availability of fresh produce of good quality, careful handling before processing; efficient preparation of produce; correct loading and operation of

the drier; drying to correct moisture content; proper packaging and storage of the dried product (Fellows 1997; NRI 1996). To ensure the production of safe products fit for human consumption, there must be efficient management of all operations to assure quality, to minimise loses and maximise the shelf-life of the dried product (Fellows *et al.* 1995).

During solar drying, nutrients such as vitamin A and ascorbic acid are often greatly reduced, but solar drying also reduces the water content of produce and so increases the concentration of nutrients (FAO 1997). The extent of the nutrient loss depends on the pre-treatment applied, drying temperatures, duration of the drying process and post-processing storage conditions (Ammorigi 1999). The preparation of fruit and vegetables usually involves the following steps: selection; washing; peeling (for some produce such as tomatoes peeling is unnecessary); cutting; slicing; drying; packaging and storage (table 2.2) (Fellows 1997).

All selected fruits and vegetables should be of the highest quality and at optimal levels of maturity (Fellows *et al.* 1995). Produce attacked by insects, rodents, diseases and discoloured product parts must be removed before drying (Mircea 1995). The stages should be carried out under the most hygienic conditions possible (Fellows 1997). Most vegetables are blanched prior to drying (UNIFEM 1993). Blanching means dipping the prepared vegetables in boiling water or suspending the produce in steam, for a few minutes, followed by cooling in ice-cold water to prevent further cooking (UNIFEM 1993).

Blanching helps to retain minerals and vitamins, gives better colour and flavour, reduces the microbial load and also reduces the time needed for soaking before cooking (UNIFEM 1995). For example, blanching destroys enzymes that are responsible for changes in flavour, colour and texture during drying and storage (Fellows 1997). Blanching reduces the loss of vitamins A, C and thiamine during dehydration and storage (Gilbert 2004). Blanching also helps to clean the produce and reduce microoganisms population present on the product surfaces (Mircea 1995).

2.2 Table 2.2 Preparation procedures for fruits and vegetables before drying (Fellows 1997, p.20)

Product	Common preparation procedures for drying fruits and vegetables						
	Cleaning	**Sorting/ Grading**	**Peeling**	**Size reduction**	**Blanching**	**Salting**	**Sulphuring**
Fruits	Needed for all fruits	Important for all fruits	Required for most fruits	Larger fruits cut for faster drying	Not usually done for fruits	Used for very few fruits	Treatment for some fruits to prevent browning
Vegetables	Needed for all vegetables	Important for all vegetables	Used for some vegetables	Slicing for larger vegetables or shredding cabbage	Commonly used for softening and preventing browning	Used for some salted products e.g. cabbage	Used with few light coloured vegetables to prevent browning

Sulphur dioxide is the best antioxidant treatment for preserving colour and retarding the growth of yeasts and moulds in fruits and some light coloured vegetables (Ammorigi 1999). Sulphur also helps prevent loss of vitamins A and C (UNIFEM 1995). Sulphur dioxide can be produced for use in fruit drying in two ways (Ammorigi 1999). First, sulphur can be burnt in a sulphur chamber to produce sulphur dioxide gas, which permeates into food tissues. Second, produce can be soaked for 10 minutes in a solution of sodium sulphite or sodium metabilsulphite (Ammorigi 1999).

The prepared fruits and vegetables should be loaded onto the drier trays very carefully and packed as closely together as possible but with no overlapping (NRI 1996). The solar drier should be positioned on a flat surface unobscured by trees or buildings, so that it is fully exposed to the sun throughout the day (UNIFEM 1995). Under fine weather and sunny conditions the fruit and vegetable slices should dry after one or two days respectively (NRI 1996). The fruit slices are dry if it is not possible to squeeze out moisture from the slices. Vegetables are sufficiently dried when they are hard and brittle or tough and leathery, depending on the vegetable (Fellows *et al.* 1995).

2.5 Packaging and storage to improve the quality of dried fruits and vegetables

The basic objective of storage is to create the appropriate environmental conditions that provide sufficient protection for the product to maintain its quality and safety, and reduce product losses (UNIFEM 1993). Packaging and storing dried products requires special attention (NRI 1996). Once dried, the product should be protected from sunlight, moisture, and heat to prevent the development of off-flavours, colour changes and spoiling (UNIFEM 1993). Pottery, glass, metal, or plastic containers are all suitable for packaging dried fruits and vegetables as long as they are sterile and be properly sealed (ITDG 2002). Availability of suitable glass packaging is a constraint in many developing countries without glass producing facilities (ITDG 2002). In such situations, it is common practise to use recycled glass containers and cheap polythene bags (UNIFEM 1993).

Dried fruits and vegetables should be packaged and stored immediately after drying to avoid re-absorption of moisture and reduce attacks by insects and other pests (NRI 1996). Mofubetsoana (1995) has shown that dried fruits and vegetables packaged in thin polythene bags in Lesotho not only contained a higher moisture content than those stored in glass jars, but also experienced attack by insects and rodents (Mofubetsoana 1995). To prevent such damage, dried foods packaged in plastic bags should be placed in an outer container (plastic or glass jars) for extra protection against light, moisture and pests (UNIFEM 1995). Thorough washing and preparation of packaging material is crucial since a good product packaged into a dirty container will soon deteriorate (Fellows *et al.* 1995). The packages, should be stored in a cool dry place protected from light, rodents and other pests (NRI 1996). Most dried fruits and vegetables should stay wholesome for up to about one year if packaged and stored correctly (Kerr 2004).

2.6 Quality assurance and safety during processing of dried fruits and vegetables

Seventy percent of diarrhoea cases that occur in developing countries are of water or food borne origins (FAO 1997). Some factors that affect food quality and safety in developing countries include: poor physical quality, contamination with poisonous chemicals, bacterial or parasitic contamination, fungal and mycotoxin contamination, rapid rotting, other biological contamination (rodents and insects) and poor quality control of industrial or cottage-industry products (Fellows *et al.* 1995).

An important element in food marketing is the food quality control procedures necessary to ensure that food, whether raw, semi-processed, manufactured or prepared is safe, of high quality and nutritionally sound (FAO 1997). For example, dried fruits and vegetables do not allow microorganisms to grow provided that drying is carried out correctly and the food is stored under proper storage conditions (protected from light, moisture, rodents and other pests) (Mircea 1995). However, if the food is contaminated before drying, or if it is allowed to get damp during storage, micro organisms can grow (Ammorigi 1999). In addition to microorganisms, naturally occurring enzymes rapidly change the colour, flavour and texture of fruits and vegetables after harvest (Fellows *et al.* 1995). Therefore, during the processing

of dried fruits and vegetables, good processing practices and good hygiene must be practised (Dominic 2003).

Quality and safety of dried fruits and vegetables during processing can be controlled by implementing a management method known as Hazard Analysis Critical Control Point System (HACCP) (Fellows 1997). HACCP involves identifying critical stages during processing that may undermine the quality and safety of the final product (Anon 2004). These stages are identified as control points and quality control checks are made at these points to control the production process (Fellows 1997). Use of a quality operation in which the critical control points are identified and controlled during processing should be established (UNIFEM 1995).

Details of critical points where control is needed to ensure food safety during processing of fruits and vegetables by solar drying are summarised in figure 2.2. The quality checks ensure food quality is as high as possible (UNIFEM 1993). For example, inspection of raw materials should be carried out before processing to ensure that only sound fruit and vegetables that are sufficiently matured are used for processing and they should be processed as soon as possible after harvest to reduce the risk of spoilage before processing (UNIFEM 1995). The selected fruits and vegetables for processing should be washed absolutely clean to rid them of dirt, insects and extraneous plant material (Mircea 1995).

Each processing step should be assessed and an associated potential quality risk established (Fellows 1997). For example, the temperature of blanching water and blanching time should be adequate to destroy enzymes and microorganisms (Fellows 1997). The amount of sulphur used should be determined and also the time of exposure to the produce (Mircea 1995). During drying on the drier trays, care should be taken to minimise contamination by dirt and other contaminants, and so the drier should be well covered (Fellows 1997). Packaging should be done in a clean environment and the packaging material should be clean (UNIFEM 1995). The dried products should be stored under good storage conditions sufficient to maintain the products quality and shelf-life (UNIFEM 1993).

Stage in process Essential/Optional	Quality check (quality assurance)	Equipment needed
Harvest	check for full maturity but not over over-ripe	
↓		
Wash	to remove contaminants	wash tanks or special washers
↓		
Sort/grade	essential to produce uniform quality products	
Peel	check that all traces of peel are removed	knives, peelers
Cut/Slice/ core	check for uniform sized pieces	fruit and vegetable choppers, cutters or slicing machine
Blanch	check blancher water, temperature, time of heating and concentration of any salts added	boiling pan, heat source, wire basket, or steamer
Acid dip and Treatment with sulphur or sulphur dioxide	check concentration of acid check weight of concentration of sulphite and time of treatment	weighing scales or scoops, food grade plastic tank
Dry	check rate of drying and temperature of drying, check for mould growth and insect contamination	solar dryer, fuel fired dryer or electric dryer
↓		
Pack→Packages	check full-weight and correctly sealed pack	electric heat sealer for plastic bags, candle and wire
↓		
Label and store	check that label and storage conditions are correct	labels

Figure 2.2 Summary table of main quality control points for dried fruits and vegetables (Fellows 1997 p.26)

In addition to the establishment of a HACCP system, there should be checks by the processor on all factors relating to hygiene during processing (Fellows *et al.* 995). For example, utensils and equipment surfaces that are in contact with food must be cleaned often to prevent food contamination (FAO and WHO 1999a). Equipment surfaces that are not in contact with food should also be cleaned frequently to minimise accumulation of dust, dirt, food particles (ITDG 2002). Any water that comes into contact with food or processing equipment must be safe and of adequate sanitary quality (Mircea 1995).

Any person who has an illness, open lesions (including boils, sores and infected wounds), or any other abnormal source of microbial contamination must not work in a food processing centre or in areas where they could be in contact with food, food-contact surface, or food packaging materials (Fellows *et al.* 1995). People who work in direct contact with food preparation and food ingredients, equipment or utensils that will contact food must wear clean outer garments, maintain a high degree of personal cleanliness and conform to hygienic practices while on duty. They must also wash their hands thoroughly and where possible, sanitise their hands before starting work, after each absence from the workstation and at any other time when the hands have become soiled or contaminated (FAO and WHO 1999a).
All necessary steps have to be taken by supervisors to prevent operators from contaminating foods with microorganisms or foreign substances such as perspiration, hair, cosmetics, tobacco, chemicals and medicines (Ammorigi 1999). People who handle food, should remove all jewellery that cannot be properly sanitised; wear effective hair restraints (such as hairnets, caps, headbands or beard covers) and must not store clothing or any other personal belongings in food processing areas (FAO and WHO 1999a).

Eating, drinking beverages or smoking must not be allowed in food processing areas. Food handlers and supervisors should receive training that will make them aware of the danger of poor personal hygiene and unsanitary work habits (ITDG 2002). Grounds around a food processing area must be free from improperly stored equipment, litter, waste or refuse; uncut weeds or grass close to buildings; excessively dusty roads, yards or parking lots; inadequately

drained areas (potential breeding places for insects or microorganisms) and inadequately operated systems for waste treatment and disposal (Fellows *et al.*1995).

2.7 Laboratory Quality Control of dried fruits and vegetables

In most developing countries, the requirement to produce safe foods in a hygienic way is part of the law and there are penalties for those who contravene hygiene and food safety legislation (FAO 1997). Standards for food composition, quality and safety have been developed and applied over many years to protect consumers and to eliminate unfair trading practices (FAO 1997). Most such standards are contained in the Codex Alimentarius, which was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of hygienic practice under the joint FAO/WHO Food Standards Programme Codex Alimentarius Commission (FAO and WHO 2003).

With the advent and development of a food quality consciousness amongst consumers, stimulated by the work of the Joint FAO/WHO Standards Programme Codex Alimentarius Commission through its elaboration of food standards, codes of hygienic practice and the Code of Ethics for International Trade in Food, an increasing number of countries have adopted food laws and established food control agencies (FAO 1997). Codex standards cover hygiene, labelling, the use of chemical additives (such as colorants), pesticides residues and many other factors important in ensuring the protection of consumers and fair practices in the food trade (FAO and WHO 2003).

The food laws in most countries govern the production, composition, labelling and safety of processed foods (Fellows *et al.* 1995). National food legislation varies considerably in detail from country to country but applies to these broad areas: the plant in which the food is made, its correct design and construction; cleanliness and worker hygiene; the physical characteristic of the food including foreign bodies and adulteration; the chemical composition levels and microbiological quality; the correct labelling of the product including related aspects such as expiry date (FAO and WHO 1999a). In Lesotho, with the help of FAO, a programme to establish an operational food control infrastructure is being implemented, and proposals for the introduction of general product standardisation and quality assurance systems such as ISO 9000 series of quality management is underway (FNCO and Multi-Sectoral Taskforce 1997).

According to the recommended international code of hygienic practices for solar dried fruits and vegetables (CAC/RCP 3-1969, Rev. 3-1997 Amd. 1999 part I), dried fruits and vegetables should have a moisture content level that can be held under normal conditions without significant deterioration by decay, mould or bacterial action, enzymatic or other causes of deterioration (table 2.3) (FAO and WHO 1999a). The colour, texture, and general appearance of the dried product should be characteristic of the fresh product (FAO and WHO 1999a). Dried fruits and vegetables should be free from foreign matter and should not contain pathogenic microorganisms or toxic substances originating from microorganisms (Andrew 1992). For example, the shelf-life of dried fruits and vegetables depends on equilibrium relative humidity (ERH) of the product under expected conditions (Gustavo *et al.* 2003). This is a measure of the amount of water that is available within the product that can support the growth of contaminating microorganisms (Gustavo *et al.* 2003). ERH is found by measuring the moisture content of the dried product (FAO and WHO 1999b).

Table 2.3 Summary of quality standards for processed fruits and vegetables (FAO and WHO 1999a p.24-56)

Food	**Quality attributes**			
	Presence of foreign matter	**Flavour/Odour /Colour/Texture**	**Moisture Content**	**Bacteriological content**
Dried fruit and vegetables	Should be practically free from extraneous vegetable matter, insect debris and other objectionable matter	Should be characteristic of the product	Dried fruits should not be more than 20 percent Dried vegetables should not be more than five percent	If mouldiness emerges from half of the food samples, then mouldiness is 100 percent. Should be free from pathogenic microorganisms and any toxic substance originating from microorganisms

2.8 Application of food quality controls during drying of fruits and vegetables at the household level

Household food processing does not differ from industrial food processing as far as the main principles are concerned (Paltrinieri and Figuelora 1997). Quality assessment should be placed on subjective assessment by the processor (Fellows *et al.* 1995). For example, the more the quality assurance and control during preparation, processing stages, packaging, storage, environmental and personal hygiene, the greater will be the level of control (Fellows *et al.* 1995).

A sound household processing system requires planning in terms of raw materials and products (Paltrinieri and Figuelora 1997). Quality control should be applied throughout the processing cycle (Paltrinieri and Figuelora 1997). The best way to apply quality assurance and control is to focus on quality production, that is, apply good quality concepts to each step of the process (Gustavo *et al.* 2003). To improve household fruit and vegetable processing by solar drying at household level, food quality and safety should be secured through effective food quality control at all stages of production, processing and handling, packaging and storage (Paltrinieri and Figuelora 1997). Food quality and safety, secured through effective food quality control at all stages of production, processing and handling, also influences nutritional well being of households (FAO, 1997). Improved agricultural practices, appropriate technology and the establishment of small-scale agro-processing industries (at community level) in fruits and vegetables can significantly increase employment and income generating opportunities and thus positively affect household access to food (ITDG, 2002).

CHAPTER 3
CHARACTERISTICS OF SURVEY AREA AND STUDY SAMPLE

The kingdom of Lesotho is a landlocked country of 30,350 km^2 and lies 1000 metres above sea level, with mountains reaching 3000m above sea level (Ministry of Tourism 2002). The country is largely mountainous with four agro ecological zones namely: the mountains, foothills, lowlands and the Senqu river valley. There is little arable land. This has led to population pressure on forced settlements in marginal areas (Ministry of Tourism 2002). According to the 1996 Lesotho population census, the lowlands are the most populated and intensively inhabited and cultivated zones (Lesotho Bureau of Statistics and UNFPA 2000). The country is also divided into ten administrative districts (figure 3.1) (Lesotho Bureau of Statistics and UNFPA 2003). Lesotho is one of the poorest countries in the world (Sechaba Consultants 2000). Its economy is based on agriculture, light manufacturing and remittances from miners employed in South Africa (UNDP 2002). About 65.7% of the population live below the income poverty line of US$2 per day and consequently have income levels that are inadequate to ensure basic and non-food consumption (table 3.1).

Table 3.1 Lesotho human development indicators (UNDP 2002 p.22)

Indicators	**2001**	**2002**
Population (millions)	1.8 9 (1996)	1.1 (1975)
Life expectancy at birth (years)	38.6	49.5 (1975)
GDP per capita (PPP US$)	2,420	2,031
Population living below one US$ a day (%)	43.1	43.1
Population living below two US$ a day (%)	65.7	65.7
Adult literacy rate (% age 15 and above)	83.9	83.4
People living with HIV/AIDS, adults (%)	31	–
Access to affordable essential drugs (%)	–	80-94 (1999)
Access to water and sanitation (%)	–	49-78
TB cases (per 100,000)	277	291 (1999)
Under-five mortality rate (per 1,000 live births)	132	190 (1970)

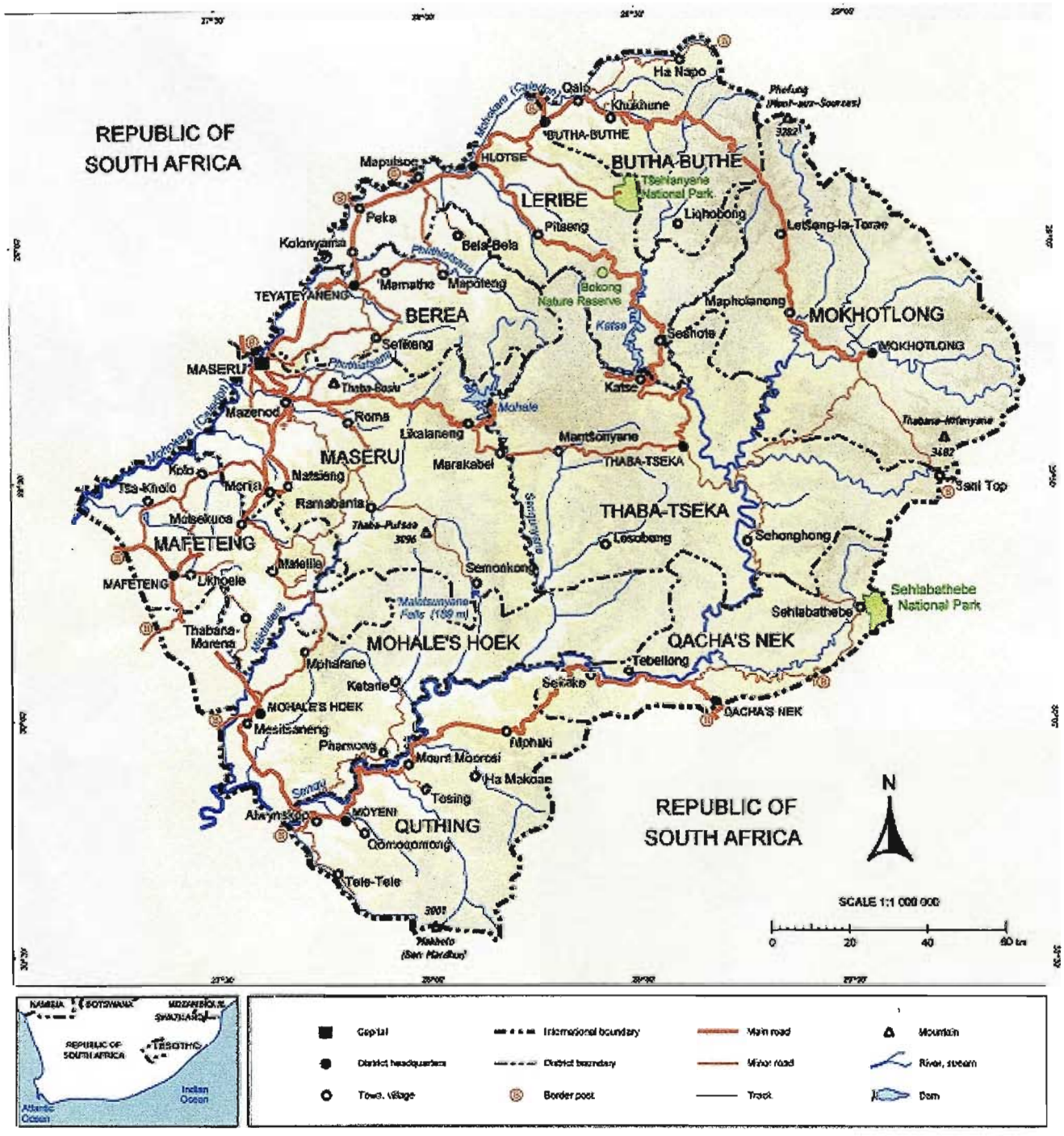

Figure 3.1 Map of Lesotho showing administrative districts (Lesotho Bureau of Statistics and UNFPA 2003 p.92)

Butha-Buthe district is situated in the northern lowlands of Lesotho (figure 3.1 and 3.2) (Lesotho Bureau of Statistics and UNFPA 2003). The district is directly north of Maseru, the capital of Lesotho. It is one of the 10 administrative districts in Lesotho and the smallest with a total area of 1,767 km^2 (Lesotho Bureau of Statistics and UNFPA 2000). To the South, it borders Leribe district and to the North, the Free State province of South Africa (figure 3.2). According to the 1996 population census, the total *de jure* population stood at 109,905 people with 72,601 living in the lowlands, 30,686 living in the foothills and 6,618 living in the mountains (Lesotho Bureau of Statistics and UNFPA 2000). This population forms six percent of Lesotho's population and comprises of 54,633 males and 55,272 females. The 1999 agricultural census revealed that there are 21,394 households in the district with an average household size of 4.9 (Lesotho Bureau of Statistics and FAO 2002).

Agriculture is the major economic activity in Butha-Buthe district (Lesotho Bureau of statistics and UNFPA 2000). Eighty five percent of the total households in the district practice subsistence agriculture (Lesotho Bureau of Statistics and FAO 2002). The average agricultural land size in the district is 0.04 to 0.05 ha per household, but the quality and area of available for farming is threatened by soil erosion, poor land management and overgrazing (Lesotho Bureau of statistics and FAO 2002).

The UNDP national human development report showed continuing high levels of relative poverty and unemployment in the district (UNDP 2002). According to the report, 54.95% households were found to be poor and 37.66% ultra poor (UNDP 2002). Two to three percent of the working age group population of males are working as unpaid family workers, 3 % as casual workers, 0.2% as unpaid family workers and there is low proportion of population working as employers (table 3.2) (Lesotho Bureau of statistics and UNFPA 2003). According to an assessment on vulnerability and food security, 23 percent of the population have needed food assistance since February 2002 (LVAC 2002).

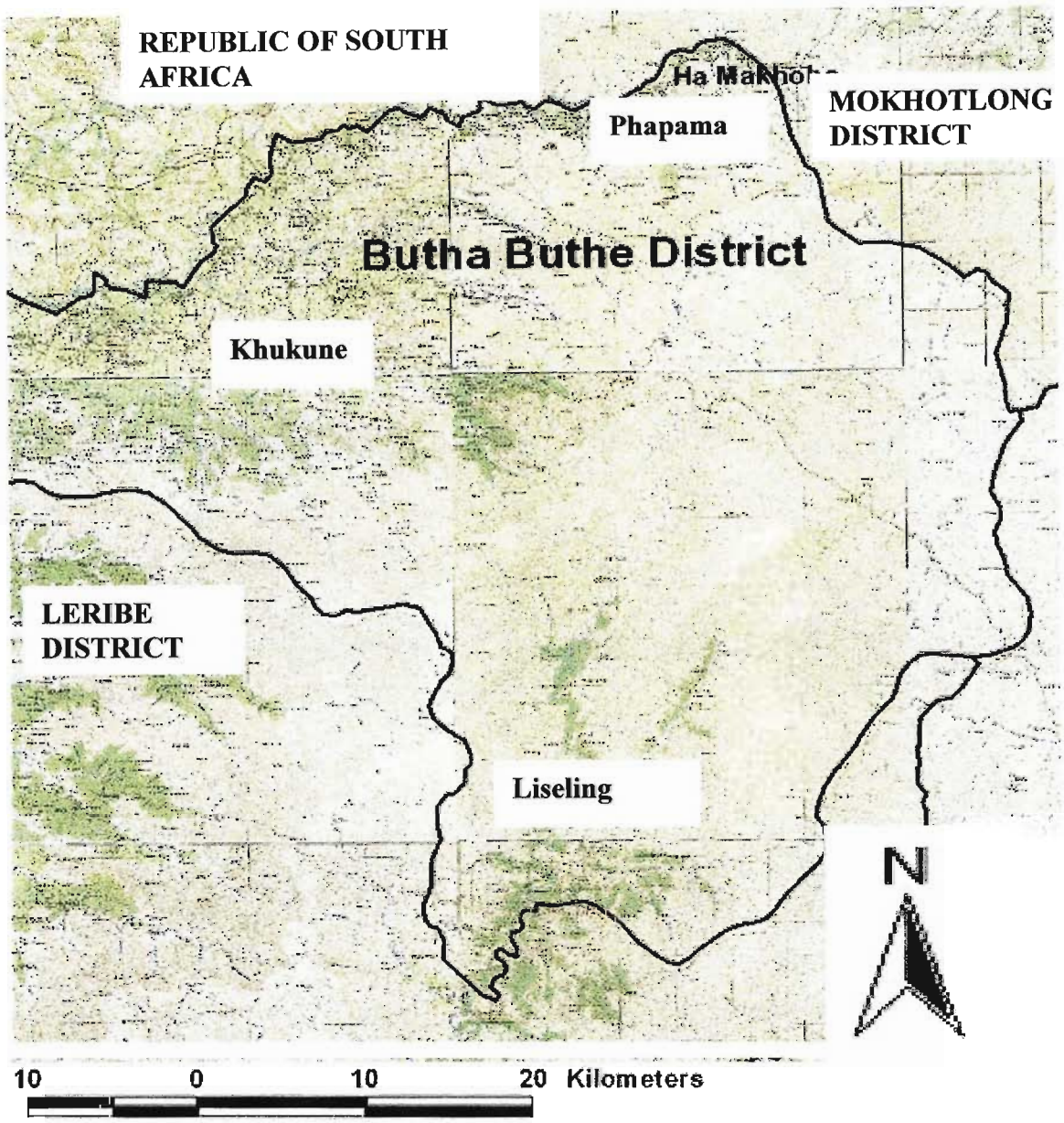

Figure 3.2 **Map of Butha-Buthe district: Study area (Lesotho Bureau of Statistics and UNFPA 2003)**

Table 3.2 Percentage distribution of the population in Butha-Buthe district aged 10 years and over by employment status (Lesotho Bureau of statistics and UNFPA 2003, p.212)

Employment status	**Population (%) n=1,841**
Employer	0.1
Own account worker	10.1
Regular wage/salary earner	24.3
Casual worker	3.4
Unpaid family worker	3.2
Job seeking	3.6
Job seeking for the first time	4.1
House maker	0.6
Housewife	21.9
Retired	1.4
Student	26.1
Disabled	0.1
Other	0.1
Don't know	0.1

Erratic weather, including heavy rainfall, frost, hailstorms, and even tornadoes have severely affected agricultural production and food security at household and community levels in the Butha-Buthe district during the past few years (FAO and WFP 2002). Sharply declining employment opportunities and rising staple food prices have adversely affected household resilience to cope with declining food availability and access (FAO and WFP 2002). Rising food insecurity in the district has been further exacerbated by high rates of HIV/AIDS infection that stands at 25 percent (UNAIDS 2002).

Many households in the district employ multiple income earning strategies, including labour-seeking in South African mines (Sechaba Consultants 2000), but as employment opportunities have reduced across the border, many households rely on livelihood strategies such as home

beer brewing and selling firewood and livestock at depressed prices (Sechaba Consultants and CARE Lesotho 2001).

Fruit and vegetable production is widespread in the district (Moletsane and Wyeth 1994). The common types of fruit trees grown are peach, apple, pear, grapes, quince, apricot and plums (Lesotho Bureau of Statistics and FAO 2002). Some fruit trees like the peaches, apricots and prunes also grow wild (FNCO and Multi-Sectoral Taskforce1997). About 93 percent of fruit trees in Buthe-Buthe district are peach trees (table 3.3) (Lesotho Bureau of Statistics and FAO 2002). Most available fruits and vegetables are seasonal and (FNCO and Multi-Sectoral Taskforce 1997). Vegetable varieties include those grown in the gardens such as spinach, pumpkin, onions, turnips, beetroots, cabbage and high value crops such as asparagus, mushrooms, and wild vegetables (Moletsane and Wyeth 1994).

Table 3.3 Number of productive fruit trees in Butha-Buthe district (Lesotho Bureau of Statistics and FAO 2002, p.45)

Fruit trees	Numbers
Peach	71,933
Apple	4,000
Pear	300
Grapes	300
Quince	1,100
Apricot	4,400
Plums	500
Others	200
Total	82,733

The district has a mild climate with temperate to hot summers (the rainy season) and cold, dry winters. The mean daily temperatures exceeds14^{0}C for 180 days of the year. Summer extends from November to January and is usually hot, with temperatures rising to 26^{0}C (figure 3.3). Autumn is usually sunny (Lesotho Meteorology Services 2003). Winter is from May to July and is bitterly cold with temperatures dropping below freezing.

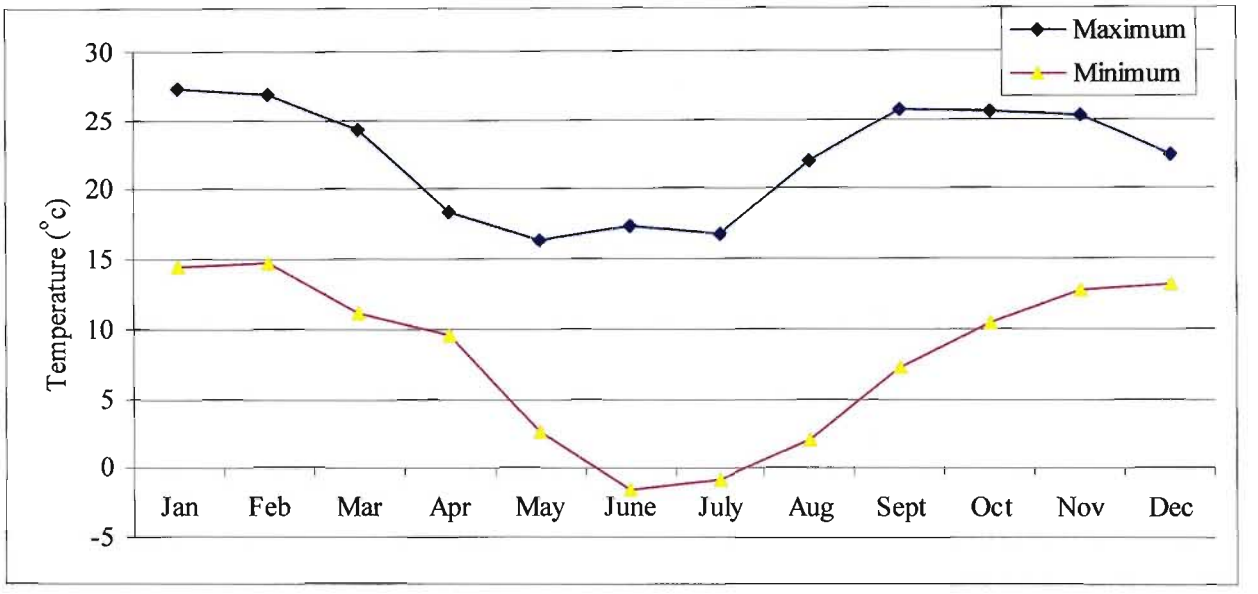

Figure 3.3 Mean temperatures (maximum and minimum) for Butha-Buthe district for the year 2003 (Lesotho Meteorological Services 2003).

Spring usually arrives in August announced by peach-blossoms in almost every village, turning the district into drifts of pale pink (Ministry of Tourism 2002). Snow in the foothills and mountains occurs almost annually. Generally, the district has more than 300 days of brilliant sunshine (Lesotho Meteorology Services 2003). Eighty-five percent of Butha-Buthe's rainfall, (between 700mm and 800mm), usually falls between October and April (figure 3.4).

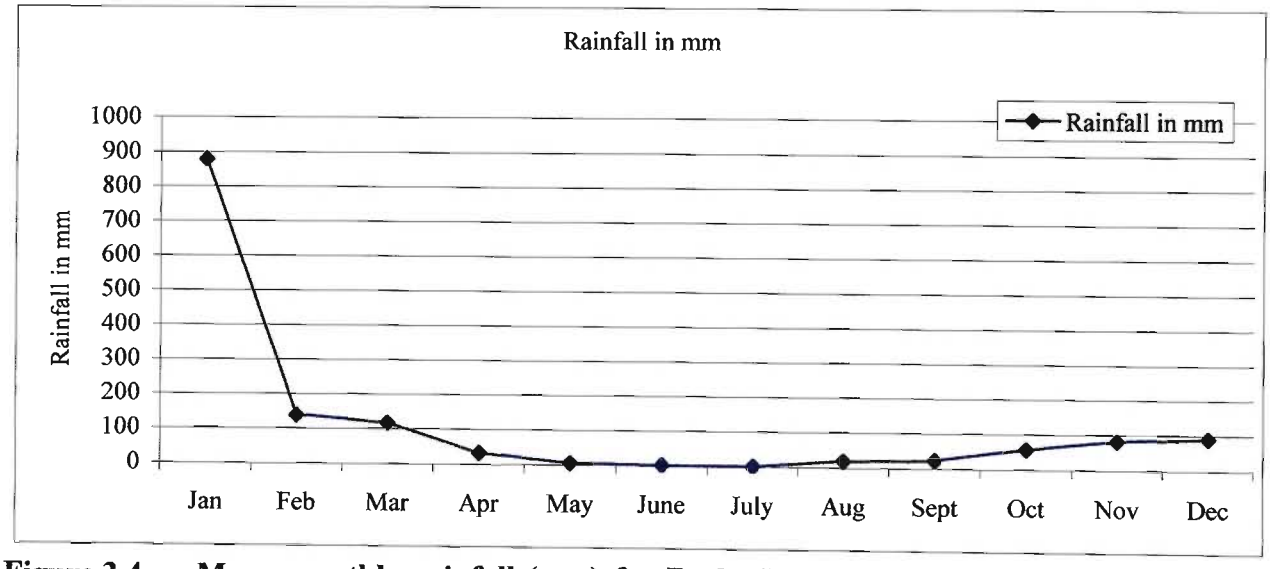

Figure 3.4 Mean monthly rainfall (mm) for Butha-Buthe district for the year 2003, (Lesotho Meteorological Services 2003).

The three areas selected for the study were Liseling, Khukune and Phapama (figure 3.2). The demographic characteristics/profile of the three locations areas are given in table 3.4. The population of the three locations compares favourably to the national average in terms of Human Development Index (table 3.1).

Table 3.4 Total Population of selected villages for the study (Lesotho Bureau of statistics and UNFPA 2000, p.1-13)

Selected villages n=21,394 households	**Population**				
	Males	**Females**	**Total**	**Total number of households**	**% of total sample**
Liseleng	151	162	313	71	0.33
Khukhune	227	222	449	138	0.65
Phapama	240	226	466	190	0.89
Total	618	610	1,228	399	1.87

CHAPTER 4
METHODOLOGY

The study adopted various methodological approaches in investigating issues related to quality and safety of dried fruits and vegetables produced in Butha-Buthe district, using ATS solar driers. Qualitative and quantitative data was collected through focus group discussions held in three locations in the district namely Liseling, Khukune and Phapama and also through laboratory analysis of dried fruit and vegetable samples donated by respondent households.

4.1 Respondents selection

The Butha-Buthe district was purposively selected because it has the highest number of households that have adopted ATS solar driers. Between 1998-2001, ATS sold 2,500 solar driers in Lesotho (Ministry of Local Government 2002). Five hundred and forty of these solar dryers have been purchased by households in the Butha-Buthe district, representing 21.6 percent of all solar driers purchased from ATS, Maseru.

Focus group discussions were held in three locations in the district. The locations were selected by an extension officer based in the district on the basis of ease of cooperation, familiarity with the households, and accessibility by road. The extension officer identified a household in each location, that was willing to host the discussion. Other households who had purchased solar driers in the neighbourhood were invited to attend the discussions and were requested to bring samples of their dried fruit and vegetables.

Participation of the three discussion groups was as follows: At Liseleng, the workshop was conducted on 13th November, 2002 and a total of 15 household representatives attended. The workshop at Phapama was conducted on 12th December, 2002 and five households attended. The last workshop was conducted on 25th February, 2003 at Khukune and a total of 26 households attended. The total number of households that participated on the focus group discussion was therefore 46 (see figures 4.2, 4.3, 4.4, and 4.5). This represented nine percent of the total number of households in the Buthe-Buthe district who had purchased ATS solar

driers. A total of twenty households donated dried samples of fruits and vegetables, 14 at Khukune, five at Liseleng and one at Phapama. The donated samples were sent for laboratory quality control analysis, conducted at the department of Agriculture Research Centre of the Ministry of Agriculture in Maseru. A total of 20 dried samples of fruits and vegetables were analysed.

4.2 ATS solar drier used

The solar drier was been developed by the Appropriate Technology Section (ATS) of the Ministry of Local government, Lesotho. The drier costs about US$50 and can hold about five kilograms of produce. The drier comprises of drying trays placed on a framework at table height. This allows the produce to be evenly spread out to allow air to circulate freely around the drying material and keeps dirt of the produce. The drier has a fibre glass roof which serves as a solar energy collector, thereby increasing its efficiency as a vehicle for removal of moisture from the drying produce (figure 4.1).

Figure 4.1 ATS solar drier (MOLG 2000)

Figure 4.2 **Respondents preparing fruits and vegetables for drying at the Liseling workshop (Butha-Buthe, November, 2002)**

Figure 4.3 **Respondents preparing drying of fruits and vegetables at the Phapama workshop (Butha-Buthe, December 2002)**

Figure 4.4 **Respondents preparing fruits at the Khukune workshop (Butha-Buthe February 2003)**

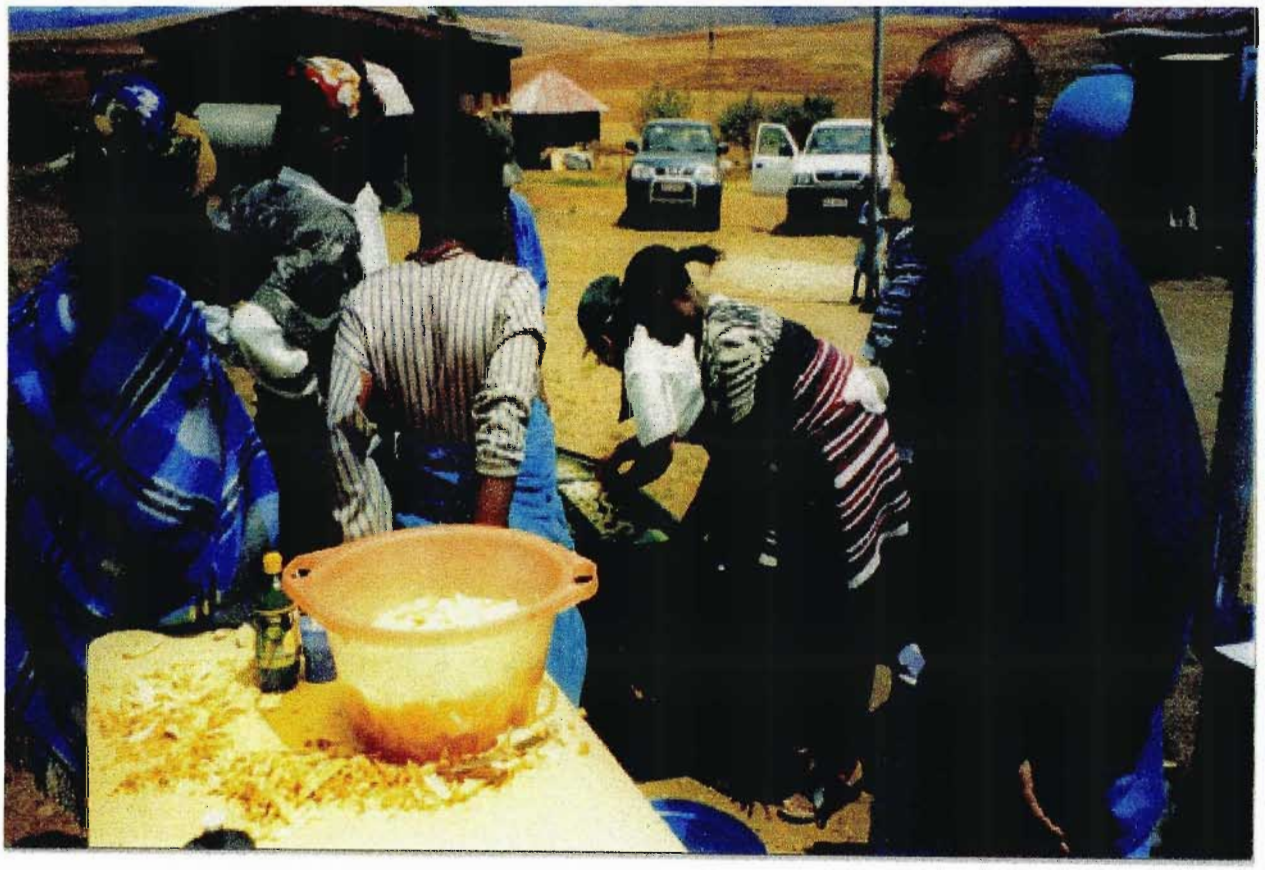

Figure 4.5 **Discussions at the Liseling workshop (Butha-Buthe, November 2002)**

4.3 Research design

Qualitative and quantitative data was collected in two phases. In the first phase, qualitative data were collected through focus group discussions, a structured questionnaire and application of a quality control assurance check-list completed by the researcher. A participatory action research method was employed by the researcher to discuss best food drying practices with respondents. The researcher actively involved the respondent households in the preparation and treatment of fruits and vegetables for solar drying (figures 4.2, 4.3, 4.4 and 4.5). During demonstrations on how to produce dried fruits and vegetables using the ATS solar drier by the researcher, the respondent households were engaged in discussions on how they prepared fruits and vegetables for drying and treatment applied to the fruits and vegetables before drying and the information recorded (figure 4.6). Participatory action research therefore sought to actively involve the participants in generating knowledge about food drying and areas of improvement.

Figure 4.6 Discussions at the Khukune workshop (Butha-Buthe, February 2003)

A structured questionnaire was introduced at the end of the discussions. Respondents were assisted in filling the questionnaire by the extension officer and a dissemination officer from ATS. Data collected this way included: seasonal availability of fruits and vegetables for drying, amounts of dried fruits and vegetables dried by the households, reasons for drying, preparation and processing of fruits and vegetables for drying and on the socio-economic constraints that hampered the production of quality dried fruits and vegetables. The questionnaires was translated into Sesotho and responses translated back into English for analysis (appendix A).

A quality assurance checklist (appendix B) was also applied during the first phase of data collection. The checklist was adapted from FAO guidelines on quality control and assurance and international trade, good manufacturing practices, hygiene requirements, hazard analysis and critical control points. Guided by the checklist, a subjective quality assessment during preparation and processing of fruits and vegetables was done by the researcher. Quality assurance during preparation and processing of fruits and vegetables for solar drying is directed at ensuring that the final products have been processed in a hygienic and efficient manner (FAO and WHO 1999a).

In the second phase of data collection, quantitative data from laboratory analysis of the dried fruit and vegetable samples from the households was investigated in respect to quality and safety. Laboratory quality control tests were conducted to ensure that the final dried products conformed to the requirements for processed fruits and vegetables recommended by FAO/WHO Codex Standards for processed fruits and vegetables (C/RCP 3-1969, Rev. 3-1997 and Amd.1999 part I). The results were recorded in a data sheet (appendix C), for interpretation.

4.4 Methodology for laboratory quality control of dried fruit and vegetable samples from the respondents

Laboratory quality control tests followed recognised standard analytical methods in order that the results could be interpreted. For example sampling methods, analysis and laboratory

procedures for dried fruits and vegetables are stipulated in Codex Standard for dried fruits and vegetables CAC/RCP 3-1969, Rev. 3-1997 and Amd.1999 part II (FAO and WHO 1999b), while microbiological tests followed the Principles for the Establishment and Application of Microbiological Criteria for Foods CAC/GL 21-1997 as described in the FAO/WHO manual for food quality control (Andrew 1992). The laboratory tests were done at the Agriculture Research Laboratory by the researcher from November 2002 to March 2003.

4.4.1 Testing for colour, odour and general cleanliness

This was done organoleptically, i.e. involving human senses. Colour and general cleanliness relating to absence of foreign matter and infestation by insects was done by observation, odour by smelling and texture by touching in the laboratory. The results were then compared with the FAO/WHO Joint Alimentarius Codex Standards (FAO and WHO 1999a) for dried fruits and vegetables on general quality requirements, which are as follows:

- colour should be a characteristic of the variety and the type of treatment applied during processing,
- flavour, odour and texture should be characteristic of the product, and
- the dried sample should be free from living insects and mites, also, should be free from foreign matter i.e. practically free from extraneous vegetable matter, insect debris and other objectionable matter (FAO and WHO 1999a).

4.4.2 Analysing dried fruits and vegetable samples for moisture

FAO/WHO Joint Alimentarius Codex methods of analysis for moisture content in dried fruits and vegetables (CAC/RCP 3-1969, Rev. 3-1997 and Amd.1999, part II) were applied (FAO and WHO 1999b). The oven method at 100^0C was followed. The following equipment was used: electronic vacuum oven set at 100^0C, metal crucibles, calibrated analytical balance and metal tongs. The procedure followed was as follows. Exactly 100g of dried fruit and vegetable sample was accurately weighed on a metal crucible and transferred to a vacuum oven set at 100^0C. Weights of the sample were taken after 30 minutes and after an hour until a constant weight was recorded. Average moisture content was calculated using the following formula:

$$\% \text{ moisture content on wet basis} = \frac{A-B}{A} \times 100$$

where, A=weight of the sample before drying and B=final constant weight after drying in the oven

4.4.3 Microbiological analysis of dried fruit and vegetable samples from the respondents

Test procedures for microbiological assessment of food as described in the FAO/WHO manual for food quality control in microbiological analysis (Andrew 1992), were followed for an anaerobic plate count and in enumerating yeasts and moulds in dried fruits and vegetables. These are described below.

4.4.3.1 Procedure for total aerobic plate count

The total anaerobic plate count (TAC) is useful to indicate the overall microbiological quality of a product and is useful in indicating potential spoilage in foods (Andrew 1992). TAC is therefore useful in indicating the sanitary conditions under which the fruits and vegetables were produced or processed by respondents. The following laboratory equipment was used: forceps, spoons, calibrated analytical balance, petri dishes, bunsen burner, sterile pipettes (1ml, 5ml, 10ml graduated in 0.1ml units), an electron microscope, dilution bottles (160ml with rubber stoppers), pipette petri dishes and a water bath to atemperate the agar thermostatically, an incubator and a colony counter. The water bath was controlled at 48°C.

Media and reagents used were as follows: dilution blanks 90ml butterfields phosphate buffer as dilution blanks, total plate count agar and sterile distilled water. The procedure used was as follows: 10g of the dried fruit and vegetable samples were aseptically added to a flask containing 90ml of the diluent to make 100ml and mixed thoroughly. Using separate sterile pipettes, dilutions of 10^{-2}, 10^{-3}, up to 10^{-5} were prepared by transferring 10ml of previous dilutions to the 90ml diluent, 1ml of each dilution was pipetted into separate duplicates of petri dishes appropriately marked. Twenty millilitres of plate count agar (cooled to 44^0C-46^0C) was added to each plate within 15 minutes of the original dilution. The sample dilutions containing agar medium were thoroughly and uniformly mixed immediately, the agar was then allowed to solidify and the petri dishes inverted and incubated promptly for 48 hours at 35^0C.

After incubation, colony counts were done for duplicate plates having 25-250 colonies and the results recorded. The results were then compared with FAO/WHO Recommended

International Code of Hygienic practice for dried fruits and vegetables (CAC/RCP 3-1969, Rev. 3-1997 and Amd.1999 part I), which stipulates that dried fruits and vegetables should not contain any pathogenic microorganisms or any toxic substance originating from microorganisms (FAO and WHO 1999a). The results were presented in the form of a data sheet table (appendix C).

4.4.3.2 Procedure for yeasts and mould count (MYC)

The purpose of MYC test was to detect the presence of moulds and yeasts on the dried samples of fruits and vegetables and establish whether such were pathogenic or not, and identify the genera and species obtained. Equipment used was the same as for TAC also the reagents, but with the addition of potato dextrose agar and a tetracycline antibiotic to inhibit bacterial growth. Preparations of the dilutions and inoculations were also carried out as for TAC. Plating was done in triplicates. Incubation was carried out in the dark at 22^0C-25^0C for five days and all plates containing 10-150 colonies were counted. Low power (10-30X) microscope magnification was used to identify the genera and species of the moulds and yeasts present. The results were recorded in the form of a data sheet table (appendix C).

CHAPTER 5: RESULTS AND DISCUSSION
FACTORS AFFECTING THE QUALITY AND SAFETY OF DRIED FRUITS AND VEGETABLES PROCESSED BY RESPONDENTS

This chapter describes the findings of the survey to investigate the quality and safety of solar dried fruits and vegetables produced using ATS solar driers in the Butha-Buthe district, Lesotho. The findings focus on process and environmental conditions that influence the quality and safety of dried fruits and vegetables. Quality and safety of dried fruits and vegetables is influenced by many factors including availability of fresh produce of good quality, careful handling before processing, efficient preparation of produce, correct loading and operation of the drier, drying to correct moisture content, proper packaging and storage of the dried product (chapter 2, section 2.4). In addition, efficient management operations such as quality checks by the processor on all factors relating to personal and environmental hygiene should be put into place during processing, to prevent contamination during processing and storage (chapter 2, section 2.6).

The chapter is divided into seven sub-sections. Sub-section one investigates the availability and source of raw material (fresh fruits and vegetables), to investigate how this affects the quality and safety of the dried fruits and vegetables. Sub-section two examines the volume of dried fruits and vegetables by the respondents, while sub-section three investigates reasons for drying as this can provide the respondents with an incentive to improve on quality and safety of the dried products. The fourth sub-section section investigates the characteristic of the processing equipment of the respondents while sub-section five assesses the processing methods applied by the respondents including packaging and storage of dried products. Sub-section six examines quality assurance and control practices during processing, from selection of raw material, preparation, processing techniques, storage, GMP and hygiene during processing. Lastly, sub-section seven assesses the constraints limiting the production of quality and safe dried fruits and vegetables by the respondents.

5.1 Availability and source of raw materials for solar drying (fresh fruits and vegetables) in the Butha-Buthe district

The results from the seasonal calendar (table 5.1) showed that most available fruits and vegetables for drying are seasonal, ripening mainly from November to April. This shows that there is availability of fruits and vegetables for drying during November to April and little or no produce during May to October. The harvesting season is generally very short i.e. about four months (table 5.1). The pressures are therefore high to harvest and process large volumes of fruits and vegetables quickly.

Table 5.1 Seasonal availability of fruits and vegetables for drying (Butha-Buthe district, November to March 2003) n=46 households

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Peaches												
Nectarines												
Plums												
Apples												
Apricots												
Quinces												
Pears												
Grapes												
Cabbages												
Spinach												
Tomatoes												
Carrots												
Beetroot												
Onions												
Green												

Key

- Ripe fruits and matured vegetables ready for harvesting
- Scarcity of fruits and vegetables
- Fruit flowering seasoning and planting of vegetables

Processing large volumes of fruits and vegetables within a short time can present quality problems. For example, the fruits ripen quickly and soften when they are ripe. This can increase the risk of bruising and splitting especially if not handled properly. Damage to fruits and vegetables through poor handling allow moulds and yeasts to grow rapidly in the damaged areas leading to spoilage (chapter 2, section 2.4).

The fruit and vegetable harvesting season coincides with summer when there are long hours of sunshine. For example, the average maximum temperatures during November to April for 2003 was 25.2^{0}C (chapter 3), that is high enough to allow for fast drying. Drying fruits and vegetables at this time (summer) may ensure their availability during the months from April to October when they are scarce. However, care should be taken while drying during summer because high temperatures can present quality problems especially changes in colour, texture and taste due to scorching and case hardening (chapter 2, section 2.2).

Seventy percent of respondents cultivated peach trees at their homesteads, while 30 percent cultivated peach trees and a single tree of one or more of the following fruit tree varieties: apricot, apple, quince or pear. It was established that peaches are the most productive fruit trees and accounted for 99 percent of all the fruits dried, and have the longest harvesting period. The average number of fruit trees per respondent was four. All respondents grew vegetables including, cabbage, spinach, kale and tomato on a small scale in kitchen gardens. Vegetables were found to have a longer harvesting period than fruits (table 5.1). Only five percent of respondents reported buying fruits and vegetables for drying from neighbours to supplement their own production.

Own production of raw material by respondents may mean increased varieties of fruits and vegetables for processing. Also, handling of the raw material is less because there is no transportation of the raw material over long distances, which may increase damage. Respondents are well placed to harvest the raw material at the right stage of maturity and free from infection. This can have an impact on flavour, colour and safety of the final dried product.

5.2 Production and processing volumes

Eighty nine and 72 percent of the respondents respectively, dried 10 kg of fresh fruit and vegetables per season respectively (figure 5.1). On average, the quantity of fresh fruits and vegetables processed annually by respondents seven kilograms and three kilograms respectively.. The results indicate that more fruits were dried than vegetables (figure 5.1). Fruits are more available in the district since little or no care is needed for their production, unlike most vegetables which require intensive production. Some fruits such as peaches grow wild in the district.

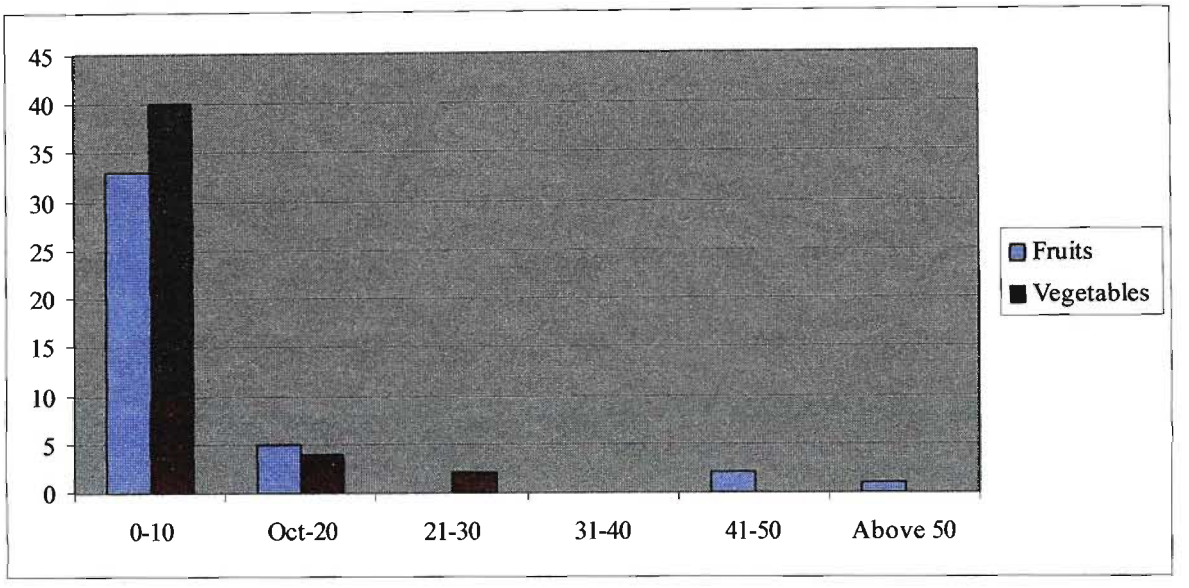

Figure 5.1 Amount of fresh fruits and vegetables dried by respondents annually (Butha-Buthe district, November 2002-March 2003) n=46 households

The majority of respondents did not produce more than 10 kg for a number of reasons. For example, as seen in section 5.1, all the respondents grew vegetables on a small scale in their kitchen gardens and they all had a few fruit trees. Solar drying of fruits and vegetables was mostly a household activity, i.e. the respondents did not hire out labour even during the peak season. For example as shown in figure 15 none of the respondents dried on daily basis and majority of the respondents (89 percent) dried once a month. Only 11 percent dried fruits and vegetables on a weekly basis.

The respondents reported that they could not process more fruits and vegetables due to the short harvesting period (section 5.1) which also coincided with other household activities such as weeding in the fields, leaving little time to spare for off-farm activities such as drying

of fruits and vegetables. Lack of spare time for drying could also have affected the respondents capacity to practice or engage in more organised processing techniques required to improve the quality and safety of dried fruits and vegetables. Five percent of the respondents reported that the dried fruits and vegetables they produced were consumed immediately by the household. Fifteen percent of the respondents cited that lack of equipment hampered them from drying larger volumes. They gave an example of the ATS solar drier which they said holds about five kilograms of produce.

Only two percent of respondents reported drying 50 kg and above of the fresh produce to generate income. They complained that the practice was not very profitable but saw drying medicinal herbs as potentially more profitable. Respondents reported that the fruits and vegetables dried did not last until the next harvesting season.

5.3 Why do respondent households dry fruits and vegetables?

Eighty seven percent of the respondents dried fruits and vegetables for home consumption and only 13 percent reportedly dried to sell. Dried fruits were reportedly eaten as snacks any time of the day. Dried vegetables were reconstituted and cooked in various ways, for example, eaten with maize, porridge, mixed with meat or on their own (table 5.2).

Table 5.2 Ways in which dried fruits and vegetables are incorporated into respondents diet (Butha-Buthe district, November 2002 to March 2003)

Incorporation in household diet	Number of respondents n=46	Percentage of sample (%)
Snacks	46	100
In soups and stews	29	63
Reserved for snacks for visitors	7	15

Sixty three percent of sample respondents reported incorporating vegetables in soups and stews. Fifteen percent reserved dried fruits for visitors only. This infers a high value attached to dried fruits and vegetables. Respondents reported that the availability of dried fruits provided an interesting snack greatly enjoyed, especially by children. The results confirmed the contribution of fruits and vegetables in promoting dietary diversity and healthy diets.

All the respondents reported drying fruits and vegetables during the period when they were available. This coincided with the ripening period of most fruits and harvesting of vegetables (table 5.1). This further confirms (as seen in section 5.2) that dried fruits and vegetables were consumed immediately after production. Only thirteen percent of respondents reported drying fruits and vegetables for a longer period, i.e. September-April. This shows that very little or no drying took place around this period. The results therefore shows that consumption of dried fruits and vegetables in the district was seasonal even with solar drying of fruits and vegetables, thus solar drying did not ensure availability of fruits and vegetables in the district.

Only 13 percent (6) of respondents dried fruits and vegetables for sale (table 5.3). It was reported that dried fruits were more likely to be bought than dried vegetables. The sales turnover from dried fruits and vegetables was low. For example, only two percent of sample respondents reported sales turnovers of R150 and more per drying season from the sale of medicinal herbs (i.e. not from dried fruit and vegetables). Nine percent of the respondents cited the lack of market opportunities for the dried fruits and vegetables that was limited to neighbours and school children.

All respondents reported that the dried fruits and vegetables had a short shelf-life due to poor storage qualities and so they could not store to sell during the off-peak season when they may have fetch better prices. The seasonality of fruits and vegetables limited production to those seasons when they were available and so the processing volume was low (see section 5.2). Moreover, respondents reported that dried fruit and vegetable products could not compete with dried fruits and vegetable products imported mainly from South Africa and sold in supermarkets. Respondents reported that the brown colour of their dried fruit products and the unappetising appearance of dried vegetables lead to lack of customer confidence, further limiting sales and market opportunities.

Of the respondents who dried fruits and vegetables mainly for sale (table 5.3), only one respondent indicated that the income from the sales of dried fruits and vegetables contributed to a quarter of the household's total income. The reason he gave was because he mostly dried medicinal herbs such as *hloenya, mohalakane, khomo ea balisa*, that were in demand in the

community. These herbs grow as wild plants in the community and survive harsh winter weather (Moletsane and Wyeth 1994).

Table 5.3 Sales turn-over due to sale of dried fruits and vegetables-Butha-Buthe district, November 2002-March 2003, n=46 households

Sales turnover per month (R)	Number of respondents	Percentage of sample (%)
No sales	40	87
0-50	2	4
51-100	2	4
101-150	1	2
151-200	0	0
201-250	1	2
Total	**46**	**100**

5.4 Characteristics of processing equipment used by respondents

ATS solar driers were the only specific equipment owned and used by respondents for drying fruits and vegetables. All respondents reported that the ATS drier enabled them to produce better products than before. Using these driers, reportedly enabled the production of clean products, as the products were protected from dust and insects within the drier. Half the respondents reported that drying was quicker using the drier and that it offered a considerable degree of protection from rain, which meant that they did not need carrying the drying product inside should it rain. However the respondents were not aware that leaving the drier outside in the rain increased the moisture content of the drying product due to sudden cooling, and cooler overnight temperatures that lead to condensation. The effect of increased moisture content of the drying produce is prolonged drying, and increased chances of the drying product rotting and moulding.

All respondents reported experiencing problems with ATS solar driers (chapter 4, figure 4.5). They complained that the drier was too small, limiting production during season when fruits and vegetables were available. The respondents reported over-loading the driers with produce. Piling up of the produce in the drier may result in prolonged drying, increasing the chances of rotting and growth of moulds (UNIFEM 1995). Twenty percent of respondents

reported that the driers wore out too fast, especially the mesh on the drying trays which easily tore as a result of frequent washing. The hinges that connected the fibre glass roof to the rest of the body reportedly fell off after a short period of time and in some cases they had to carry out drying without the drier's cover, thus making it technically unable to produce good products. All the respondents complained that the Appropriate Technology Section was too far away to repair the driers and no technical assistance was available to repair the driers on site.

Respondents all reported using ordinary kitchen equipment for processing dried fruits and vegetables, for example, wash basins, cooking pots and knives in preparing fruits and vegetables for drying. Stainless steel knives should be used during the preparation of fruits and vegetables to prevent discolouration (see chapter 2, section 2.6). The respondents were not aware of specialised equipment such as fruit peelers, sulphurising cabinets which allow for quality preparation of fruits and vegetables.

5.5 Processing methods applied by the respondents during production of dried fruits and vegetables

All respondents reported applying the preparatory procedures for fruits and vegetables before drying (cleaning, sorting, grading, peeling, size reduction, blanching, salting and sulphuring) (chapter 2, table 2.2). However the preparatory procedures were limited only to selecting, sorting and washing (figure 5.2). The respondents reported washing the selected fruits and vegetables with clean water before preparing to process them. The processing procedures were also limited and included; slicing of the washed fruits and vegetables into smaller pieces to increase the drying speed, turning the drying product on the drier trays to facilitate fast drying, packaging either in polythene bags or glass jars and storing the dried final product. The processing procedures were therefore very basic i.e. sorting, washing, slicing, drying, packaging and storage. No respondents applied more technical processes such as sulphuring of fruits and blanching of vegetables to improve quality and safety of produce (figure 5.2).

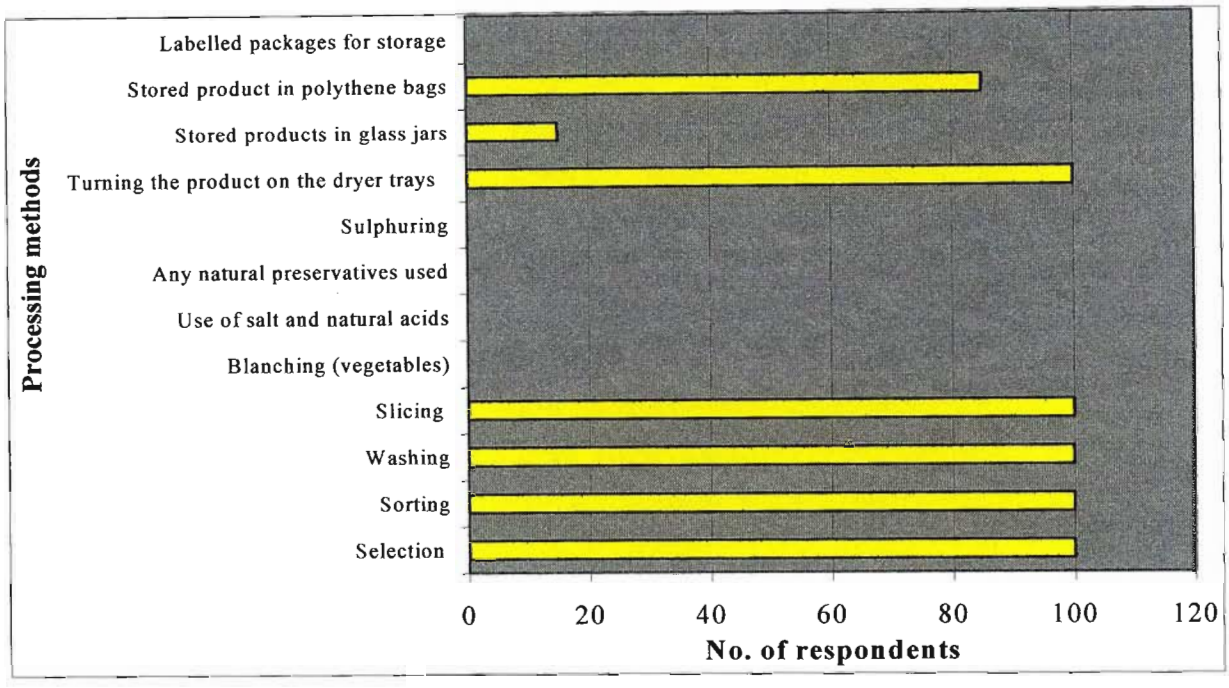

Figure 5.2 Summary of processing methods applied by respondents during fruits and vegetables solar drying (November 2002 to March 2003) n=46

The findings indicate that respondent's processing techniques were mainly borrowed from traditional methods of processing which does not ensure that the desirable characteristics of food are retained throughout production, handling, preparation, processing, packaging and storage (chapter 2, section 2.4). The respondent's dried fruits and vegetables are therefore likely to have a short shelf-life and compromised safety due to inferior processing techniques.

5.5.1 Packaging and storage of dried fruits and vegetables by respondents

Most respondents (87%) reported drying fruits and vegetables with the intention of storing these to consume during off seasons. Respondents reported that stored dried fruits and vegetables did not last as produce deteriorated relatively fast. For respondents who stored dried fruits and vegetables (post-drying), 85 percent stored produce in polythene bags, and 15 percent used in recycled glass jars (figure 5.2). As seen in chapter 2, section 2.5, packaging of dried products requires special attention because dried products are destroyed by exposure to too much sunlight, moisture, and heat (chapter 2, section 2.5). From the results, the glass and polythene packaging material could not offer enough protection. Polythene bags are

easily attacked by insects while glass, if not coloured allows light through, exposing products to light that may cause discolouration of the products.

All respondents reported that they did not label packages with information on when the product was processed. They were not aware about the importance of proper sealing of packages. They also reported that they did not have a specific storage room for storing dried fruits and vegetables, instead storing packaged products in cupboards and shelves in their houses. The most common cause of loss in quality of stored produce was colour changes, and insects (24 and 12 percent of dried fruits and vegetables respectively). On average, dried fruits and vegetables kept for two months. Respondents showed much interest in being helped to produce products that could keep for a longer time, especially during off season.

5.6 Quality control/assurance during processing of dried fruits and vegetables by respondents

The study made use of a quality assurance checklist (appendix B), where the critical control points were identified by the researcher to evaluate whether the respondents quality assured their products during processing. It is necessary to process, package and store food under conditions that will minimise the potential for undesirable microbial growth, toxin formation and deterioration or contamination (FAO 1999a). One way to achieve this is by using a quality control operation in which the critical control points are identified and controlled during processing or manufacturing (chapter 2, section 2.6).

It was found that although the respondents did not consciously assure the quality of products during processing. However, they did apply quality control measures during processing through following good manufacturing or processing practices, but quality control measures were rudimentary. It was observed that respondents inspected and sorted the raw materials to ensure that they were clean, wholesome and fit for processing into human food. They also washed the raw material to remove soil and other contamination. The more technical processing methods that aid in improving quality and safety of the final drying products such as heat blanching of vegetables and sulphating of fruits were not carried out by the respondents.

The respondents obtained water from small streams and shallow wells, located in their villages. Well and river water is often contaminated by microbes and water borne pathogens and runoff from the land, thus not suitable for processing foods unless treated (UNIFEM 1995). The water used for processing dried fruits and vegetables by the respondents was not potable and the respondents did not take measures to ensure that the water was safe, such as treating it before use as in boiling or using sterilisers such as household bleach.

Sorting and selection of fresh fruits and vegetables (raw material) was found to be inadequate as the respondents had a tendency to select overripe fruits and over matured vegetables with the perception that it is what should be preserved i.e. should not be thrown away. Slicing and peeling of fruits and vegetables was found inadequate because it was not uniform (the same thickness). Uneven slices dry at different rates and result in poor quality products (Mircea 1995). At the Phapama workshop, the respondents were not aware the need to peel their fruits before drying.

The processing equipment that respondents used such as knives, buckets and pots used in most cases were not suitable for processing fruits and vegetables. For example, as most fruits are rather acidic, it is normally recommended that either stainless steel, or good quality plastic or wood are used (chapter 2, section 2.6). It was observed that most of equipment used by the respondents including ATS solar driers were not easy to clean. The ATS solar drier has very sharp joints that can lead to accumulation of food, dirt and organic particles increasing chances of product contamination. Other equipment such as pots and knives were not made of stainless material and had rough surfaces that were difficult to clean.

Figure 5.3 shows typical solar drying of fruits and vegetables processing background by many respondents. As can be seen, respondents are preparing to dry the fruits and vegetables in an open environment that is very dusty. Respondents did not have a designated or established places for carrying out processing, so drying was carried out outside in the open environment which was usually dusty (see figure 5.3). Dust can increase chances of product contamination during processing. Processing foods in the open environment can attract flies and rodents (chapter 2, section 2.6). The respondents personal cleanliness was also questionable, especially as their clothing was not very clean. This means that adequate hygienic practices may not be followed during processing. The sanitary conditions were rated as in adequate.

No toilet tissues were provided at workshops and all toilets lacked a provision for washing hands and towels to dry hands. Unsanitary toilets can increase contamination to food processing through airborne contamination, flies and contamination of food processor's hands when handling the food (Fellows 1997). The results showed that many respondents were not aware of the danger of poor personal hygiene, and unsanitary work habits

Figure 5.3 Preparing fruits and vegetables for drying at the Khukune workshop (Butha-Buthe, February 2003)

5.7 Constraints limiting the production of quality and safe dried fruits and vegetables

Quality problems were seen as the biggest problem to producing quality and safe dried fruits and vegetables by respondents. Respondents did not understand why their produce was of inferior quality compared to commercial products and why product deterioration was problematic. The respondent's dried products had a short shelf-life and the appearance was not appetising. There was no or low availability and awareness to the respondents of alternative technologies for producing high quality dried products such as blanching of

vegetables and sulphuring of fruits. Respondents were not aware of quality standards such as FAO and WHO Codex Quality Standards and ISO which were available at FAO offices at Maseru and at the Department of Trade and Industry. There was no mechanism for the flow of accurate information on these quality standards to the respondents.

The respondents reported that they had no access to services and incentives such as services of the field agents, information and training. The respondents felt that this was because the government gave little recognition to solar drying. Support systems such as the services of financial institutions and credit agencies are not highly developed in Lesotho. For example, there is no rural development bank to take care of the financial needs of cottage industries. Respondents reported the need to access credit to expand their solar drying operations and enable them produce quality products through purchasing more driers, more appropriate processing equipment such as peelers and building processing sheds.

Ninety-five percent of the respondents had not completed primary level of education. The proportion of respondents with high school qualifications was just five percent. It is important for food processors to have the education and or experience to make them aware of the danger of poor personal hygiene and unsanitary work habits (Fellows 1997). Serious skills deficiency highlighted by respondents was underlying technical skills (blanching and sulphating), packaging, pricing and marketing of their dried products.

CHAPTER 6: RESULTS AND DISCUSSION: LABORATORY QUALITY CONTROL TESTS ON DRIED FRUIT AND VEGETABLE SAMPLES SUPPLIED BY RESPONDENTS

Laboratory tests on dried samples of fruits and vegetables from the respondents were conducted for three purposes. First, to confirm the findings from chapter 5 by conducting objective tests which are more accurate. Second, to find out whether the dried products conformed to food safety protocols, quality and operational standards. Last to determine whether dried fruits and vegetables produced by respondents in Butha-Buthe district are safe for human consumption. Joint FAO and WHO Codex Alimentarius Quality Standards for dried fruits and vegetables (chapter 2, section 2.5.1) were used for reference. A total of 20 dried samples from the respondents (11 dried fruit samples and nine dried vegetable samples) were analysed and the results recorded (figure 6.1, table 6.1 and 6.2).

Figure 6.1 **Dried peaches and vegetables from respondents (Khukune workshop, Butha-Buthe, 2003)**

6.1 Results and discussion for general tests

Organoleptic tests were carried out using human sensory judgement based on sight, smell and feel and included, presence or absence of foreign matter (general cleanliness), colour, odour and texture (chapter 4, section 4.3). From the results (table 6.1 and 6.2), 54 percent (6 samples) of the dried fruit samples and 55 percent (5 samples) of the dried vegetable samples contained foreign matter (insects, extraneous plant matter, visible mould growth). Twenty seven percent of dried fruit samples that were packaged in polythene bags were riddled with insect holes and contained ants. Eleven percent of the fruit packages contained worms. Thirty percent of dried fruits and twenty five percent of dried vegetable samples had mould on surfaces in form of grey and blue spots. Dried fruits and vegetables packaged in cheap polythene bags showed more infestation by insects and mould growth. This shows that glass offers better protection against infestation by insects and mould growth.

The results confirm the findings from chapter 5, section 5.7, about possible contamination of the products during processing with insects, extraneous matter and dead leaves due to unhygienic processing conditions (inadequate cleanliness of processing equipment, processing area, processors and using untreated water) and unsanitary work habits. Poor packaging could also have contributed to being contaminated with insects and worms.

Half of the dried fruit and vegetable samples did not meet the recommended FAO/WHO standards for general cleanliness, that stipulate that dried fruits and vegetables should be practically free from extraneous vegetable matter, insect debris and other objectionable matter (chapter 2, section 2.7). Texture and odour of both the dried fruits and vegetables was within FAO/WHO Codex Standards for processed fruits and vegetables which is supposed to be characteristic of the product.

Table 6.1 **Results from Laboratory quality control tests of dried fruits (Agriculture Research Laboratory, November 2002 to March 2003), n=11**

Samples	Type of package	Presence/absence of foreign matter	Moisture content (wet basis)	Colour	Texture	Bacteriological tests
						Total yeasts and moulds count/g
1	Polythene	None	16	Brown	Characteristic	125
2	Plastic container	None	16	Brown	Characteristic	130
3	Glass jar	Presence of blue and grey spots of mould growth	14	Brown	Characteristic	112
4	Plastic container	None	15	Brown	Characteristic	92
5	Glass jar	None	13	Brown	Characteristic	50
6	Polythene	Ants and worms, insect holes	13	Brown	Characteristic	55
7	Glass jar	None	12	Brown	Characteristic	47
8	Polythene	Presence of blue and grey spots of mould growth	15	Brown	Characteristic	61
9	Polythene	Ants, insect holes	15	Brown	Characteristic	121
10	Glass jar	None	14	Brown	Characteristic	46
11	Polythene	Presence of blue and grey spots of mould growth	15	Brown	Characteristic	100

Table 6.2 Results from Laboratory quality control tests of dried vegetables (Agriculture Research Laboratory, November 2002 to March 2003) n=9

Samples	Type of package	Presence/absence of foreign matter	Moisture content (wet basis)	Colour	Texture	Bacteriological tests
						Total yeasts and moulds count/g
1	Plastic container	None	5	Dark brown	Characteristic	45
2	Polythene	None	3	Dark brown	Characteristic	43
3	Polythene	Presence of extraneous plant matter and dead tree leaves, presence of mould growth	4	Dark brown	Characteristic	43
4	Polythene	Presence of extraneous plant matter and dead tree leaves	3	Dark brown	Characteristic	42
5	Polythene	Presence of mould growth	3	Dark brown	Characteristic	44
6	Polythene bag	Presence of mould growth	3	Dark brown	Characteristic	43
7	Polythene	Absent	3	Dark brown	Characteristic	43
8	Glass jar	Presence of mould growth	4	Dark brown	Characteristic	42
9	Plastic container	None	3	Dark brown	Characteristic	40

All dried fruit and vegetable samples were brown and dark brown in colour respectively. The colour results for both samples did not meet the recommended Joint FAO/WHO Codex Alimentarius Standards for processed fruits and vegetables, which stipulate that colour should be characteristic of the product (chapter 2, section 2.7). Browning of dried fruits and vegetables could have been as a result of many factors including enzymatic activities, action of microorganisms, exposure to light and to high moisture content (chapter 2, section 2.6). Results from the application of quality assurance checklist (chapter 5, section 5.7), showed that respondents did not pretreat the fruits and vegetables, by use of sulphur or acids such as citric and ascorbic acid to fruits or to vegetables before drying. These treatments (application of sulphur and blanching), have been found to slow down browning during drying (chapter 2, section 2.7).

Colour changes of could also have been the result of poor storage and inappropriate packaging. This confirms the results presented in chapter 5, section 5.6 where 85 percent of respondents stored dried products in polythene bags that allow light penetration. Browning of dried fruits and vegetables could have been due to the use of ATS solar drier. The ATS transparent fibre glass roof allows light to pass through, exposing the dried products to direct sunlight. Colour changes could have been accelerated by high summer temperatures during which drying took place.

6.2 Results and discussion for moisture content

The average moisture content of both dried fruits and vegetables samples (14.36 and 3.4 percent respectively) was within FAO/WHO Codex Standards (chapter 2, section 2.5.1). This shows that the temperatures during drying were sufficient to allow for drying.

6.3 Results and discussion for microbiological tests

Mould growth appeared on all samples. The predominant fungal germs identified was *Aspergillus.* The degree of fungal contamination was found to be influenced by inappropriate packaging material and insect infestation. Fungal growth occurred more in polythene bags than in glass bottles. This can be attributed to the packaging material in the sense that such evidence of insect infestation was realised in polythene bags most of which were riddled with insect inflicted holes. It could not be concluded whether fungal growth was as a direct consequence of insect infestation, air contamination prior to packaging or whether spores may

have entered the packages through holes in the packages made by insects. The results confirmed that the environmental, personal and sanitary hygiene during processing of fruits and vegetables was not adequate.

According to FAO/WHO recommended international codes of hygienic practice for solar dried fruits and vegetables, (CAC/RCP 3-1969, Rev.1997 and Amd.1999 part I), dried fruits and vegetables, should be free from moulds and yeast, pathogenic microorganisms and any toxic substance originating from microorganisms. From the results, mould was present in all samples. The results did not conform to FAO/WHO standards for microbiological content for dried fruits and vegetables (chapter 2, section 2.5.1).

Although no pathogenic microorganisms were found, the dried fruit and vegetable samples were not safe for human consumption because of the presence of spoilage moulds and yeasts. The presence of spoilage moulds and yeasts and continued storage of the dried samples meant their multiplication and thus increasing the chances of the growth of pathogenic microorganisms. The presence of yeasts and moulds also indicates the high probability of further spoilage, reducing shelf-life and storage capacity. This could imply that, dried fruits and vegetables produced by respondents were not safe for human consumption.

CHAPTER 7
CONCLUSIONS AND RECOMMEDATIONS

The study investigated the quality and safety of dried fruits and vegetables produced in Butha-Buthe district using ATS solar driers. To increase the shelf-life of dried fruits and vegetables produced in the Butha-Buthe district and maintain wholesomeness and safety, the dried fruits and vegetables must be of high quality standard. The study investigated factors that influenced the quality and safety of dried fruits and vegetables. These were: quality of raw materials, processing, level of hygiene, sanitary conditions of the processing environment, packaging materials and storage.

Sub-problem one set out to assess the processing techniques applied by the respondents, during the production of dried fruits and vegetables. Processing techniques included: quality of raw materials, sorting, washing, peeling, slicing, sulphating fruits, vegetable blanching, drying on the drier, packaging, and storage of the dried products. Sub-problem two set out to analyse the quality and safety of solar dried fruits and vegetables produced by the respondents, using ATS solar drier against FAO/WHO Food Standards Programme Codex Alimentarius Commission quality standards for processed fruits and vegetables in Butha-Buthe district.

7.1 Main findings

Solar drying was carried out on a seasonal basis, depending on the types of fruit and vegetable available. Most drying was carried out during December to March, a relatively short period. The respondents mostly dried for home consumption and consumed the dried fruits as snacks, while vegetables were mainly incorporated to stews and soups. Respondents obtained fruits and vegetables for drying from their own production. The sales turnover from dried fruits and vegetables was low due to low product volumes, limited market and poor quality products. Diversifying to drying medicinal herbs and spices was more profitable.

Respondents reported that the ATS solar drier contributed to drying fruits and vegetables in hygienic manner. However, its small capacity limited drying in large scale and respondents piled produce onto trays during drying. Use of simple kitchen equipment such as knives and basins was used during processing of dried fruits and vegetables.

The processing techniques applied by the respondents were basic i.e. sorting, washing, slicing, drying, packaging and storage. The applied processing techniques were found to be inadequate. For example, washing was normally carried out in plastic basins with recirculating water which was not potable. Sorting and selection of the raw material was inadequate because the respondents had a tendency of selecting overripe fruits and over matured vegetables for processing. Peeling of fruits and shredding of vegetables was inadequate as the pieces were not of uniform size. Suitable packaging and proper storage was found to be useful in keeping the final dried products safe from nutrient losses due to colour changes and contamination from insects and moisture. For example, dried samples that were packaged in polythene bags showed a high level of infestation by insects than those in glass bottles and plastic containers.

Respondents indicated that they undertook measures to ensure the quality of the inputs and outputs of their solar drying operations, albeit basic and rudimentary measures. However, hygiene conditions were not adequate in many ways. For example, washing was not adequate as the water used for washing was not sterilised and sanitation during processing was also poor. This is because no soap, hot water or clean towels for drying wet hands were used during processing. No treatment of the fruits and vegetables was carried out either by blanching or using natural or artificial preservatives, thus increasing the chances of contamination by microorganisms.

The sanitary conditions of grounds around the processing area could have contributed to contamination of the product being processed such as excessive dust accumulation. Poor sanitary services such as lack of sewage and garbage disposal were additional factors in the possible contamination of the dried fruits and vegetables, as were the personal health and hygienic practices of the respondents.

Results from laboratory tests further confirmed the production of poor quality of dried fruits and vegetables from respondents. For example, all samples of dried fruits and vegetables were discoloured. The presence of foreign matter in some packages indicated contamination during processing and packaging. There was a high presence of yeasts and moulds as found through the microbiological laboratory tests.

It was realised from the study that the respondents did not have enough skills and knowledge to improve the quality of the dried fruits and vegetables that they produced. They lacked awareness and information on best processing techniques and on quality control and safety standards. The respondents felt that the government should do more to support the production of quality and safe dried fruits and vegetables through the provision of extension services such as training in solar drying (technical and business training) and credit facilities.

The study findings strengthened the importance of assuring quality at all stages of processing of dried fruits and vegetables, from inspection of raw materials, processing and during storage of the final dried products. Quality improvements to solar drying are to be found in best processing practices procedures, hygiene control during processing, proper packaging and storage

For respondents to produce dried fruits and vegetables, safe for human consumption and of high quality, the raw material should be of high quality. It is not possible to obtain products of high value from inferior quality raw materials. The respondents should therefore use the best fruits and vegetables suitable for processing. On the other hand, the quality of the raw material also depends on the way that it is handled throughout the production process.

Preliminary operations i.e. sorting, washing, peeling, cutting are required for all fruits and vegetables. The processing operation consists of eliminating the dirt sticking to the material before it enters the processing line, thus avoiding complications deriving from the possible contamination of the raw material. Thus, washing must be performed using clean water, which should be as pure as possible. The purpose of sorting is to separate the ripe fruits and over matured vegetables from the under ripe fruits and vegetables not suitable for processing. At the same time, parts of damaged fruits and vegetables are removed. Peeling facilitates the

operation of cutting the raw material into pieces or into slices before processing. The slices must be of the same thickness. Slices of the same thickness will require the same drying time. Blanching and sulphating treatments improve the quality and keeping properties, and preserve the natural colour of dried fruits and vegetables.

Hygiene measures are very important, during the processing of fruits and vegetables. In the absence of such measures, the products will be liable to contamination by bacteria, yeasts and moulds. The addition of salt and/or sugar and sulphur dioxide in the form of potassium or sodium metabisulphite can provide protection for fruit and vegetables from the organisms mentioned above. However, preservatives cannot prevent the multiplication of germs if unsanitary conditions prevail during the preparation of the products.

7.2 Conclusions

The results from this study show that the respondent's production practices are founded on traditional drying techniques that do not focus on product quality and safety. The respondent's dried fruits and vegetables are therefore likely to have a short shelf-life and compromised safety due to inferior processing techniques.

It can be concluded that the quality and safety of produced dried fruits and vegetables by the respondents was poor. For example, all the dried fruits and vegetables were discoloured. The presence of foreign matter in some packages indicated contamination during processing. There was a high presence of yeasts and moulds as realised from the microbiological laboratory tests. It can also be concluded that quality and safety deterioration started right from selection of raw material and continued throughout the processing cycle as indicated by the results from the quality assurance checklist. This could have been due to inferior processing techniques, contamination of the product during processing from the equipment, environment and water used.

The main conclusion from this study is that, the dried fruits and vegetables produced by the respondents in Butha-Buthe district were of inferior quality and short shelf-life. A short shelf-life meant that the dried fruits and vegetables could not be stored to be consumed when there was no availability of fresh fruits and vegetables (off peak seasons) and could not

compete well in the market. Inferior quality products could also mean continued deterioration during storage and the high probability of the growth of toxic microorganisms thus rendering them unsafe for human consumption. Solar drying of fruits and vegetables in Butha-Buthe district cannot ensure year round availability of fruits and vegetables.

7.3 Recommendations to improve the quality and safety of dried fruits and vegetables produced by the respondents

For the respondents to produce good quality dried fruits and vegetables that are acceptable for human consumption, there is need for the respondents to adopt acceptable processing practices and techniques. For example, adopt blanching of vegetables and sulphating of fruits, which has been found to improve on products quality and safety. Improvements in product preparation and handling practices would assist in reducing contamination and in protecting the health of the consumers. The processing techniques should always be carried out with due diligence at all times with regard to hygiene and food safety.

It is recommended that the following rules be adhered to:

- respondents should carefully wash their hands before the processing of fruits and vegetables.
- the utensils and equipment should be properly cleaned before and after use, in order to remove dust and any possible organic particle.
- it is advisable to use equipment that allow for an adequate cleaning, so that no traces of dirt are left in the subsequent phases.
- the packaging, i.e. bottles and jars, should be washed with hot water in order to reduce the microbial load.
- damaged parts of the fresh products, as well as the wastes, should be discarded and disposed of outside the working area.
- the preparation and drying area must be located in an area free from dust, and any other material likely to contaminate the product.
- before storage, the finished products should be properly labelled.

To prevent the products from being exposed to direct sunlight during drying, the fibre glass roof of the ATS solar drier should be shaded e.g. with a black cloth or polythene. Attention

should also be given to packaging and storage. As seen in the study, care should be taken if using cheap polythene bags for packaging because they are more susceptible to attack by insects. Glass bottles offer more protection against insects and moisture but they should be stored away from light because they allow light through.

For the respondents to adopt best processing techniques in solar drying of fruits and vegetables, they need training in solar drying. The respondents would benefit from appropriate training in food hygiene and sanitation. Training on best husbandry practices in producing fruits and vegetables can also help the respondents in producing more quality raw material. Such training can also build their confidence or assertiveness and can make them aware of the dangers of poor personal hygiene and unsanitary work habits.

The Lesotho government and development agencies should also understand the nutritional needs of the population as a whole. For example, the need in poor communities for adequate, safe and appropriate diets. This understanding will enable them acknowledge the role food processing plays in enhancing household food security and improved nutrition and thus support the household food processors. This can be done, for example, by extending extension services to them and setting up policy guidelines for improving the quality of dried fruits and vegetables in Lesotho. Information on markets, technology and quality specifications by the appropriate government departments and non-governmental organisations should also be extended to the households. The government should promote hygienic conditions and practices in solar drying by providing safe water for food preparation and washing of utensils.

There is need for the household processors to improve business management skills to run effective agribusinesses. Development agencies such as Non-Governmental Organisations (NGO's) should facilitate skills development aimed at improving the business skills of household processor. Also, assist households in acquiring credit to invest in technologies and processing techniques that improve quality. Providing credit to poor households with insufficient finances could create a problem for financial institutions. It would thus be

important for the households in Butha-Buthe district to form cooperatives in order to improve their credit worthiness. Individual households may not have the time, knowledge or money to organise a business around improved solar drying techniques. An organised group may be able to share these types of responsibilities, using members of the group to compensate for times when certain members are not available.

An effective food processing, distribution and marketing system requires a well maintained infrastructure, including markets, road networks and extension services to advise the households on improved processing techniques or on how to bulk produce to reduce marketing costs. This may require interventions by both the government and the private sector. With regard to the special needs of households in the district involved in solar drying of fruits and vegetables, the government can assist by providing information and training on the use of appropriate processing technology and providing extension support for marketing of the final dried products.

There is need for ATS to design larger driers since the current drier does not support large scale production. ATS should also subcontract local artisans in Butha-Buthe, to manufacture the driers as this would reduce the travel expenses involved in buying the drier and for repairs. Engineering drawings and instructions using simple language, targeting local artisans in Butha-Buthe, should be developed by ATS and disseminated. ATS should also strengthen the capacity of local workshops in Butha-Buthe to repair and maintain the solar driers. The capacity of ATS dissemination officers in providing information solar on drying should also be strengthened through, for example, having courses or on job training in food processing.

7.4 Recommendations for the improvement of the study

Within the scope of time and resources, primary data collection was only limited to Butha-Buthe district. A larger population and sample is recommended for future studies. A comparative study of traditional sun drying of fruits and vegetables and the performance of the ATS solar drier, could have been important for the comparison of the research findings. Comparing the quality of dried fruits and vegetables produced using traditional methods

would have helped the researcher understand the comparative advantages and disadvantages of using the two methods.

The study only studied the solar drying of fruits and vegetables. Other products that the respondents could have dried such as tubers and meat were not studied. It could have been important to study the solar drying of all possible products that can be dried in the district so as to find out their socio-economic viability for sustainability.

7.5 Implications for further research

For household solar drying of fruits and vegetables to be sustainable, it now emerges that other areas related to the problems at hand also need to be thoroughly investigated. Such areas include a proper analysis of open air drying system which as established from literature is practised by the majority of the households in Lesotho.

Market research to analyse consumers and markets is another area that needs further research to help households identify potential market opportunities for dried products. A ready market for the dried fruits and vegetable products could serve as an incentive for the respondents to improve on the quality and safety of the dried products.

The nutritional composition of the dried fruits and vegetables dried by the households could be established to determine nutrient loss during the processing of dried fruits and vegetables. Establishing the extent of the nutrient loss during processing can also lead to further research on establishing the best solar drying processing practices that minimises nutrient loss appropriate at the household level.

Possibility of the development of culturally appropriate recipes using dried fruits and vegetables such as instant soup mixes and complimentary food mixtures for home consumption and the market should be explored. This would go along way for the households in adding more value to dried products, thus increasing their worth and acceptability.

Further research should also be conducted on the ATS solar drier so that it can support drying through the night and during cloudy and rainy weather. By so doing it may be possible for respondents to increase their drying capacity without compromising the quality and safety of the products.

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APPENDICES

Appendix A

Solar drying questionnaire

Location:.....Respondents name:.....
Date: ..... .Respondents No.....

1. You are engaged in solar drying of fruits and vegetables. What are the types of vegetables that you dry and what months are they in season.
   Fruits Vegetables Months
   i).....
   ii) .....
   iii) .....
   iv) .....
   v) .....

2. About how much dried fruits and vegetables do you dry per drying season?

3. Where do you obtain the fresh fruits and vegetables for drying?
   grow from own garden [ ] buy from neighbours [ ]Buy from the shops [ ]

4. Are dried fruits and vegetables mainly for home consumption or for sale?
   Home consumption [ ] Sale [ ] both for home consumption and sale [ ]

5. How often are dried fruits and vegetables consumed by the household and what months? Everyday [ ] once per week [ ] twice per month [ ]
   January-March [ ] April-June [ ] July-September [ ]
   September-December [ ]

6. How are they incorporated in the household's diet? [ ] As in between snacks [ ] As salads before the main course [ ] as in soups, sauces and stews [ ]

7. How often do you dry fruits and vegetables? [ ] Everyday [ ] once per week; [ ] once every month

8. If for sale, what is the sales turnover per month?
   What could be the reason for this?
   i) .....
   ii) .....
   iii) .....

9. About what percentage of your total income is from the sales of dried fruits and vegetables?

10. Do the dried fruits and vegetables last until the next harvesting season? Yes [ ] No [ ] If no what are the reasons for this?
    i) .....
    ii) .....
    iii) .....

11. What are the noted advantages/disadvantages of using the Appropriate Technology section solar dryer (ATS) solar dryer over the previous drying methods before?
    i) .....
    ii) .....
    iii) .....

12. How long does the drying take and how is the weather during drying?
    [ ] One day [ ] two days [ ] other
    [ ] Cloudy [ ] Sunny [ ] Rainy

13. How would you describe solar drying as an activity? Has it contributed to the welfare of the household? Y [ ] N [ ]
    [ ] Seasonal Annual [ ] Any other [ ]

14. What type of problems do you encounter during drying?
    i) .....
    ii) .....
    iii) .....

15. What support services from ATS, Government etc would you like to receive in regards to drying?
    i) .....
    ii) .....
    iii) .....

16. Please tick against apply or never for the processes that you apply/do not apply during solar drying

Process	Apply	Never
Selection		
Sorting		
Washing		
Slicing		
Blanching as in vegetables		
Use of salt and natural acids such as lemon juice		
Any preservatives used Sulphuring Ascorbic acid		
Location of the dryer in relation to sun		
Turning of the product on the dryer trays for faster drying		
Stored in glass jars		
Stored in polythene bags		
Dried products stored in a dark dry place		
Labelling of the packages for storage		

Appendix B

Quality assurance checklist during the processing of dried fruits and vegetables (Adapted from FAO guidelines on quality control/Quality assurance and international trade; gmp; haccp (FAO 1992).

1.Processes and controls
Are the fruits and vegetables to be dried inspected and sorted to ensure that they are clean, wholesome and fit for processing into human food? Adequate [ ] Inadequate [ ] None [ ]
Is the processing of the dried fruits and vegetables carried out under conditions that minimize the potential for undesirable microbiological growth, toxin formation, deterioration or contamination, through careful monitoring of such factors as time, temperature, peeling, slicing, use of preservatives etc? adequate [ ] inadequate [ ] none [ ]
Is heat-blanching for vegetables done by heating the food to the required temperature (2 minutes), holding it at this temperature for the required time, and then either rapidly cooling it or passing it to the next manufacturing step without delay? Yes [ ] no [ ]
Are the fruits treated with any preservative, natural or artificial to preserve them? Yes [ ] no [ ]
2.Ground and surroundings
Do the grounds around the processing area harbour conditions which may contribute to contamination of the product being processed such as unsatisfactory drainage, excessive trash and scrap accumulation, rodent activity, dust etc yes [ ] No [ ]
Is waste disposal adequate to minimize attraction of insects, rodents and birds? Adequate [ ] Inadequate [ ] none [ ]
Is there excessive trash and scrap accumulation yes [ ] no [ ]
Are there other conditions which may contribute to contamination of the products being processed yes [ ] no [ ]
3.Sanitary facilities
Is there a toilet in the homestead? Yes [ ] no [ ]
Is hot water, soap and clean towels available in the processing room? Yes [ ] no [ ]
Is cleaning carried out in a manner that minimizes the possibility of contaminating foods or equipment surfaces that contact food? Adequate [ ] inadequate [ ] none [ ]
4.Good manufacturing practices (gmp)
Is the person processing the food in good health, for example having no open lesions, including boils, sores, infected wounds, or any other abnormal source of microbial contamination which could result in the food, food-contact surface, or food packaging materials becoming contaminated? Yes [ ] no [ ]
Are surfaces of equipment or utensils that gets into contact food clean? Adequate [ ] inadequate [ ] none [ ]
Does the processor maintain a high degree of personal cleanliness and conform to hygienic practices during processing e.g. washing hands thoroughly with soap etc yes [ ] no [ ]
Does the processor have the education and/or experience to make them aware of the danger of poor personal hygiene and unsanitary work habits? Yes [ ] no [ ]

Appendix C

Laboratory tests analysis data sheet

Total anaerobic plate count data sheet
Sample No:
Date of analysis:

Food type:
Total aerobic plate count/g

Dilutions	**Anaerobic plate count**		
	Plate 1	**Plate 2**	**Plate 3**
10^{-1}			
10^{-2}			
10^{-3}			
10^{-4}			
10^{-5}			

Yeast and mould count record data sheet
Sample No:
Date of analysis:

Food type:
Total yeasts and mould count/g

Dilutions	**Yeasts and mould count**		
	Plate 1	**Plate 2**	**Plate 3**
10^{-1}			
10^{-2}			
10^{-3}			
10^{-4}			
10^{-5}			

Appendix D
Raw data

A Raw data from questionnaire

1. Types of fruits and vegetables available for drying and their seasonality by the respondent households.

Month	Fruits	Vegetables
January	Peaches, nectarines, plums, grapes	Cabbages, tomatoes, green beans,
February	Peaches, nectarines, plums, apples, pears, grapes, quinces	Cabbage, tomatoes, potatoes, green beans
March	Peaches, apples, pears, grapes, quinces	Cabbage, beetroot, carrots, tomatoes
April	Peaches, apples, pears	Cabbage, tomatoes, onions
May	Limited winter peaches not suitable for drying	Cabbage, onions, pumpkin,
June	-	Pumpkin
July-October	Oranges imported from South Africa	Very limited harvests of vegetables and it is not wise to preserve them because of limited sunshine
November	Peaches, nectarines, plums, apricots	Onions, cabbages, carrots
December	Peaches, nectarines, plums, apricot, grapes	Cabbages, beetroot

All the households had peach trees in their homesteads.

14 households had other fruit trees apart from peach namely: apricots, apple, quince and pear trees.

All the households grow vegetables in their gardens.

2.Amount of dried fruits and vegetables dried by the respondent households per drying season

Amount (kg) of fresh fruits and vegetables)	**Fruits n=46 households**	**Vegetables n=46 households**
0-10	33	40
11-20	5	4
21-30	0	2
31-40	0	0
41-50	2	0
Above 50	1	0
Missing	5	0
Total	46	46

3. Four households responded that they bought fruits and vegetables for drying from their neighbours and shops to supplement own production.

4. Six respondents dried fruits and vegetables with the intention of generating an income through sales of the dried products while the rest 40 respondents dried mainly for home consumption.

5.Periods of the year dried fruits and vegetables mostly consumed by the respondents
Dried fruits and vegetables consumed only when available i.e. immediately after drying

6.Ways dried fruits and vegetables are incorporated into the household's diet

Incorporation in household diet	**Number of respondents n=46**
Snacks	46
In soups and stews	29
Reserved for snacks for visitors	7

7.Frequency of drying fruits and vegetables by the respondents during the drying season and months usually dried.

Frequency of drying	**(Frequency) Drying period=4 months**
Everyday	0
Once per week	5
Once per month	41

7b.Period of the year respondent's dry fruits and vegetables

Months	**n=46 households**
January –March	40
April-June	0
July-September	0
October-December	0
September-May	6

8b.Reasons for low sales by respondents

Sales turnover per month ®	
No sales	40
0-50	2
51-100	2
101-150	1
151-200	0
201-250	1
Total	46

9.All the respondents but one could not account for the percentage of the total income from the sales of dried fruits and vegetables because of lack of records.

One respondent: solar drying contributed to a quarter of the household income

10. All the households responded that their dried fruits and vegetables did not last until the next drying season. They cited various reasons for this as follows

Reasons	**n=46 respondents**
Spoilage during storage	46
No excess dried fruits and vegetables for storage (consumed immediately)	29
Missing	6

11.Noted advantages/disadvantages of using ATS solar drier

Advantages/Disadvantages	N=46 respondents
Improved hygiene during drying due to minimized contamination of the products by birds, animal droppings, dust and extraneous plant material.	46
Reduced time spent during drying as they did not require someone to keep watch since the drying product were well covered and protected from thieves, rain, animals etc.	23
Improved confidence and self-motivation as the other community members regard them with a lot of respect.	31
The solar dryer too small limiting production during seasons of abundant fruits and vegetables	46
Cost of purchasing the dryer limits buying many dryers to increase production	41
ATS too far to cater for repairs and damages of the solar dryer	24

12.All the households responded that with uninterrupted sunshine, drying of fruits and vegetables usually took two days.

13. All the households responded that solar drying of fruits and vegetables was a seasonal activity due to the seasonality of fruits and vegetables and that drying had a positive impact in the household welfare.

14.Constraints encountered by the households

Constraint	n=46 households
Poor quality of the dried products	46
Lack of information	40
Lack of markets	7
Lack of repairs of the ATS dryer	5
Inefficiency of the ATS solar dryer	4
ATS solar dryer too small	7
Lack of credit	10
Lack of time	4
Lack of confidence in drying	12
Low recognition and poor perception of the dried products	7

15.Support services from the government

Services	**N=46 households**
Credit	46
Skills and training	46
Marketing	46
Repairs for their solar driers	46

16.Solar drying of fruit and vegetable processing techniques by the respondents

Processing methods applied	**Number of respondents n=46 households**
Selection	46
Sorting	46
Washing	46
Slicing	46
Blanching as in vegetables	0
Use of salt and natural acids such as lemon juice	0
Any preservatives used Sulphuring Ascorbic acid	0
Location of the dryer in relation to sun	46
Turning of the product on the dryer trays for faster Drying	46
Dried products stored to be consumed later	40
Stored products in glass jars	7
Stored product in polythene bags	39
Labelling of the packages for storage	0

Raw data from the application of the quality assurance checklist

1.Processes and controls
Are the fruits and vegetables to be dried inspected and sorted to ensure that they are clean, wholesome and fit for processing into human food? Adequate [x] Inadequate [ ] None [ ]
Is the processing of the dried fruits and vegetables carried out under conditions that minimize the potential for undesirable microbiological growth, toxin formation, deterioration or contamination, through careful monitoring of such factors as time, temperature, peeling, slicing, use of preservatives etc? adequate [x] inadequate [ ] none [ ]
Is heat-blanching for vegetables done by heating the food to the required temperature (2 minutes), holding it at this temperature for the required time, and then either rapidly cooling it or passing it to the next manufacturing step without delay? Yes [ ] no [x]
Are the fruits treated with any preservative, natural or artificial to preserve them? Yes [ ] no [x]
2.Ground and surroundings
Do the grounds around the processing area harbour conditions which may contribute to contamination of the product being processed such as unsatisfactory drainage, excessive trash and scrap accumulation, rodent activity, dust etc yes [x] No [ ]
Is waste disposal adequate to minimize attraction of insects, rodents and birds? Adequate [x] Inadequate [ ] none [ ]
Is there excessive trash and scrap accumulation yes [x] no [ ]
Are there other conditions which may contribute to contamination of the products being processed yes [x] no [ ]
3.Sanitary facilities
Is there a toilet in the homestead? Yes [x] no [ ]
Is hot water, soap and clean towels available in the processing room? Yes [ ] no [x]
Is cleaning carried out in a manner that minimizes the possibility of contaminating foods or equipment surfaces that contact food? Adequate [x] inadequate [ ] none [ ]
4.Good manufacturing practices (gmp)
Is the person processing the food in good health, for example having no open lesions, including boils, sores, infected wounds, or any other abnormal source of microbial contamination which could result in the food, food-contact surface, or food packaging materials becoming contaminated? Yes [x] no [ ]
Are surfaces of equipment or utensils that gets into contact food clean? Adequate [ ] inadequate [x] none [ ]
Does the processor maintain a high degree of personal cleanliness and conform to hygienic practices during processing e.g. washing hands thoroughly with soap etc adequate [ ] inadequate [x]
Does the processor have the education and/or experience to make them aware of the danger of poor personal hygiene and unsanitary work habits? adequate [ ] inadequate [x]

Raw data from laboratory tests

Analysing dried fruits for general cleanliness, texture and colour

Samples	Type of package	Presence/absence of foreign matter	Colour	Texture
1	Polythene	Presence of ants, insect holes, presence of mould growth	Brown	Characteristic
2	Plastic container	None	Brown	Characteristic
3	Glass jar	Presence of mould growth	Brown	Characteristic
4	Plastic container	None	Brown	Characteristic
5	Glass jar	None	Brown	Characteristic
6	Polythene	Presence of ants and worms, insect holes	Brown	Characteristic
7	Glass jar	None	Brown	Characteristic
8	Polythene	Presence of mould growth	Brown	Characteristic
9	Polythene	Presence of ants, insect holes	Brown	Characteristic
10	Plastic container	None	Brown	Characteristics
11	Polythene	Presence of blue and grey spots of visible mould growth	Brown	Characteristic

Analysing dried vegetables for general cleanliness, texture and colour

Samples	Type of package	Presence/absence of foreign matter	Colour	Texture
Dried vegetable samples				
1	Plastic container	None	Dark brown	Characteristic
2	Polythene	None	Dark brown	Characteristic
3	Polythene	Presence of extraneous plant matter and dead tree leaves, presence of mould growth	Dark brown	Characteristic
4	Polythene	Presence of extraneous plant matter and dead tree leaves	Dark brown	Characteristic
5	Polythene	Presence of mould growth	Dark brown	Characteristic
6	Polythene bag	Presence of mould growth	Dark brown	Characteristic
7	Polythene	None	Dark brown	Characteristic
8	Glass	Presence of mould growth	Dark brown	Characteristic
9	Plastic	None	Dark brown	Characteristic

Analysing dried fruit and vegetables samples for microbiological content

All the plates for total anaerobic count did not yield any bacteria colonies

Total yeast and mould count data sheet

Samples Dried fruit samples	**Total yeast and mould count**		
	Plate 1 10^{-1}	**Plate 2 10^{-2}**	**Average colonies/g**
1	100	150	125
2	128	132	130
3	119	105	112
4	81	102	92
5	68	32	50
6	59	51	55
7	40	54	47
8	52	69	61
9	122	120	121
10	40	52	46
11	43	57	100
Dried vegetable samples			
1	26	64	45
2	32	54	43
3	35	51	43
4	29	55	42
5	38	50	44
6	35	51	43
7	31	55	43
8	34	50	42
9	38	42	40

Raw data for moisture analysis

Formula for calculating moisture

% moisture content on wet basis= $\frac{A-B \times 100}{A}$

Sample	**Sample weight after 30 minutes**	**Sample weight after 1 hour**	**Sample weight after $1^{1/2}$ hours**	**Average moisture Content (%)**
Dried fruit samples				
1	0.18	0.16	0.16	16
2	0.17	0.16	0.16	16
3	0.16	0.14	0.14	14
4	0.16	0.15	0.15	15
5	0.15	0.13	0.13	13
6	0.16	0.13	0.13	13
7	0.15	0.12	0.12	12
8	0.19	0.15	0.15	15
9	0.18	0.15	0.15	15
10	0.17	0.14	0.14	14
11	0.20	0.15	0.15	15
Dried Vegetable samples				
1	0.08	0.05	0.05	5
2	0.05	0.03	0.03	3
3	0.01	0.04	0.04	4
4	0.06	0.03	0.03	3
5	0.05	0.03	0.03	3
6	0.04	0.03	0.03	3
7	0.03	0.03	0.03	3
8	0.08	0.04	0.04	4
9	0.05	0.03	0.03	3

Appendix E

SPSS data analysis

Data log explaining codes for SPSS data analysis

Case No		**Codes**
Fruits	no. of fruits dried	
Vegetables	no. of vegetables dried	
Amount dried dried (kg)	Amount of fruits and vegetables	
Source	From where do you obtain the fruits and vegetables for drying	1=grow from own garden 2=buy from neighbours 3=buy from shop
Consumption	Dried fruits and vegetables for home consumption or for sale	1=home consumption 2=for sale 3=both
Fconsumption	hh frequency of consumption of dried fruits and vegetables	1=everyday 2=once per week 3=twice per month
Fdrying	How often do you dry fruits and vegetables?	1=everyday 2=once per month 3=once per week
Sdried	Which months are fruits and vegetables mostly dried	1=Jan-March 2=April-June 3=July-September 4=October-November 5= September-December
Hh diet	How are the dried fruits and vegetables incorporated in the households diet	1=as in between snacks 2=as salads before main course 3=as in soups, sauces and stew
income	Income from selling dried fruits and vegetables(Rands)	
%income	% income contribution from sales of dried fruits and vegetables to the total hh income	
Storage	Do the stored dried fruits and vegetables last until the next harvesting season?	1=yes 0=no

Advantages	Advantages of using Appropriate technology section solar dryer	1=yes 0=no
Disadvantages	Disadvantages of using Appropriate Technology Section dryer	1=yes 0-no
Duration	Days taken for the fruits and vegetables to dry	
Weather	Condition of the weather during drying	1=cloudy 2=sunny 3=rainy
Welfare	Has drying contributed to the welfare of the household	1=yes 0=no
Problems	Problems encountered during drying	1=yes 0=no
Support	Support services from the ATS, government in regards to drying	1=yes 0=no
Selection	Do hh select the fruit and vegetables for drying?	1=apply 0=never
Sorting	Do hh sort fruits and vegetables for blemishes, over-ripening, attack by insects etc?	1=apply 0=never
Washing	Are the fruits and vegetables washed before slicing and peeling?	1=apply 0=never
Slicing	Is slicing and peeling done?	1=apply 0=never
Blanching	Is vegetable blanching carried out?	1=apply 0=never
Natural	Is use of salts and natural acids such as lemon juice applied during processing?	1=apply 0=never
Preservatives	Use of sulphur	1=apply 0=never
Dryer	location of the dryer to maximise the sun's energy	1=apply 0=never
Product turning	Do hh occasionally turn the product during drying?	1=apply 0=never
Glass jars	hh use of recycled glass jars to store the dried fruits and vegetables	1=apply 0=never

Polythene bags	hh use of plastic bags high or low density for storing the dried products	1=apply 0=never
Labelling	Do hh label the packages?	1=apply 0=never
Storing	Are dried fruits and vegetables Stored in a cool, dry place?	1=apply 0=never

Quality assurance checklist

Rselection — How is quality of the selected fruits and vegetables for drying?1=good 2=unsatisfactory

Pcontrol — Do the processing conditions minimize the potential for undesirable microbiological or contamination through careful monitoring? 1=yes 2=no

Ehygiene — How clean are the equipments and utensils that come into contact with the food? 1=adequate 2=inadequate

gmp — Are good manufacturing practices (gmp) observed such as personal hygiene and health status, are processors aware of the danger of poor personal hygiene and unsanitary work habits? 1=apply 2=never

En. hygiene — Are the grounds around the processing area harbour conditions which may contribute to contamination of the product being processed such as unsatisfactory drainage, excessive trash and scrap accumulation, rodent activity and dust ?1=adequate 2=inadequate

Hsanitary hygiene — Is sanitary hygiene maintained during processing such as use of clean water, sewage disposal, hand washing facilities, use of detergents and disinfectants? 1=adequate 2=inadequate

Laboratory tests

%Fmoisture — percentage moisture content of dried fruit sample%

Vmoisture — percentage moisture content of dried vegetable sample

FColour — characteristic colour of the dried fruit sample

VColour — characteristic colour of the dried vegetable sample

Ftexture — characteristic texture of the dried fruit sample

Vtexture — characteristic texture of the dried vegetable sample

Fplate count — dried fruit sample, total plate count

Vplate count — dried vegetable sample, total plate count

Fyeasts/moulds	total yeast and mould count from the dried fruit sample
Vyeasts/moulds	total yeast and moulds count from the dried vegetable sample